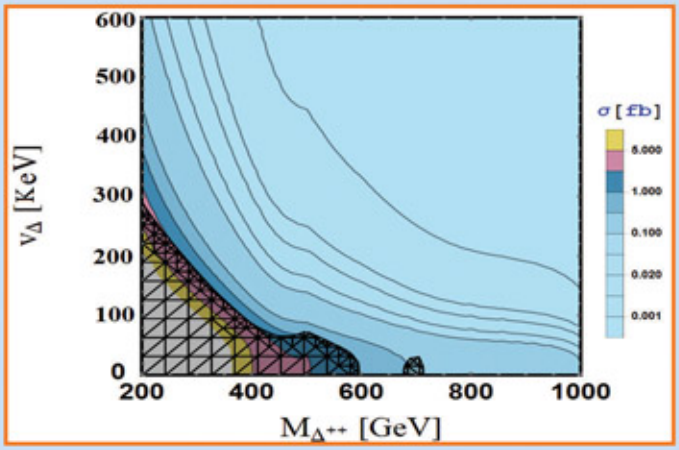
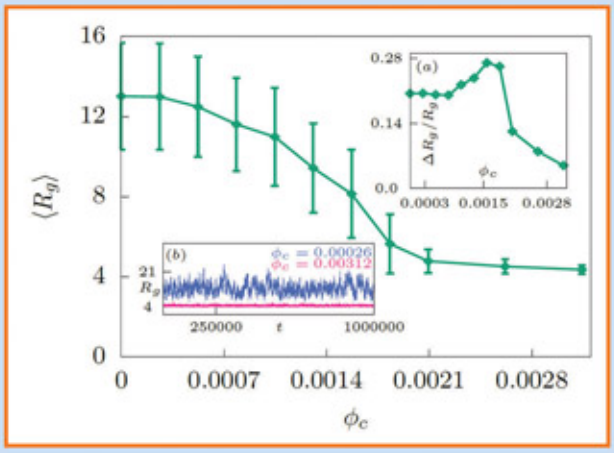
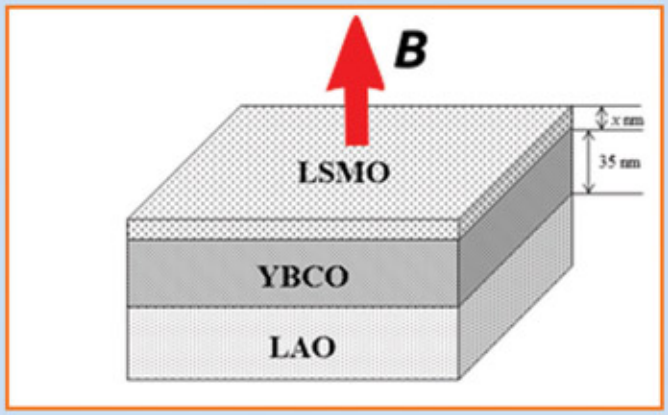
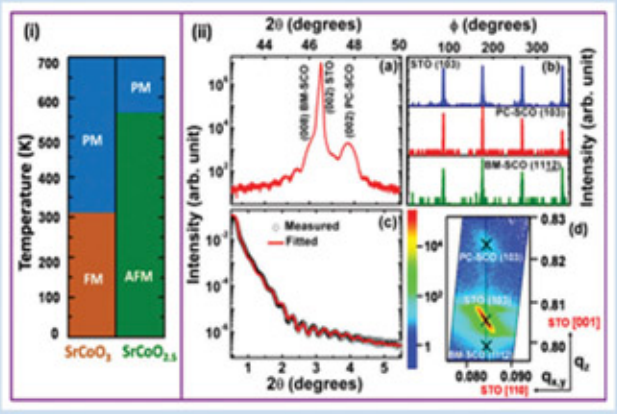
Annual Report
&
Audited Statement of Accounts
2017-18

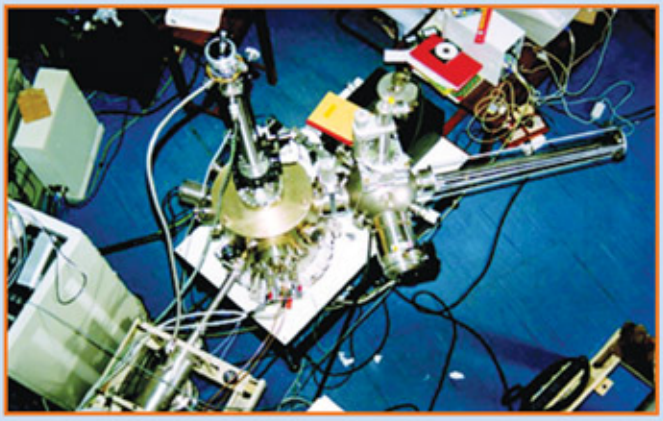
Institute of Physics
Bhubaneswar

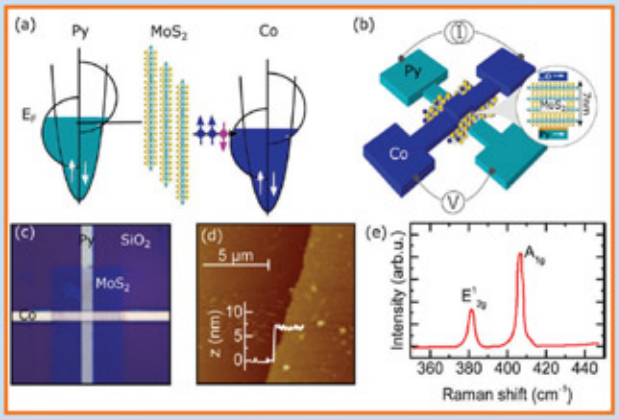

600
500
400
300
200
100
0
v_Δ [KeV]
200
400
600
800
1000
$M_{\Delta^{++}}$ [GeV]
σ [fb]
5.000
1.000
0.100
0.020
0.001

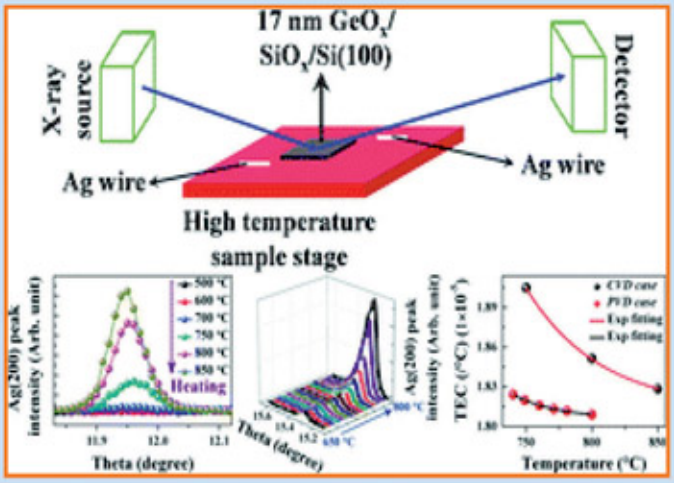

16
12
8
4
0
$\langle R_g \rangle$
0
0.0007
0.0014
0.0021
0.0028
ϕ_c
(a)
$\Delta R_g / R_g$
0.28
0.14
0.0
0.0003
0.0015
0.0028
ϕ_c
(b)
$\phi_c = 0.00026$
$\phi_c = 0.00312$
21
R_g
4
250000
t
1000000

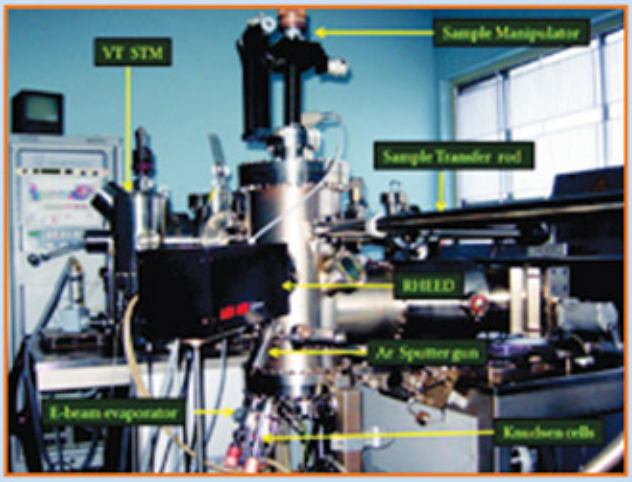

B
x nm
35 nm
LSMO
YBCO
LAO


(i)
Temperature (K)
700
600
500
400
300
200
100
0
PM
PM
FM
AFM
$SrCoO_3$
$SrCoO_{2.5}$
(ii)
2θ (degrees)
44
46
48
50
ϕ (degrees)
100
200
300
Intensity (arb. unit)
(008) BM-SCO
(002) STO
(002) PC-SCO
(a)
(b)
STO (103)
PC-SCO (103)
BM-SCO (1112)
(c)
Measured
Fitted
(d)
PC-SCO (103)
STO (103)
STO [001]
STO [110]
0.83
0.82
0.81
0.80
0.080
0.090
$q_{x,y}$
q_z
2θ (degrees)




(a)
Py
MoS_2
Co
E_F
(b)
Py
Co
MoS_2
(c)
Py
SiO_2
MoS_2
Co
(d)
5 μm
z (nm)
10
5
0
(e)
Intensity (arb.u.)
A_{1g}
E^1_{2g}
360
380
400
420
440
Raman shift (cm^{-1})


17 nm GeO_x/
SiO_x/Si(100)
X-ray source
Detector
Ag wire
Ag wire
High temperature
sample stage
Ag(200) peak intensity (Arb. unit)
500 °C
600 °C
700 °C
750 °C
800 °C
850 °C
Heating
11.9
12.0
12.1
Theta (degree)
Ag(200) peak intensity (Arb. unit)
Theta (degree)
TEC ($/^oC$) (1×10^{-6})
CVD case
PVD case
Exp fitting
Exp fitting
1.89
1.86
1.83
1.80
750
800
850
Temperature (^oC)


VT STM
Sample Manipulator
Sample Transfer rod
RHEED
Ar Sputter gun
E-beam evaporator
Knudsen cells

Annual Report

and

Audited Statement of Accounts

2017-18

Institute of Physics

Bhubaneswar

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About the Institute

Institute of Physics, Bhubaneswar is an autonomous research institution within the Department of Atomic Energy (DAE), Government of India. The Institute was established in 1972 by the Government of Odisha and continues to receive financial assistance from DAE and Govt. of Odisha.

The Institute has a vibrant research programme in the fields of theoretical and experimental condensed matter physics, theoretical high energy physics and string theory, theoretical nuclear physics, ultra-relativistic heavy-ion collisions and cosmology, quantum information and experimental high energy nuclear physics. The accelerator facilities include a 3MV Pelletron Accelerator and a low-energy implanter. These are being used for studies in low energy nuclear physics, ion beam interactions, surface modification and analysis, trace elemental analysis, materials characterization, and radiocarbon dating studies. One of the important areas in the Institute is in the field of Nanoscience and Nanotechnology in general and surface and interface studies in particular.The Institute has several advanced facilities for sample preparation and for the study of various physical and chemical properties of nanostructures and bulk condensed matter systems. The Institute is actively involved in the International Collaborations with CERN (Switzerland), BNL (USA), ANL (USA), GSI (Germany), and other laboratories abroad. The Institute is also participating in various research activities related to India-based Neutrino Observatory.

The Institute offers Ph.D. programme to the scholars who successfully complete the one year pre-doctoral course at the Institute. The selection for the pre-doctoral programme is through the Joint Entrance Screening Test (JEST). Candidates qualifying the CSIR-UGC NET examination and those having high GATE scores are also eligible for an entry to the pre-doctoral program.

The Institute campus has housing facilities for the employees and hostels for the scholars and post-doctoral fellows. Compact efficiency apartments are available for post-doctoral fellows and visitors. Both indoor and outdoor games and sports facilities are also available in the campus. The Institute has a Mini-Gym in the New Hostel. The Institute also has a guest house, auditorium, and dispensary in the campus.

The Foundation Day of the Institute is celebrated on 4th of September every year.

CHAIRMAN AND MEMBERS OF THE GOVERNING COUNCIL

Dr. Sekhar Basu : Chairman
Chairman (AEC) and Secretary (DAE),
Department of Atomic Energy,
Anushakti Bhavan, C.S.M. Marg,
Mumbai-400001 (from 03.08.2017)

Prof. V. Chandrasekhar : Member
Director,
National Institute of Science Education and Research,
P.O. : Sainik School,
Bhubaneswar - 751005
(up to 09.06.2017 (FN).

Prof. Sudhakar Panda : Member
Director,
National Institute of Science Education and Research,
P.O. Sainik School, Bhubaneswar-751005
(from 13.06.2017 (AN).

Prof. J. K. Bhattacharjee : Member
Director, Harish-Chandra Research Institute,
Chhatnag Road, Jhunsi,
Allahabad-211019 (up to 09.04.2017).

Prof. Pinaki Majumdar : Member
Director, Harish-Chandra Research Institute,
Chhatnag Road, Jhunsi, Allahabad - 211019 (from 10.04.2017)

Prof. Ajit Kumar Mohanty : Member
Director, Saha Institute of Nuclear Physics,
Sector-1, Block-A/F, Bidhan Nagar, Kolkata- 700064

Dr. Shashank Chaturvedi : Member
Director, Institute of Plasma Research,
Bhat Village, Near Indira Bridge,
Gandhinagar- 382428.

Shri A. R. Sule, IDAS, Joint Secretary (R&D), Department of Atomic Energy Anushakti Bhavan, C.S.M. Marg, Mumbai - 400001 (from 10.07.2017).	:	Member
Joint Secretary, (Finance), Department of Atomic Energy, Anushakti Bhavan, C.S.M. Marg, Mumbai - 400001.	:	Member
Principal Secretary Science & Technology Department, Govt. of Odisha, Bhubaneswar - 751001.	:	Member
Prof. Saroj Kumar Nayak School of Basic Sciences, Indian Institute of Technology, Bhubaneswar - 751013.	:	Member
Prof. Sukanta Kumar Tripathy P. G. Department of Physics, Berhampur University, Bhanja Vihar, Ganjam - 760007	:	Member
Prof. Sudhakar Panda Director, Institute of Physics, Bhubaneswar - 751005.	:	Member

Secretary to the Governing Council

Shri R. K. Rath
Registrar, Institute of Physics,
Bhubaneswar - 751005

From Director's Desk

I am delighted to present before you the Annual Report of Institute of Physics (IoP), Bhubaneswar for the year 2017-18. This Annual Report gives a brief description of our various academic, research activities and accomplishments. IoP is an autonomous Institute, under Department of Atomic Energy, Government of India. It is one of the premier research institutions in India, perusing high quality and cutting-edge research in the areas of experimental and theoretical Physics.

During the academic year 2017-2018, excellent research work on both fundamental and applied physics has been carried out by the members of IoP and this has resulted in about 150 publications in the International Peer-Reviewed Journals. Moreover, the faculty members of IoP have received academic recognitions in the form of J. C. Bose National Fellowship, Young Scientist Research Grant, Presidentship of the Electron Microscope Society of India and members of Editorial Board of National and International journals.

Every year attempts have been made to improve the research ambiance of IoP by having colloquiums, meetings/workshops etc. This year, about 25 eminent scientists of national and international repute have been invited to deliver colloquium and popular talks. We understand the importance of collaborative research work that would bring like-minded researchers on the same platform to address the cutting edge scientific research problems. To strengthen such activities at IoP, different workshops like Indo-Japan collaboration meeting on Neutrinos and Particle Physics, a joint venture of Max Planck Institute of Solid State Research and IoP through Max Planck partner Group Programme, and the India-CMS collaboration meeting were organized. The purpose of these meetings are to seek opportunities of collaboration between IoP and other national and international institutes on emerging areas in physics.

IoP has been playing a pivotal role in spreading the awareness of Science and promote scientific temper among young school and college students through various

programs such as the National Science Day celebration, student visit program, sky watching program etc. This year, IoP celebrated The National Science Day-2018 where Dr. Anil Bhardwaj, Director of Physical Research Laboratory, Ahmedabad talked about the exciting opportunities and achievemnts of the Indian Space Program to 250 young students from different Colleges/Schools from 30 districts of Odisha.

We are excited by both the challenges and opportunities that the next academic year has to offer. In the days to come, let's all stand ready and work together with renewed intensity and vigor in taking the institution to greater heights.

I take this opportunity to acknowledge and appreciate the support and encouragement received from all the stake holders associated with IoP including the Governing Council. I also express my gratitude to those who have contributed their time and energy to give shape to this Annual Report in the current form.

Prof. Sudhakar Panda
Director, IoP

CONSTITUTION OF THE ACADEMIC COUNCIL OF THE INSTITUTE

The Governing Council of the Institute in its 100th Meeting held in the Institute on 21.04.2017 decided to constitute a Sub-Committee of the Governing Council comprising of all its academic members called the Academic Council. Formation of such a committee is as per the Provision 2.10 of the Bye-Laws of Institute of Physics, Bhubaneswar. The scope of the Academic Council will be to take decisions on the academic matters pertaining to the Institute.

ACADEMIC PROGRAMMES

1.1	Pre-Doctoral Program	:	03
1.2	Doctoral Program	:	04
1.3	Theses Defended / Submitted	:	04
1.4	Summer Student's Visiting Program (SSVP)	:	05

1.1 PRE-DOCTORAL PROGRAM

One of the most important objectives of the Institute is to train and guide young scholars to do research in physics. Since 1975, IoP has a regular Pre-doctoral (Post M.Sc.) course, which is a very important academic program because it is designed to train the M.Sc. students for carrying out research activities. This programme is aimed at imparting a broad based training in advanced physics and research methodology to students. The course work is planned with the view that it should help the students not only in doctoral research, but also enable them to become a good physics teacher. The Institute participates in conducting the Joint Entrance Screening Test (JEST) to select students who are interested in pursuing Ph.D. in physics. The final selection of a student is based on the result of written test and an interview conducted at the Institute. This year, the Pre-doctoral course began in August, 2017 and ended in July, 2018. Utkal, Berhampur and Sambalpur Universities have recognized our Pre-doctoral program equivalent to their M.Phil degrees. On completion of the Pre-doctoral program, students are eligible to join research under the supervision of faculty members of the Institute, leading to the Ph.D. degree awarded by Homi Bhabha National Institute (HBNI).

To recognize the talent, the Institute has instituted Lalit Kumar Panda Memorial Endowment Fellowship (*L. K. Panda Memorial Fellowship)* for the most outstanding pre-doctoral student. The fellowship consists of an award of Rs.5,000/- and a citation.

A total of 281 students were called for written test and interview for admission to the predoctoral course in July, 2017. This includes JEST qualifiers, UGC-CSIR qualifiers and valid GATE score holders. Following students successfully completed the doctoral course work in July, 2018:

1. Mr. Bibhabasu De
2. Mr. Chinmmaya Ku. Panda
3. Mr. Diwakar
4. Mr. Gupteswar Sabat
5. Mr. Pranjal Pandey
6. Mr. Rahul Roy
7. Ms. Rojalin Padhan
8. Mr. Rupam Mandal
9. Mr. Saiyad Ashanujjaman

Mr. Rupam Mandal was adjudged as the most outstanding scholar and was awarded the L. K. Panda Memorial Fellowship for the year 2017-18.

Details of the courses offered and course instructors are given below.

Semester – I

Advanced Quantum Mechanics : Dr. S. Banerjee
Advanced Statistical Mechanics :
Dr. D. Chaudhuri
Quantum Field Theory – I : Dr. Debottam Das
Many Body Physics : Dr. Arijit Saha
Advanced Experimental Technique :
Dr. Dinesh Topwal
Experimental Physics : Dr. Satyaprakash Sahoo

Semester – II

Mathematical Methods and Research Methodology : Dr. Arun K. Nayak
Advanced Condensed Matter Physic:
Dr. Saptarshi Mandal
Advanced Nuclear Physics : Prof. P. K. Sahu

Quantum Field Theory – II : Dr. Manimala Mitra
High Energy Physics : Dr. K. Ghosh
Special Topics in Statistical Mechanics :
Prof. S. Mukherji

As a part of the course work, students also worked on projects in the last trimester under supervision of faculty members of the institute. Titles of the projects undertaken by student during 2017-2018 are given below along with the name of the supervisor.

Name of Supervisor	Name of Student	Title of Project
Dr. D. Das	Bibhabasu De	*Theory of Dark Matter*
Dr. D. Samal	Chinmaya Ku. Panda	*Excitonic Insulator*
Dr. A. K. Nayak	Diwakar	*To determine the CP properties of Higgs boson at LHC*
Dr. D. Samal	Gupteswar Sabat	*Dimensionality effect of metal-insulator transition*
Dr. S. Banerjee	Pranjal Pandey	*Conformal Primary states in 6D*
Dr. D. Samal	Rahul Roy	*Jahn-Teller distortion and related effects*
Dr. M. Mitra	Rojalin Padhan	*See-Saw mechanism to explain the smallness of neutrino mass*
Prof. T. Som	Rupam Mandal	*Ion implantation induced materials modification using ECR-based ion sources.*
Dr. K. Ghosh	Saiyad Ashanujjaman	*Neutrino mass models, and low energy signatures of TeV scale see-saw type I mechanism in view of* $\mu \to e + \gamma$ *decay*

1.2 DOCTORAL PROGRAM

Presently Institute has thirty seven doctoral scholars working in different areas under the supervision of its faculty members. All the scholars are registered with Homi Bhabha National Institute (HBNI), a deemed-to-be University within DAE. Progress of each doctoral scholar is reviewed annually by a review committee. This year reviews were held in the months of July-August.

1.3 THESES (Submitted / *Defended)

The following scholars have been awarded Ph.D. degree by Homi Bhabha National Institute on the basis of thesis submitted / *defended.

1. Mr. Soumyabrata Chakraborty

Advisor : Prof. Sudipta Mukherji

Thesis Title : *Field Theory on Cosmological Spactime: Some Results from* AdS/CFT**.**

2. Mr. Subhadip Ghosh

Advisor : Dr. Goutam Tripathy, Co-guide– Prof. Debasish Chaudhuri

Thesis Title : *Active Maintenance of Structure and Transport : Impact of Molecular.*

3. Mr. Arpan Das

Advisor : Prof. Ajit M. Srivastava

Thesis Title : *Consequences of phase transition dynamics in neutron stars*

4. Ms. Sudipta Mahana

Advisor : Dr. Dinesh Topwal

Thesis Title : *Magnetic and Ferroelectric Properties of Some Advanced.* Functional Oxides and Related Phenomena.

5. Shri Sabyasachi Chaterjee

Advisor : Dr. Sanjib K. Agarwalla.

Thesis Title : *Exploring Light Sterile Neutrinos and Long-Range Forces in* Long-Baseline Experiments.

6. Puspendu Guha

Advisor : Prof. P. V. Satyam

Thesis Title : *Silver Nanostructures on Oxide Surfaces: Growth, Characterizations.*

7. Himanshu Lohani*

Advisor : Prof. B. R. Sekhar

Thesis Title : *Superconductors Using Photoelectron Spectroscopy and First* Principles Calculations.

8. Indrani Mishra*

Advisor : Prof. Shikha Varma

Thesis Title : *Modifications of SiOx, TiO_2 and PDMS surfaces & their Interactions* with DNA and Cell.

9. Jim Chacko*

Advisor : Prof. Goutam Tripathy

Thesis Title : *Interacting Systems Out-of-Equilibrium: Disordered ratchets,* Molecular motors and Sandpiles.

10. Bidisha Chakrabarty*

Advisor : Dr. Amitabh Virmani

Thesis Title : *Studies on non-supersymmetric D1-D5-P gravitational bound* States.

1.4 Summer Student's Visiting Program (SSVP) :

The motivation of the SSVP program is to expose young students to frontline research especially in the areas of research work pursuing at the Institute. This year the SSVP was held from 1st May to 15th July, 2017. Twelve students participated in the program. Round trip train fare, accommodation on campus, and a monthly stipend of Rs. 5000/- was provided to all the visiting students. Under this program, each student worked under the guidance of a faculty member of the Institute. At the end of the program, students presented their work in a seminar on the assigned topics.

Name of the Student	Topic of the Seminar	Advisor
Ms. Aiswarya N. K.	*Active random walk: Path building and path finding*	Dr. D. Chaudhuri
Ms. Apurba Biswas	*Solar neutrino deficit and neutrino oscillation*	Dr. K. Ghosh
Ms. Athira P. S.	*Electron muon reconstruction*	Dr. A. K. Nayak
Ms. Jyotimoy Mukherjee	*Higgs mechanism*	Dr. M. M. Mitra
Ms. Sushri Sangya Jena	*Quark gluon plasma and data analysis in simulation model at LHC energy*	Prof. P. K. Sahu
Mr. Aman Gupta	*Neutrino: The little neutral one*	Dr. S. K. Agarwalla
Mr. Lalit Pandey	*Pyrochlore- an interesting class of materials*	Dr. D. Topwal
Mr. Nayana Narayanan	*Bose Einstein condensation of magnon*	Dr. D. Samal
Mr. Pavithra Rao	*Thermoelectric materials*	Dr. D. Topwal
Mr. Pratik Nandy	*D-Branes in String Theory*	Dr. A. Virmani
Mr. Pratyush Kumar Patel	*Supersymmetry breaking*	Dr. S. Banerjee
Mr. Siddhartha Poddar	*Symmetry and conservation laws*	Prof. P. Agrawal

RESEARCH

2.1	Theoretical High Energy Physics	:	09
2.2	Theoretical Nuclear Physics	:	22
2.3	Experimental High Energy Physics	:	24
2.4	Quantum Information	:	33
2.5	Experimental Condensed Matter Physics	:	36
2.6	Theoretical Condensed Matter Physics	:	44

2.1 Theoretical High Energy Physics

At IOP, the main areas of research are string theory, quantum gravity, black holes, collider and neutrino phenomenology, quark-gluon plasma, astroparticle physics, and cosmology. Individual member's work is in following three categories.

String Theory

String theory — as a broad discipline — has made remarkable progress during last three decades. It has generated ideas that have contributed to several other fields of physics as well as of mathematics. The string theory group has interest in classical and quantum properties of black holes, cosmology, AdS/CFT, application of gauge-gravity duality to strongly coupled gauge theories, symmetries of string theory, interface of information theory and AdS/CFT etc.

High Energy Physics Phenomenology

The High Energy Physics Phenomenology plays an important role at the energy, intensity, and cosmic frontiers to unravel the deep long-standing mysteries of the Universe. The group research activities have a special emphasis on collider physics, neutrino physics, dark matter, astroparticle physics, and beyond-the-standard-model (BSM) scenarios. Members are exploring the Higgs and top-quark physics, and physics beyond the Standard Model at the ongoing experiments at the LHC, and the proposed experiments at 100 TeV collider, CLIC, ILC, and ep collider LHeC. The work at these colliders involve event-genrator based analyses, machine learning, and radiative corrections.

In the neutrino physics, interest is in in neutrino oscillation, the detection of the BSM models of neutrino mass generation at ongoing and proposed experiments, and the connection with astroparticle physics. The India-based Neutrino Observatory (INO) is a flagship mega-science project of India to study the fundamental properties of Neutrinos. Members are involved in physics and detector simulation studies related to the Iron Calorimeter detector at INO, and the the proposed neutrino experiments named DUNE (in US), and Hyper-Kamiokande (in Japan). The direct and indirect searches of dark matter is also an active field of research these days and the members of the HEP group are quite active in this area of research.

Quark Gluon Plasma, Cosmology and Astroparticle Physics

Quark Gluon Plasma is quite an active field with experiment being carried out at LHC and RHIC. Group members are performing extensive simulations related to quark-hadron phase transitions, and magnetohydrodynamics to understand the flow dynamics. The group members have also been carrying out tabletop liquid crystal experiments which can provide tests of theories of cosmic defects. They are also spending time to explore the emerging issues in astroparticle physics like dark matter, dark energy, baryogenesis, gravitational waves etc.

(S. Panda, A. M. Srivastava, P. Agrawal, S. Mukherji, S. K. Agarwalla, S. Banerjee, D. Das, M. Mitra, K. Ghosh)

1. Quantum entanglement in de Sitter space from Stringy Axion: An analysis using α vacua.

In this work, we study the phenomena of quantum entanglement by computing de Sitter entanglement entropy from von Neumann measure. For this purpose, we consider a bipartite quantum field theoretic setup in presence of axion originating from **Type II B** string theory. We consider the initial vacuum to be CPT invariant non-adiabatic α vacua state under SO(1, 4) ismometry, which is characterized by a real one-parameter family. To implement this technique we use a S^2 which divide the de Sitter into two exterior and interior sub-regions. First, we derive the wave function of axion in an open chart for α vacua by applying Bogoliubov transformation on the solution for Bunch-Davies vacuum state. Further, we quantify the density matrix by tracing over the contribution from the exterior region. Using this result we derive entanglement entropy, Rényi entropy and explain the long-range quantum effects in primordial cosmological correlations. We also provide a comparison between the results obtained from Bunch-Davies vacuum and the generalized α vacua, which implies that the amount of quantum entanglement and the long-range effects are larger for non zero value of the parameter α. Most significantly, our derived results for α vacua provides the necessary condition for generating non zero entanglement entropy in primordial cosmology.

Sayantan Choudhury, Sudhakar Panda

2. Entangled de Sitter from Stringy Axionic Bell pair I: An analysis using Bunch-Davies vacuum.

In this work, we study the quantum entanglement and compute entanglement entropy in de Sitter space for a bipartite quantum field theory driven by axion originating from **Type IIB** string compactification on a Calabi-Yau three fold (CY^3) and in presence of NS5 brane. For this compuation, we consider a spherical surface S2, which divide the spatial slice of de Sitter (dS4) into exterior and interior sub regions. We also consider the initial choice of vaccum to be Bunch-Davies state. First we derive the solution of the wave function of axion in a hyperbolic open chart by constructing a suitable basis for Bunch-Davies vacuum state using Bogoliubov transformation. We then, derive the expression for density matrix by tracing over the exterior region. This allows us to compute entanglement entropy and Rényi entropy in 3+1 dimension. Further we quantify the UV finite contribution of entanglement entropy which contain the physics of long range quantum correlations of our expanding universe. Finally, our analysis compliments the necessary condition for generating non vanishing entanglement entropy in primordial cosmology due to the axion.

Sayantan Choudhury, Sudhakar Panda

Relativistic Heavy-Ion Collisions

3. Magneto hydrodynamics Simulation in relativistic heavy-ion collisions, elliptic flow and flow fluctuations.

We show nontrivial effects of initial magnetic field in heavy-ion collisions using magneto

hydrodynamics simulations. We show the non-trivial centrality dependence on the elliptic flow and even-odd power spectrum oscillations which has implications for initial stages of inflation.

A. Das, S.S. Dave, P.S. Saumia and A. M. Srivastava

4. High baryon density phases of QCD, magnetic field and Dynamo effect.

We investigate the possibility magnetic flux folding due to vortex formation in heavy-ion collisions at low energies. This dynamo effect can have dramatic effects in heavy-ion collisions, especially for chiral magnetic and chiral vertical effects.

A. Das, S.S. Dave, P.S. Saumia and A. M. Srivastava

5. Magneto hydrodynamics Simulation of Uranium-Uranium collision and quadrupole magnetic field at fermi scale.

We study special crossed configurations of uranium-uranium collisions in heavy-ion collisions and study the nature of resulting magnetic field. We show that it leads to quadrupolar field at the scale of fermi. Its beam-focusing effects will be manifested in terms of non-trivial rapidity dependence of radial flow, specifically in violation of Broken boost invariance.

A. Das, S.S. Dave, P.S. Saumia and A. M. Srivastava

6. Continuing project: Adiabaticity violation and Quarkonia Disintegration due to spatial and temporal fluctuations in Relativistic Heavy Ion Collisions.

We study adiabaticity violation of J/ψ evolution due to spatial and temporal variations of energy density in relativistic heavy-ion collisions by calculating the survival probability of J/ψ and γ using time dependent perturbation theory.

P. Bagchi, N. Dutta, and A. M. Srivastava

7. Disintegration of quarkonia due to dependence of quark masses on Polyakov loop in Relativistic Heavy Ion Collisions.

Non-trivial profile of the Polyakov loop of the Z(3) domain walls in QGP leads to spatially varying effective mass of the quarks. We study the interaction of Upsilon with Z(3) interfaces which disintegrates quarkonia by exciting it to higher states of $q\bar{q}$ system.

A. Atreya, P. Bagchi, and A. M. Srivastava Cosmology and astrophysics

8. Effects of random density fluctuations on pulsar dynamics, glitches and pulse modulation.

We model density fluctuations arising from phase transitions in terms of a random matrix and study its effects on pulsar dynamics. We study resulting changes in pulse timings which can account for glitches and study its correlations with the modulation of pulse profiles. We also estimate resulting gravitational wave intensity.

P. Bagchi, A. Das, B. Layek, and A. M. Srivastava

9. Initial conditions for inflation with Reaction diffusion equation.

We discuss the issue of setting appropriate initial conditions for inflation. Specifically, we consider natural inflation model and discuss the fine tuning required for setting almost homogeneous initial conditions over a region of order several times the Hubble size which is orders of magnitude larger than any relevant correlation length for field fluctuations. We then

propose to use the special propagating front solutions of reaction-diffusion equations for localized field domains of much smaller sizes. Due to very small velocities of these propagating fronts we find that the inflaton field in such a field domain changes very slowly, contrary to naive expectation of rapid roll down to the true vacuum. Continued expansion leads to the energy density in the Hubble region being dominated by the vacuum energy, thereby beginning the inflationary phase. Our results show that inflation can occur even with a single localized field domain of size much smaller than the Hubble size.

P. Bagchi, A. Das, S.S. Dave, S. Sengupta, and A. M. Srivastava

10. Pulsars as Weber gravitational wave detectors.

A gravitational wave passing through a pulsar will lead to a variation in the moment of inertia of the pulsar affecting its rotation. This will affect the extremely accurately measured spin rate of the pulsar as well as its pulse profile (due to induced wobbling depending on the source direction). The effect will be most pronounced at resonance and should be detectable by accurate observations of the pulsar signal. The pulsar, in this sense, acts as a remotely stationed Weber detector of gravitational waves whose signal can be monitored on earth. With possible gravitational wave sources spread around in the universe, pulsars in their neighborhoods can provide us a family of remote detectors all of which can be monitored on earth. Even if GW are detected directly by earth based conventional detectors, such pulsar detectors can provide additional information for accurate determination of the source location. This can be of crucial importance for sources which do not emit any other form of radiation such as black hole mergers. For the gravitational wave events already detected by LIGO (and VIRGO), our proposal suggests that one should look for specific pulsars which would have been disturbed by these events, and will transmit this disturbance via their pulse signals in any foreseeable future. If these future pulsar events can be predicted with accuracy then a focused effort can be made to detect any possible changes in the signals of those specific pulsars.

Arpan Das, Shreyansh S. Dave, Oindrila Ganguly, Ajit M. Srivastava

11. Analogue gravity in heavy-ion collisions, black hole and Hawking radiation in relativistic heavy-ion collisions.

Unruh had proposed analogue gravity models wherein a fluid flow can represent a black hole horizon at the point where flow becomes supersonic. This leads to the prediction of Hawking radiation effects in hydro dynamical models of quantum fluids. We apply these ideas to rapidly expanding QGP in relativistic heavy-ion collisions and investigate the effects of resulting Hawking radiation of particle momentum distributions.

A. Das, S.S. Dave, O. Ganguli, and A. M. Srivastava

12. Formation of topological vortices during superfluid transition in a rotating vessel.

Formation of topological defects during symmetry breaking phase transitions via the Kibble mechanism is extensively used in systems ranging from condensed matter physics to the early stages of the universe. Kibble mechanism

uses topological arguments and predicts equal probabilities for the formation of defects and anti-defects. Certain situations, however, require a net bias in the production of defects (or ant defects) during the transition, for example, superfluid transition in a rotating vessel, or flux tubes formation in a superconducting transition in the presence of external magnetic field. In this paper we present a modified Kibble mechanism for a specific system, superfluid transition for 4He, which can produce the required bias of vortices over antivortices. Our results make distinctive predictions which can be tested in super fluid 4He experiments. These results have important implications for super fluid phase transitions in rotating neutron stars and also for any super fluid phases of QCD arising in the non-central low energy heavy-ion collision experiment.

S.S. Dave and A. M. Srivastava, Liquid Crystal Experiments

13. Duality of defects in isotropic-nematic phase transition in liquid crystals.

We are pursuing our earlier study of duality between point defects in 2-D and line defects in 3-D which we observed in isotropic to nematic transition with a crossed polarizer setup. We are also carrying out numerical simulation of this duality and our results are in confirmation with our experimental results. We are planning a setup to extend it to string to domain wall duality using isotropic-nematic transition in the presence of electric field.

Ajit M. Srivastava

14. Production of HHH and HHV (V = γ, Z) at the hadron colliders.

We consider the production of two Higgs bosons in association with a gauge boson or another Higgs boson at the hadron colliders. We compute the cross sections and distributions for the processes $pp \to HHH$ and HHZ within the standard model. In particular, we compute the gluon-gluon fusion one-loop contributions mediated via heavy quarks in the loop. It is the leading order contribution to $pp \to HHH$ process. To the process $pp \to HHZ$, it is next-to-next-to-leading-order (NNLO) contribution in QCD coupling. We also compare this contribution to the next-to-leading-order (NLO) QCD contribution to this process. The NNLO contribution can be similar to NLO contribution at the Large Hadron Collider (LHC), and significantly more at higher center-of-mass energy machines. We also study new physics effects in these processes by considering ttH, HHH, $HHHH$, HZZ and $HHZZ$ interactions as anomalous. The anomalous couplings can enhance the cross sections significantly. The $gg \to HHH$ process is specially sensitive to anomalous tri linear Higgs boson self-coupling. For the $gg \to HHZ$ process, there is some modest dependence on anomalous HZZ couplings.

P. Agrawal, Debashis Saha and Ambresh Shivaji

15. Probing the Type-II Seesaw Mechanism through the Production of Higgs Bosons at a Lepton Collider.

We investigated the production and decays of doubly-charged Higgs bosons for the Type-II seesaw mechanism at an e^+e^- collider with two center of mass energies, $\sqrt{s}$ = 380 GeV and 3 TeV, and analyze the fully hadronic final states in detail. Lower mass ranges can be probed during the 380 GeV run of the collider, while high mass ranges, which are beyond the 13 TeV Large

Hadron Collider discovery reach, can be probed with $\sqrt{s} = 3$ TeV. For such a heavy Higgs boson, the final decay products are collimated, resulting in fat-jets. We perform a substructure analysis to reduce the background and find that a doubly-charged Higgs boson in the mass range 800-1120 GeV can be discovered during the 3 TeV run, with integrated luminosity $L \sim 95$ fb^{-1} of data. For 380 GeV center of mass energy, we find that for the doubly-charged Higgs boson in the range 160-172 GeV, a 5σ significance can be achieved with only integrated luminosity $L \sim 24$ fb^{-1}. Therefore, a light Higgs boson can be discovered immediately during the run of a future e^+e^- collider.

P. Agrawal, Manimala Mitra, Saurabh Niyogi, Sujay Shil, and Michael Spannowsky.

16. Time dependent background and Ads/CFT

My research work has been centered around studying physics of various time-dependent geometries with in the framework of AdS/CFT correspondence. Below, provided a brief summary. Several time dependent backgrounds, with perfect uid matter, can be used to construct solutions of Einstein equations in the presence of a negative cosmological constant along with some matter sources. We focus our attention to the non-vacuum Kasner-AdS geometry and its solitonic generalization. To characterize these space-times, we provide ways to embed them in higher dimensional space-times. General space-like geodesics are then studied and used to compute the two point boundary correlators within the geodesic approximation. Milne-universe is one of the simplest time-dependent geometry which has a bulk dual. This dual geometry can be used to approximately com- pute three point functions of strongly coupled SYM using the geodesic method. We are in the process of computing these correlators

S. Mukherji, S. Chatterjee, S. Paul Chowdhury, Y. Srivastava

17. A hybrid setup for fundamental unknowns in neutrino oscillations using T2HK (νν) and μμ-DAR ($\overline{\nu}\overline{\nu}$) .

We have studied the possibility to replace the antineutrino run of the proposed T2HK experiment with antineutrinos from muon decay at rest (μ-DAR). This approach has the advantages of having higher statistics in both neutrino and antineutrino modes, and lower beam-on backgrounds for antineutrino run with reduced systematic. We find that a hybrid setup consisting of T2HK (ν) and μ-DAR ($\overline{\nu}$) in conjunction with full exposure from T2K and NOνA can resolve the issue of mass hierarchy at greater than 3σ C.L. irrespective of the choices of hierarchy, δ_{CP}, and θ_{23}. This hybrid setup can also establish the CP-violation at 5σ C.L. for ~ 55% choices of δ_{CP}, whereas the same for conventional T2HK(ν+$\overline{\nu}$) setup along with T2K and NOνA is around 30%. As far as the octant of θ_{23} is concerned, this hybrid setup can exclude the wrong octant at 5σ C.L. if θ_{23} is at least 3^0 away from maximal mixing for any δ_{CP}. This paper got published in **JHEP 1705 (2017) 115** without any major revision.

Dr. S. K. Agrawal and collaborators

18. Indirect searches of Galactic diffuse dark matter in INO-MagICAL detector.

The Weakly Interacting Massive Particle (WIMP) is a popular particle physics candidate for the dark matter (DM). It can annihilate and/

or decay to neutrino and antineutrino pair. The proposed 50 kt Magnetized Iron Calorimeter (MagICAL) detector at the India-based Neutrino Observatory (INO) can observe these pairs over the conventional atmospheric neutrino and antineutrino fluxes. If we do not see any excess of events in ten years, then INO-Magical can place competitive limits on self-annihilation cross-section ($\langle\sigma v\rangle$) and decay lifetime (t) of dark matter at 90% C.L.: $\langle\sigma v\rangle \leq 1{:}87 \times 10^{-24}$ cm3 s for m_s = 10Ge assuming the NFW as DM density profile. This paper got published in **JHEP 1706 (2017) 057**.

Dr. S. K. Agrawal and collaborators

19. Conformal structure of massless scalar amplitudes.

We show that the one-loop on-shell four-point scattering amplitude of massless ϕ^4 scalar field theory in 4D Minkowski space time, when Mellin transformed to the Celestial sphere at infinity, transforms covariantly under the global conformal group SL(2,C) on the sphere. The unitarity of the four-point scalar amplitudes is recast into this Mellin basis. We show that the same conformal structure also appears for the two-loop Mellin amplitude. Finally we comment on some universal structure for all loop four-point Mellin amplitudes specific to this theory.

Nabamita Banerjee, Shamik Banerjee, Sayali Atul Bhatkar, Sachin Jain

20. Celestial sphere and unitary representation of the Poincare group.

Following Pasterski-Shao-Strominger we construct a new basis of states in the single-particle Hilbert space of massless particles as a linear combination of standard Wigner states. Under Lorentz transformation the new basis states transform in the Unitary Principal Continuous Series representation. These states are obtained if we consider the little group of a null momentum direction rather than a null momentum. The definition of the states in terms of the Wigner states makes it easier to study the action of space-time translation in this basis. We show by taking into account the effect of space-time translation that the dynamics of massless particles described by these states takes place completely on the null-infinity of the Minkowski space. We then second quantize the theory in this basis and obtain a manifestly Poincare invariant (field) theory of free massless particles living on null-infinity. This theory has unitary time evolution. The null-infinity arises in this case purely group-theoretically without any reference to bulk space-time. Action of BMS is particularly natural in this picture.

As a by-product we generalize the conformal primary wave-functions for massless particles in a way which makes the action of space-time translation simple. Using these wave-functions we write down a modified Mellin(-Fourier) transformation of the S-matrix elements. The resulting amplitude is Poincare covariant. Under Poincare transformation it transforms like products of primaries of inhomogeneous SL(2,C})(ISL(2,C)) inserted at various points of null-infinity.

Shamik Banerjee

21. Soft theorems and asymptotic symmetries of flat space.

One can construct a basis of massless single particle quantum states which transform in the unitary principal series representation of the four

dimensional Lorentz group. The S-matrix written in this basis gives rise to the Mellin transformed amplitude of Pasterski-Shao-Strominger and its generalization. In this basis the particle can be thought of as living on the null-infinity in the Minkowski space. We have taken some preliminary steps to show how the connection between soft theorems and symmetries work out in this picture. For simplicity we have considered only the leading soft photon and soft graviton theorems which are related to U(1) Kac-Moody and supertranslations.

Shamik Banerjee

22. Exploring Non-Holomorphic Soft Terms in the Framework of Gauge Mediated Supersymmetry Breaking.

It is known that in the absence of a gauge singlet field, a specific class of supersymmetry (SUSY) breaking non-holomorphic (NH) terms can be soft breaking in nature so that they

may be considered along with the Minimal Supersymmetric Standard Model (MSSM) and beyond. There have been studies related to these terms in minimal supergravity based models. Consideration of an F-type SUSY breaking scenario in the hidden sector with two chiral super fields however showed Planck scale suppression of such terms. In an unbiased point of view for the sources of SUSY breaking, the NH terms in a phenomenological MSSM (pMSSM) type of analysis showed a possibility of a large SUSY contribution to muon g–2, a reasonable amount of corrections to the Higgs boson mass and a drastic reduction of the electroweak fine-tuning for a higgs ino dominated $\widetilde{\chi}_i^0$ in some regions of parameter space. We first investigate here the effects of the NH terms in a low scale SUSY breaking scenario. In our analysis with minimal gauge mediated supersymmetry breaking (mGMSB) we probe how far the results can be compared with the previous pMSSM plus NH terms based study. We particularly analyze the Higgs, stop and the electroweakino sectors focusing on a higgs ino dominated $\widetilde{\chi}_i^0$ and $\widetilde{\chi}_i^{\pm}$, a feature typically different from what appears in mGMSB. The effect of a limited degree of RG evolutions and vanishing of the trilinear coupling terms at the messenger scale can be overcome by choosing a non-minimal GMSB scenario, such as one with a matter-messenger interaction.

Utpal Chattopadhyay, Debottam Das, Samadrita Mukherjee

23. Probing sterile neutrinos in the framework of inverse seesaw mechanism through lepto quark productions.

We consider an extension of the Standard Model (SM) augmented by three generations of right-handed neutrinos and lepto quarks. In order to generate the light neutrino masses and mixings, we incorporate inverse seesaw mechanism which allows to keep the seesaw mass scale below the TeV range and at the same time have order one Dirac neutrino Yukawa coupling. However, direct production of the heavy neutrinos in such neutrino mass models are usually suppressed due to electroweak production despite large Yukawa couplings. Production of these heavy neutrinos from lepto quark decays can significantly improve the predictability of the scenario owing to the large production cross-section of the leptoquarks at the LHC. We observed that at least four leptons,

same-sign tri lepton or same-sign tri lepton accompanied by at least one b/τ-jet along with missing transverse energy can be promising signals for such a scenario since these channels are associated with little or negligible SM background. This model is also motivated from experimentally observed B-physics anomalies like R_K and R_D.

Debottam Das, Kirtiman Ghosh, Manimala Mitra, Subhadeep Mondal

24. Dominant production of heavier Higgs bosons through vector boson fusion in NMSSM.

A new Higgs scalar from an extended Higgs family could easily lead to a discovery of new physics at the LHC. In case of new Higgs search, particularly, in the context of popular models of beyond Standard Model physics, gluon-gluon fusion has been considered as the most dominant production mechanism. Here, considering an extended two Higgs doublet model, like Next-to-Minimal Supersymmetric Standard Model, we have presented parameter space with small $tan\beta$ where gluon-gluon fusion would be subdued when heavier Higgs boson does not dominantly couple to up-type quarks. However, being driven by gauge interactions which depend upon the non-negligible doublet component of Higgs, we find that vector-boson fusion can become the leading mechanism for new scalar productions for masses even much less than TeV scale. Using the existing 13 TeV analyses data with 36:1 fb^{-1} luminosity, discovery possibility of this scenario in the context of present and future run of LHC has been discussed.

Debottam Das

25. Non-holomorphic (NH) soft SUSY breaking terms in the Minimal Supersymmetric Standard Model (MSSM)

Non-holomorphic (NH) soft SUSY breaking terms in the Minimal Supersymmetric Standard Model (MSSM) can lead to significant enhancement to avour violating processes like $\mu \rightarrow e\gamma$. This can also show up its imprints in the context of Higgs decays to avour violating final states. We have been studying the phenomenology of Non-holomorphic (NH) soft SUSY breaking terms in the context of different avour violating processes in MSSM framework.

Utpal Chattopadhyay, Debottam Das, Samadrita Mukherjee

26. Probing sterile neutrinos in the framework of inverse seesaw mechanism through leptoquark productions.

We have looked into alternate production of the RH neutrinos, that can originate from strongly interacting leptoquarks. This model has been proposed for the first time in the literature and an in-depth analysis has been carried out. We consider an extension of the Standard Model (SM) augmented by two neutral singlet fermions per generation and a leptoquark. In order to generate the light neutrino masses and mixing, we incorporate inverse seesaw mechanism. The right handed neutrino production in this model is significantly larger than the conventional inverse seesaw scenario. We analyze the different collider signatures of this model and find that the final states associated with three or more leptons, multi jet and at least one b-tagged and (or)τ-tagged jet can probe larger RH neutrino mass scale. We have also proposed a same-sign dilepton signal region associated with multiple jets and missing energy that can be

used to distinguish the present scenario from the usual inverse seesaw extended SM.

Debottam Das, Kirtiman Ghosh, Manimala Mitra, and Shubhadeep Mondal

27. Probing the Type-II Seesaw Mechanism through the Production of Higgs Bosons at a Lepton Collider.

We have explored the high mass range of the doubly charged Higgs. We have shown that for high mass regime, the future lepton collider, such as, Compact Linear Collider (CLIC) can probe the Higgs mass with very less amount of data. To analyse the heavy Higgs signature at CLIC, we have utilised the substructure analysis. We have investigated the production and decays of doubly-chargedHiggs bosons for the Type-II seesaw mechanism at ane+e-collider with two center of mass energies, 380GeV and 3 TeV, and analyze the fully hadronic final states in detail. Lower mass ranges can be probed during the 380 GeV run of the collider, while high mass ranges, which are beyond the 13 TeV Large Hadron Collider discovery reach, can be probed with3TeV. For such a heavy Higgs boson, the final decay products are collimated, resulting in fat-jets. We perform a substructure analysis to reduce the background and find that a doubly-charged Higgs boson in the mass range 800-1120 GeV can be discovered during the 3 TeV run, with integrated luminosity95 inverse-fb of data. For 380 GeV center of mass energy, we find that for the doubly-charged Higgs boson in the range 160-172 GeV, a 5σ significance can be achieved with only integrated luminosity 24 inverse-fb. Therefore, a light Higgs boson can be discovered immediately during the run of a future lepton collider.

Pankaj Agrawal, Manimala Mitra, Saurabh Niyogi, Sujay Shil and Michael Spannowsky

28. Constraining the right-handed gauge boson mass from lepton number violating meson decays in a low scale left-right model.

The other work focusses on the meson decay signatures, and how the imprint of sterile neutrinos can be traced back from B and charm meson decays. A number of possibilities, such as, the prospect at Belle-2, SHiP, NA62 have been analysed. We analyze the lepton number violating (LNV) meson decays that arise in a TeV scale Left Right Symmetry model. The right handed Majorana neutrinoNalong with the right handed or Standard Model gauge bosons mediate the meson decays and provide a resonant enhancement of the rates if the mass of Nlies in the range~ (100MeV–5GeV).We show that the proposed experiment SHiP is the most ideal (due to abundance in charm meson production) to discover extra charged gauge boson and heavy neutrinos.

Sanjoy Mandal, Manimala Mitra,and Nita Sinha

29. Singlet-Triplet Fermionic Dark Matter and LHC Phenomenology.

We have looked into the possibility to probe a compressed spectra for fermonic dark matter at collider. It is well known that for the pure standard model triplet fermionic WIMP-type dark matter (DM), the relic density is satisfied around 2 TeV. For such a heavy mass particle, the production cross-section at 13 TeV run of LHC will be very small. Extending the model further with a singlet fermion and a triplet scalar, DM relic density can be satisfied for even much lower

masses. The lower mass DM can be copiously produced at LHC and hence the model can be tested at collider. For the present model we have studied the multi jet ($\geq 2j$) + missing energy signal and show that this can be detected in the near future of the LHC 13 TeV run. We also predict that the present model is testable by the earth based DM direct detection experiments like Xenon-1T and in future by Darwin.

Author: Sandhya Choubey, Sarif Khan, Manimala Mitra and Shubhadeep Mondal

30. Searching for Leptoquarks at IceCube and the LHC.

Connection between IceCube results and popular leptoquark model have been analysed. An in-depth likelihood analysis have been carried out. We show, contrary to the popular literature, while the full data set of IceCube is fitted with the leptoquark model, taking the Standard Model contribution and Beyond Standard Model contribution together, the goodness of fit decreases. We analysed two scalar leptoquark models with hyper charge $Y=1/6$ and $Y=7/6$. We consider the 53 HESE events from IceCube and perform a statistical analysis, taking into account both the Standard Model and leptoquark contribution together. The lighter leptoquark states that are in agreement with IceCube are strongly constrained from LHC di-lepton+dijet search. Heavier leptoquarks in the TeV mass range are in agreement both with IceCube and LHC. We furthermore show that leptoquark that explains theB-physics anomalies and does not have any coupling with third generation of quarks and leptons, can be strongly constrained.

Ujjal Kumar Dey, Deepak Kar, Manimala Mitra, Michael Spannowsky and Aaron C. Vincent

31. Neutrino and Collider Implications of a Left-Right Extended Zee Model.

In the very recent paper, the model analysed has attractive features, such as, eV scale sterile neutrinos, that will have cosmological implications. We study a simple left-right symmetric (LRS) extension of the Zee model for neutrino mass generation. The model has an extracharged scalar that helps in generating a loop-induced Majorana mass of the neutrinos. This scenario is quite distinct from other LRS models as the right-handed neutrinos are very light of the order of a few eV to a few MeV. We study the collider signature of the charged scalar at $e+e-$ collider, where a huge enhancement in the production cross-section is possible, resulting in a much stronger signal at the ILC or CLIC experiments.

Sarif Khan, Ayon Patra and Manimala Mitra

32. Long-lived Heavy Neutrinos from Higgs Decays.

We have analysed the collider signature of charged Higgs and displaced vertex signatures of the heavy neutrinos in detail.We investigate the pair-production of right-handed neutrinos via the Standard Model (SM) Higgs boson in a gaugedB–Lmodel. The right-handed neutrinos with a mass of few tens of GeV generating viable light neutrino masses via the seesaw mechanism naturally exhibit displaced vertices and distinctive signatures at the LHC and proposed lepton colliders. The production rate of the right-handed neutrinos depends on the mixing between the SM Higgs and the exotic Higgs associated with theB–Lbreaking, whereas their decay length depends on the active-sterile neutrino mixing. We focus on the displaced leptonic final states arising from such a process,

and analyze the sensitivity reach of the LHC and proposed lepton colliders in probing the active-sterile neutrino mixing. We show that mixing to muons several order of magnitude smaller can be probed at the LHC with 100 inverse-fband at proposed lepton colliders with 5000 inverse-fb. The future high luminosity run at LHC and the proposed MATHUSLA detector may further improve this reach by an order of magnitude.

Author: Frank Deppisch, Wei Liu, Manimala Mitra

33. Neutrino Mass Generation at TeV Scale and New Physics Signatures from Charged Higgs at the LHC for Photon Initiated Processes.

We consider the collider phenomenology of a simple extension of the Standard Model (SM), which consists of an EW isospin 3/2 scalar, Δ and a pair of EW isospin 1 vector like fermions, Σ and $\bar{\Sigma}$, responsible for generating tiny neutrino mass via the effective dimension seven operator. This scalar quadruplet with hypercharge Y = 3 has a plethora of implications at the collider. Its signatures at TeV scale colliders are expected to be seen, if the quadruplet masses are not too far above the electroweak symmetry breakingscale. In this article, we study the phenomenology of multi-charged quadruplet scalars, in particular, the multi-lepton signatures at the LHC arising from the production and decays of triply and doubly charged scalars.

K. Ghosh, S. Jana and S. Nandi

34. Probing sterile neutrinos in the framework of inverse seesaw mechanism through leptoquark productions.

We consider an extension of the Standard Model (SM) augmented by two neutral singlet fermions per generation and a leptoquark. In order to generate the light neutrino masses and mixing, we incorporate inverse seesaw mechanism. The right handed neutrino production in this model is significantly larger than the conventional inverse seesaw scenario. We analyze the different collider signatures of this model and find that the final states associated with three or more leptons, multi jet and at least one *b*-tagged and (or) *t*-tagged jet can probe larger

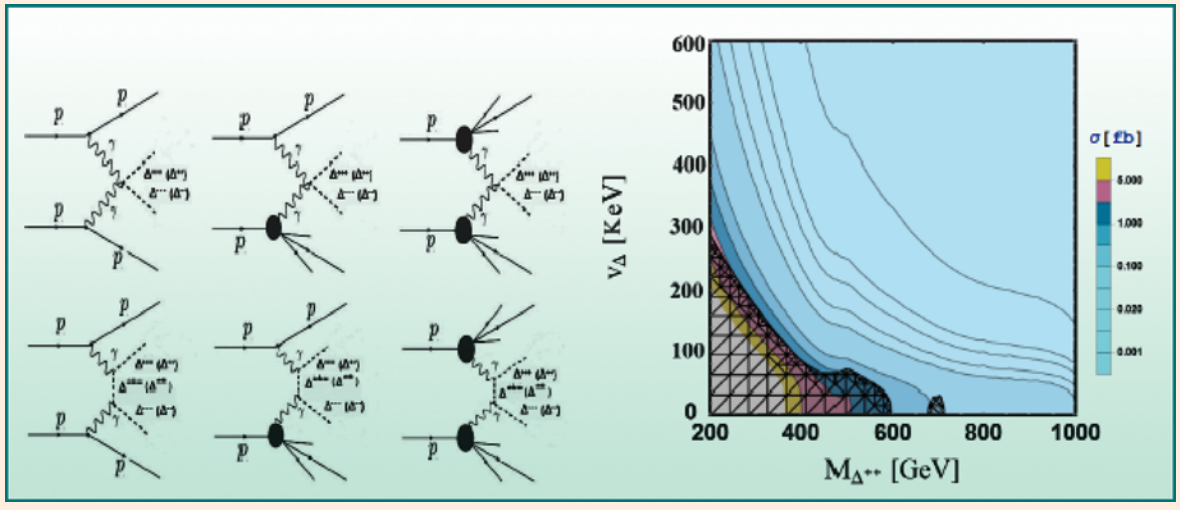

Fig.-1. (left panel)Feynman diagrams for the pair production of $\Delta^{\pm\pm\pm}$ and $\Delta^{\pm\pm}$ via photon-photon fusion process. (right panel) Contour plot of $(V^{++}\Delta y^{--})$ $Br(\Delta' \rightarrow e^{\pm} e^{\pm})$ on $n_{\bar{A}}$ - $M_{\bar{A}\pm\pm}$ plane. The crossed region of the plot is excluded from the ATLAS search [?] for same sign dilepton invariant mass peak at 13 TeV center of mass energy and 13.9 fb^{-1} integrated luminosity.

RH neutrino mass scale. We have also proposed a same-sign dilepton signal region associated with multiple jets and missing energy that can be used to distinguish the the present scenario from the usual inverse seesaw extended SM.

D. Das, K. Ghosh, M. Mitra and S. Mondal; Phys. Rev. D 97, no. 1, 015024 (2018)

35. Probing nonstandard neutrino interactions at the LHC Run II.

Searching for non-standard neutrino interactions, as a means for discovering physics beyond the Standard Model, has been one of the key goals of dedicated neutrino experiments, current and future. This has received recent _llip in the wake of reported anomalies in leptonic B-decays. We demonstrate here that much of the parameter space accessible to such dedicated neutrino experiments is already ruled out by the RUN II data of the Large Hadron Collider experiment.

D. Choudhury, K. Ghosh and S. Niyogi; Accepted for Publication in Phys. Lett B

36. Sub-TeV Quintuplet Minimal Dark Matter with Left-Right Symmetry.

A detailed study of a fermionic quintuplet dark matter in a left-right symmetric scenario is performed. The minimal quintuplet dark matter model is highly constrained from the WMAP dark matter relic density (RD) data. To elevate this constraint, an extra singlet scalar is introduced. It introduces a host of new annihilation and co-annihilation channels for the dark matter, allowing even sub-TeV masses. The phenomenology of this singlet scalar is studied in detail in the context of the Large Hadron Collider (LHC) experiment. The production and decay of this singlet scalar at the LHC give rise to interesting resonant di-Higgs or diphoton final states. We also constrain the RD allowed parameter space of this model in light of the ATLAS bounds on the resonant di-Higgs and diphoton cross-sections.

S. Kumar Agarwalla, K. Ghosh and A. Patra; JHEP 1805, 123 (2018).

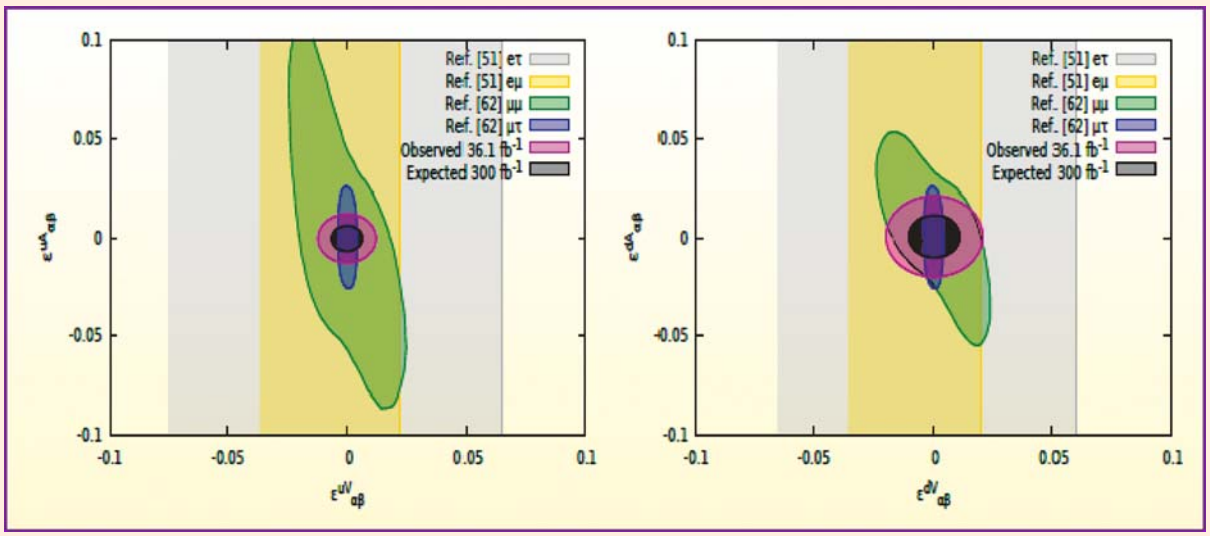

Fig.-2. Allowed parts of – planes, with q = u(d) in the upper(lower) panels. The bounds from neutrino experiments are avor specific and at 90% CL, while those from ATLAS (36 fb^{-1} at = 13TeV) apply to all avor combinations, and at 95% CL.

2.2 Theoretical Nuclear Physics

From the inception of Institute of Physics, Bhubaneswar, Theoretical Nuclear Physics is one of the major subject of research in the institute. Though most of the members of the group have already been retired except a few present members, the past as well as present contributions by the group to the theoretical Nuclear Physics community is substantially remarkable and recognized in both national and international level. Most papers of the group are published in high impact factor journals and have higher number of citations. The faculties of the Nuclear Physics Group not only work themselves, but also collaborate with faculties and students with national and international Universities and Institutions. The group members also have been recognized by many organizations and have received several awards, like Dr. M.N. Saha memorial medal, Kamal Kumari National award, Pathani Samanta Chandrasekhar award, Nandighosh sanman and associate membership of ICTP. A large number of PhDs have been trained by this Group and presently many of them are serving in various Universities and Institutions.

The theoretical Nuclear Physics group is collaborating with many National and International programmer. Based on their ideas and work an international experimental (Indo-German) collaboration was finalized, in which GSI (Germany), TIFR, IUAC and IOP were participants. This group is also active players in the Indian National Gamma Array (INGA) and International Nuclear Physics High Energy programme (ALICE) carried out at CERN, Geneva.

The group has a major contribution to the International Nuclear Physics Community on Theoretical Nuclear Structure Physics. The knowledge on Nuclear Structure is essential to understand various nuclear phenomena. The activities on Nuclear Structure had been started from the early days since 1975. It is major area of research in Nuclear Physics today at Institute of Physics, Bhubaneswar.

(S. K. Patra, P. K. Sahu)

1. Recent Activities in Nuclear Physics

Most recently, using the relativistic mean field formalism, the effective field theory motivated relativistic mean field approximation and non-relativistic models, we have studied the properties of finite nuclei properties throughout the mass table and predicted a large number of phenomena, some of them also verified experimentally by International Group. The most important of them are (i) the clustering structure of nuclei, (ii) the prediction of neutron magic number at N=100 for neutron rich Sm isotopes etc. (iii) the symmetry energy coefficient for finite nuclei at zero and finite temperature are studied for thermally fissile nuclei. (iv) We have also studied the nuclear equation of states and the structure of neutron star extensively using various theoretical models and inferred a large number of information which are current interest for the nuclear and nuclear astrophysics communities. Very recently, we used the nuclear equation of states and calculate the gravitational amplitude and compared the calculated data with various recently reported measurements. In addition to these findings, we have also constructed several new force parameters which can be used for both finite nuclei as well as nuclear matter in normal and extreme conditions. Apart from these above, a large number of important ideas have been evolved by us, which are highly recognized by both National and International community.

S K Patra and collaborators

2.3. Experimental High Energy Physics

The goal of High Energy Physics is to understand the basic constituents of matter and their interactions. The theoretical framework developed by Glashow, Salam, and Weinberg to describe the interactions between the known elementary particles is known as the Standard Model (SM) of particle physics. The cornerstone of the Standard Model is the Higgs mechanism, which is believed to give mass to all elementary particles. A Higgs boson, a particle corresponding to the Higgs field, was recently discovered at the Large Hadron Collider (LHC) at CERN, Geneva, Switzerland. A collider is a particle accelerator that accelerates two beams of particles in opposite directions to a very high energy and collides them against each other at designated interaction points where sophisticated particle detectors are placed to detect new particles produced in the collisions.

Also the goal of the High Energy Heavy-Ion physics program is to explore the study of strongly interacting matter, Quantum Chromo Dynamic phase diagram at extreme conditions such as high baryon density and high temperature using ultra high energy nucleus-nucleus collisions at RHIC (STAR), LHC(ALICE) and FAIR(CBM) experiments. In these collisions at high baryon density, the study of the equation of state of nuclear matter in the core of Neutron Stars and search of strongly interacting phase transitions and discovery of exotic new particles also are included.

At IOP, there are two experimental high energy physics groups participating in the collider-based experiments at various international laboratories. One group participates in the Compact Muon Solenoid (CMS) experiment at LHC, CERN. It is involved in the studies of SM particles and searches for beyond the SM particles in proton-proton collision events collected by the CMS detector. The other group is involved in the studies of Quark-Gluon plasma, production of new particles and a state of matter in the early universe, which are recreated in heavy ion collisions. It participates in the STAR experiment at RHIC, BNL, USA, ALICE experiment at LHC, CERN, and the proposed CBM experiment at FAIR, GSI, Germany. Apart from the physics studies the groups also contribute to the R&D of the state-of-the-art detectors for the present and future experiments.

(P. K. Sahu, A. K. Nayak).

High Energy Experimental Laboratory for ALICE and CBM:

1. Characterizations of GEM detector prototype:

Hardware:

A quadruple GEM detector prototype is built in IOP, HED lab and tested with Ar/CO2 gas mixture in 70/30 ratio. Initial characterizations for the detector are performed by measuring the count rate and anode current with cosmic muons. The detector is taken to GSI, Germany and tested with Fe 55 X-ray source and a X-ray generator. The measurement is done with a high gain preamplifier. The gain and energy resolution are measured for different voltage setting. The exponential nature of gas gain with applied voltage is observed. At 1600 V a typical gain is <“ 450 and the energy resolution is found to be <“ 14% (ó). The anode current is also measured for different configurations with both Fe55 source and X-ray generator.

Since flow rate optimization is needed for the further study, the GEM detector is tested with different gas flow rates. For this measurement Am 241 radioactive source is used. The count rate variations and current variations are observed at different flow rates with different operating GEM voltages. The flow rates are recorded with a mass flow sensor built in house.

A single layer GEM detector is also fabricated for the estimation of Ion Back Flow fraction. The voltages are provided to each electrode individually. For the measurement of current from each channel with different settings, a pico ammeter is used. The variation of Ion back flow fraction is observed with changing drift field, induction field as well as different GEM voltages.

S. Swain, P. K. Sahu, A. Tripathy and S. Sahu

Simulation:

For Characterization of detector, initiative is taken for doing numerical analysis with Garfield++ simulation package. The simulations include measurements of detector Gain, Transparency, Efficiency, Ion backflow and signal extraction etc. ANSYS scripts, based on finite element method is used to model different geometries and configurations of GEM prototype and for the calculation of electric field inside the detector volume. Here, we made a simulation study on stacks of 4-GEM to characterize the properties like gas gain, effective gain, transparency, ion backflow, energy and position resolution using Garfield++ and ANSYS field solver. A systematic analysis is done on induced signal shape for various detector field configurations and a preferable zone of operation for the detector is being discussed.

S. Swain, S. Dani and P. K. Sahu, M. M. Mondal

2. Study of ion backflow fraction for GEM based detector:

A systematic study is performed for the ion backflow fraction with GEM based detectors. The ion current along with detector gain are measured in various voltage configurations and with different gas proportions. The observed ion backflow fraction seems to be very sensitive towards the drift field and the effective gain of the detector. Further with decrease in the quencher component present in the gas mixture gain changes, which consequence a change of ion

fraction going towards the drift volume. The main idea is to optimize the detector for the minimum ion backflow current. For that a detailed scan over drift and induction field is done with different gas ratios. A minimum ion backflow fraction of 3.0% is obtained with drift field 0.1kV with Ar:CO_2 gas in 80:20 ratio.

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3. Ion Beam based characterization of Triple GEM Detector:

Gas Electron Multipliers (GEM) detector possess high rate capability and high resolution as compared to the detector based on the wire chamber or tracking drift chamber principle. This is because, the GEM has been used in high-energy experiments such as COMPASS, TOTEM, CMS and ALICE experiment at CERN and PHENIX experiment at BNL.A Triple-GEM prototype of area 10´ 10 cm^2 was fabricated and characterised using Fe^{55}source at Institute of Physics, Bhubaneswar. In this report, we used the same GEM detector to characterise by using the ion beam facility at Institute of Physics. Proton beam generated from a 3MV Tandem Pelletron was used to emit X-rays from different metal targets to study the characteristics of GEM detector. X-rays yield of the metal (Fe) is directly proportional to the proton beam current. Anode current (nA) and gain as a function of GEM voltages at different beam current have been studied and were found exponentially increases with GEM .

P. K. Sahu, S. Swain, A. Tripathy, S. Sahu and B. Maillick

4. Design and fabrication of data logger to measure the ambient parameters in gas detector R&D:

A novel instrument has been developed to monitor and record the ambient parameters such as temperature, atmospheric pressure and relative humidity. With this data logger continuous recording of temperature, atmospheric pressure, relative humidity and the time stamp can be done with a programmable sampling interval. The device is interfaced with computer by Lab-view software. This instrument is very cheap and these parameters are very essential for understanding the characteristics such as gain of gas filled detectors like Gas Electron Multiplier (GEM) and Multi Wire Proportional Counter (MWPC). In this article the details of the design, fabrication and operation processes of the device has been presented.

S. Swain, P. K. Sahu and S. K.Sahu

5. Heavy-ion collisions:

Proton nucleus collisions are important in addressing cold nuclear matter, initial conditions, energy loss and parton multiple scattering. Parton distributions are affected by various phenomena like nucleon overlap in nucleus, or EMC effect and leading to depletion of partons at high x. Parton rearrangement for the same reason give rise to shadowing (depletion at x<.04) and anti-shadowing (enhancement x~0.1). It is inevitable to understand the effects to get a clear knowledge on hot de-confined state of hadronic matter (QGP) formed in relativistic heavy ion collisions.

P. K. Sahu & collaborators.

6. Study of Λ(1520) resonance at ALICE Energies:

Some hadronic resonance states due to their short lifetimes (~few fm/c)are important to investigate some properties like the time span of the hadronic scattering medium formed in relativistic heavy-ion collisions. In particular, the

Λ(1520 (commonly known as **Λ*** baryonic resonance is important because its lifetime (~12.6 fm/c) is comparable to the time scale of the hot and dense matter produced in heavy-ion collisions.The characteristic properties such as mass, width, yield and transverse momentum spectra of **Λ*** may be very sensitive to the dynamics and in-medium effects. Basically th decay products of **Λ*** the protons and kaons, may undergo in-medium effects such as re-scattering. The re-generation process (pseudo-elastic interactions; p+K → **Λ*** →p+K may compensate for the **Λ*** yield, lost in re-scattering, if the system formed has a long expansion time.

We have studied production of **Λ** in p-p and p-Pb collisions at 7 TeV and 5.02 TeV, respectively. In p-p collisions the signal is extracted in the mid rapidity window ($|y| = 0.5$), but due to asymmetric collision of p and Pb, the signal in extracted in rapidity, $-0.5 < y < 0$. We have calculated the p_T- integrated yield and $\langle p_T \rangle$ in case of inelastic p-p collisions, Non-Single Diffracted (NSD) p-Pb collisions and in different charged particle multiplicity bins in p-Pb collisions. These measured values are compared with other resonances as well as long lived particles. We have the following findings from this study.

P. K. Sahu & collaborators.

7. Λ* follows mass ordering in $\langle p_T \rangle$ for both p-p and p-Pb collisions.

Λ* Strangeness content can be a key factor of yield enhancement in higher multiplicity bins. This enhancement is independent of mass of a particle.

Λ* flows with pi, K, p up to $p_T = 3.5$ GeV/c, and the radial flow increases with increase of charge particle multiplicity in an event.

Hadronic scattering medium has negligible effect on its yield over charge particle multiplicity. This measurement may help models to have a upper bound of the hadronic scattering medium in p-Pb collisions at 5.02 TeV.

For ALICE Collaboration: R.C. Baral, S. Sahoo and P. K. Sahu

8. Single Muon from Heavy Flavour Hadronic Decay:

The measurement of nuclear modification factor is important with event activities for heavy flavor. We will measure single muon from heavy flavor hadronic decay with muon stations at forward or backward rapidity depending on the orientation of Pb ions. High multiplicity events are much of interest for some of the observables indicating the formation of de-confined hadronic matter. R_{CP} is an observable which indicates the nuclear modification in central Pb to respect to the peripheral collisions. We are investing it for run-1 and run-2 for ALICE data.

For ALICE Collaboration: M. M. Modal and P. K. Sahu.

9. Ks/Lambda/Anti-Lambda/Xi/Anti-xi in U+U 193 GeV:

We investigate strangeness production in STAR experiment at RHIC in U+U 193 GeV collisions. Weak decay particles like Ks/ Lambda/Xi have been reconstructed from their hadronic decay channels. Reconstructed masses are in consistent with PDG values. These particles transverse momentum spectra have been corrected with detector acceptance, efficiency and branching ratio. Omega reconstruction is ongoing. We are also comparing these results with Au+Au 200 GeV results.

For STAR collaboration: S. Tripathy and P. K. Sahu

10. Long-range correlation in rapidity in STAR Energies:

For small systems in pp or Pb, long-range correlation in rapidity, a ride like structure in dihadron correlations, is being observed in CMS and ALICE for high multiplicity events. The STAR experiment so far limited by rapidity coverage in doing such measurements. Forward Meson Spectrometer and central electromagnetic calorimeter in STAR has a wide coverage and it is suitable to such studies. pp, pAu and pAl at center of mass energy 200 GeV taken in 2015 is very relevant for study of ridge structure. The same study would help to understand the onset of gluon saturation, which is the pillar of CGC. The study involves us to study on $Delta_{eta}$-$Delta_{phi}$ correlation between FMS jets/photons/ pi^0 and tracks/jet-clusters. It is quiet important to make a detailed study on jet clustering parameters so that we are enough sensitive to partonic level observables disentangling the effect of fragmentation which can potentially dilute the correlations.

For STAR Collaboration: M. M. Mondal and P. K. Sahu

11. Calculating charged particle observables using modified Wood Saxon model in HIJING for U+U collisions at 193 GeV.

We have implemented spherical harmonics in default Wood Saxon distribution of the HIJING model and calculated various physical observables such as transverse momentum, charged particle multiplicity, nuclear modification factor and particle ratios for charged particles at top RHIC energy with collisions of Uranium (U) nuclei. Results have been compared with available experimental data. We observe that, a particular type of collision configuration can produce significant magnitude change in observables. We have noticed that the tip-tip configuration shows higher magnitude of particle yield in central collisions, while the body-body configuration shows higher value in the cases of peripheral collisions, with the flip in the trend occurring for the mid-central U+U collisions.

S. K. Tripathy, M. Younus, Z. Naik and P. K. Sahu

12. Application of Nilsson model for deformed nucleus in relativistic heavy ion collisions.

For spherically symmetric nucleus (Au or Pb), Wood-Saxon (WS) distribution proves to be highly manoeuvrable and aptly suitable in giving nucleon distribution within a nucleus. Incorporating shape modification in WS, earlier attempts were made to explain observables in deformed nucleus such as Uranium(U). Although the shape of distribution remains consistent, the Modified Wood Saxon (MWS) overestimates the particle multiplicities. In this work, we use an alternate approach known as Nilsson model, to explain U+U collisions at 193 GeV of RHIC. We have implemented the formalism in HIJING model to calculate charged particle multiplicity and pseudo-rapidity distributions. The model describes the experimental data more closely than WS/MWS and thus is more suitable to study deformed nucleus within this model formalism

S. K. Tripathy, M. Younus, P. K. Sahu and Z. Naik

13. Search for the Higgs boson production in association with a top quark pair in final states with a tau lepton at LHC.

The ATLAS and CMS experiments at LHC had recently discovered a Higgs boson using the

proton-proton (pp) collision data collected at a centre-of-mass energy of 7 and 8 TeV. The measured properties of the observed resonance are consistent with the expectations for the Standard Model (SM) Higgs boson within the uncertainties, corroborating the mechanism for electroweak symmetry breaking (EWSB) of the SM. However, it is important to measure its properties precisely in order to conclude that it is the SM Higgs boson. In SM, the Higgs boson to fermion coupling is proportional to fermion mass. Thus, the measurement of the Yukawa coupling of the Higgs boson to top quark, y_t, is of high phenomenological interest due to extraordinary large values of the top quark mass compared to all other known fermions. Though, the top quark Yukawa coupling is measured indirectly from the Higgs boson production in gluon fusion process, and agrees well with the SM expectation, it can be affected by the contribution of beyond SM (BSM) particles to the loop diagram. Hence, the measurement of the production rate of Higgs boson in association with top quark pairs (tt(bar)H) provides the most precise model independent measurement of y_t.

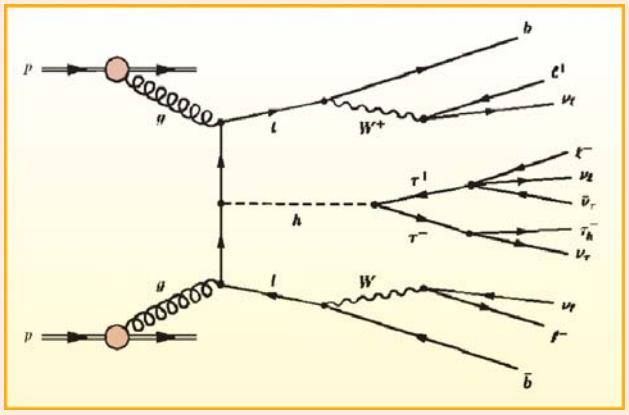


Fig.-1: A typical Feynman diagram for tt(bar) H production with subsequent decay of the Higgs boson to a pair of tau leptons.

This analysis is performed to search for tt(bar)H production in final states with tau leptons in pp collision data corresponding to an integrated luminosity of 35.9 fb^{-1}, recorded by the CMS experiment in 2016 at a centre-of-mass energy of 13 TeV. A typical Feynman diagram for tt(bar)H production in this final state is shown in Fig.1. This analysis targets tt(bar)H final states with a reconstructed hadronic tau and is sensitive to the Hàôô decay mode. Three different final states are analyzed: (1) events containing two leptons (electrons or muons) of the same charge and one hadronically decaying tau lepton ($\hat{o}_h$), (2) events containing one lepton and and two $\hat{o}_h$, and (3) events containing three lepton and one $\hat{o}_h$. The sensitivity of the analysis is enhanced by means of two different multivariate analysis techniques: by the matrix element method (MEM) and by the boosted decision trees (BDT). **Our group has played a leading role in developing the BDT discriminant for this analysis**. The signal contribution in each category is obtained by a maximum likelihood fit to the distribution of the above BDT or MEM discriminats. Signal rates ì$_{ô}$ ratio of signal cross section to that expected from SM, are computed for each of the categories individually and for their combination. The results are combined with those obtained from multilepton final states excluding $\hat{o}_h$, and are shown in Fig.2 (left). The measured signal rates are compatible with SM expectation within the uncertainties. Figure 2 (right) shows the distribution of log(S/B), obtained by combining events from each bin of the final discriminant distributions from all event categories. The excess of events observed in higher S/B regions are compatible with tt(bar)H signal production. The significance of the signal is found to be 3.2ó

(observed) against an expected significance of 2.8 ó, which provides a strong evidence for the tt(bar)H production. Furthermore, results of all the analyses, searching for tt(bar)H production in various final states and at 7, 8, and 13 TeV, have been combined together, which are shown in Fig. 3. Figure 3 (left) shows the best value of signal strength for individual channels and for the combinantion. Fig. 3 (right) shows the variation of test statistic, defined as the negative of twice the logarithim of the profile likelihood ratio, against the signal strengh (ì), which provides a **5.2ó significance for the observed signal** as compared to 4.2ó expected. **This constitutes the first observation of tt(bar)H production at LHC**.

A. K. Nayak, et.al.

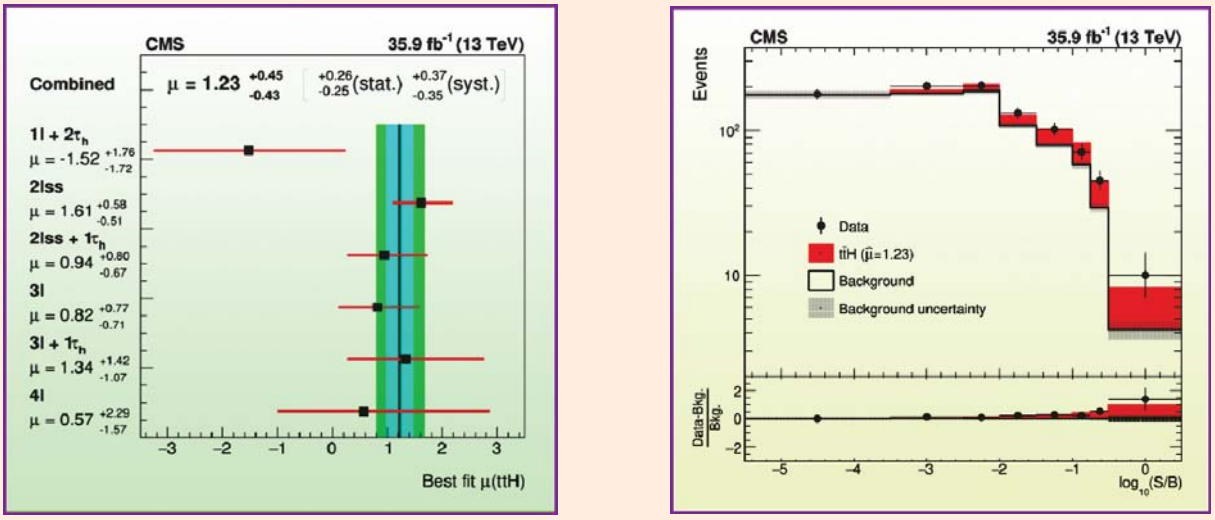


Fig.-2: *Signal rates mu, in units of the SM* tt*(bar)*H *production rate, measured in each of the categories and for the comination of all categories.*

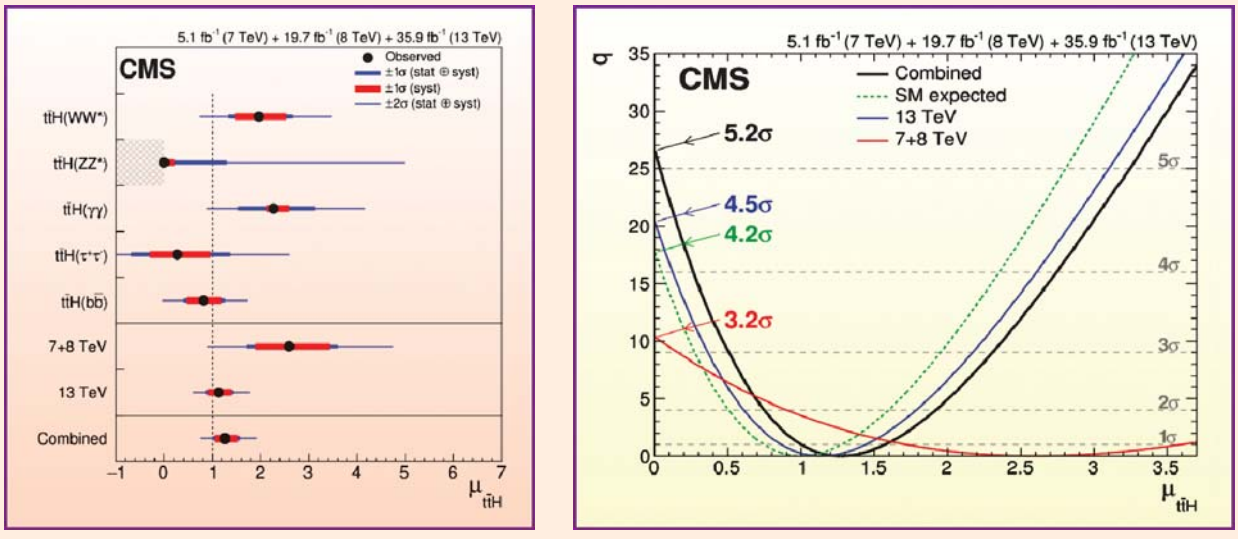


Fig.-3: *Left: Best fit value of* tt(bar)H signal strength modifier, ì, with its 1 and 2 standard deviation confidence intervals. Right: The test statistics, q, as function of ì for all event categories combined together.

14. Re-construction and identification of τ leptons in their decays to hadrons in pp collisions at √s = 13 TeV.

The reconstruction and identification of **τ** lepton in their decays to hadrons and tau neutrino is crucial for the studies of Higgs boson and many other new physics searches at LHC. The CMS group at IOP plays a leading role in the development of reconstruction and identification algorithms of the hadronic decays of **τ** leptons ($\boldsymbol{\tau}_h$). In particular, we played leading role in development of multivariate (MVA) isolation for Run-2 of LHC using boosted decision trees (BDT). The MVA-based isolation discriminants provide a factor of two reduction in jet → $\boldsymbol{\tau}_h$ mis-identification probability, while retaining same $\boldsymbol{\tau}_h$ efficiency as compared to the isolation sum discriminants, as shown in Fig 1. The group played leading role in the overall coordination of the offline tau identification developments and is also played major role in measuring the performance of the identification algorithms in proton-proton collision data recorded during 2016. The performances have been evaluated in terms of efficiency of a genuine $\hat{o}_h$ to pass the identification criteria as well as the misidentification probability of quark and gluon jets, electrons, and muons to be identified as $\hat{o}_h$. The measurements show the performances in data agree well with that of the expectation from simulation. The rescaling factors have been obtained to scale the performances in simulation to match that of data. The analyses and results have been documented for a publication in JINST, and is currently under collaboration wide review. Furthermore, we worked on re-optimizing the isolation sum discriminants for the data recorded during 2017, and provided two more high efficiency working points that may be helpful to analyses, such as high p_T SUSY searches, requiring higher signal efficiency.

A. K. Nayak, M.B.Vinaykrishnan and Collaborators.

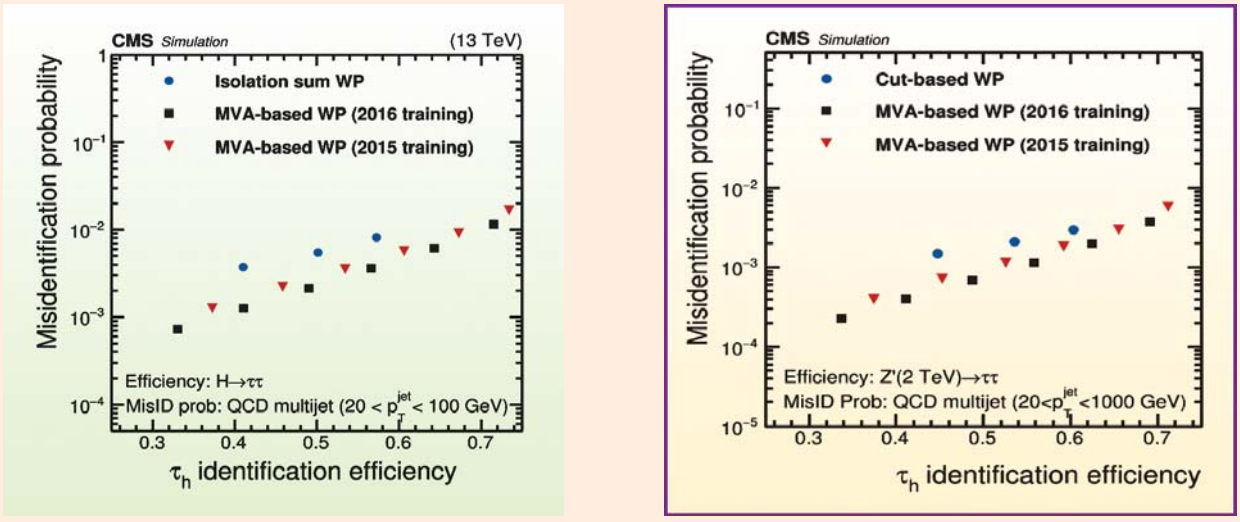


Fig.-1: Expected th reconstruction and identification efficiency against the jet à $\hat{o}_h$ mis-identification probability for cut-based and MVA-based tau isolation discriminators.

15. Development of Jet and Missing Transverse Energy Triggers for the CMS experiment.

The CMS group at IOP is involved in the coordination of activities related to the development of jets and missing transverse energy trigger in the High Level Trigger (HLT) of the CMS experiment. The reconstruction of jets and missing tranverse energy at the HLT is crucial for the design of many trigger paths that are used to record data for Higgs, SUSY, and many other new physics searches. Our group is playing a leading role in these activities from mid 2016. In addition to the coordination task the group is also contributing to the various aspects of the trigger development, such as studying the response and resolution of the jets at HLT, developing trigger menu, measuring the performance of the trigger in 2016 and 2017 data, and so on. The performances of the jet and missing energy triggers in 2017 data are shown in Fig 1, which shows good efficiency for the online reconstruction of these objects with respect to the offline.

A.K. Nayak, B. Chitroda and Collaborators.

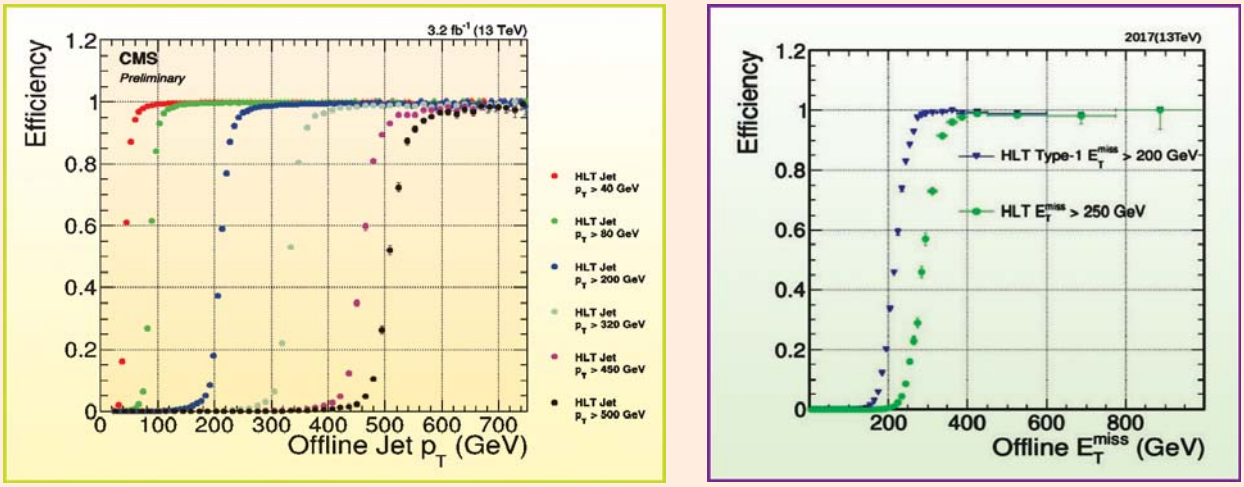


Fig.-1: The trigger efficiencies measured in data recorded during 2017 as a function of the offline reconstructed jet transverse momentum and missing transverse momentum, respectively.

2.4 Quantum Information.

Quantum information science is one of the frontier area of science and technology. It is also an interdisciplinary area of research where scientists from physics, mathematics, and computer science can contribute alike. Three major areas of interest are quantum correlations, quantum nonlocality, and quantum communication protocols. In the area of quantum correlations, the goal has been better understanding the correlations in bipartite mixed states and multipartite states. Issue has also been if there are quantum correlations beyond entanglement. Characterization, quantification, and manipulation of correlations in a quantum system can have far-reaching technological ramifications. Quantum nonlocality leads to enduring mysteries of quantum mechanical formalism. There are also systems like Popescu-Rohrlich box, which display more nonlocality than a quantum system.The group is working on better understanding of this phenomenon beyond bipartite pure states, i.e. mixed states and pure multipartite states. One of the triumph of this field has been introduction of new means of communications using entanglement as a resource. The group has been exploring many such protocols, such as secret sharing, in multipartite settings.

(P. Agrawal)

1. Distinguishing different classes of entanglement of three-qubit pure states in an experimentally implementable way.

Employing the Pauli matrices, we have constructed a set of operators, which can be used to distinguish six inequivalent classes of entanglement under SLOCC (stochastic local operation and classical communication) for three-qubit pure states. These operators have very simple structure and can be obtained from the Mermin's operator with suitable choice of directions. Moreover these operators may be implemented in an experiment to distinguish the types of entanglement present in a state. We show that the measurement of only one operator is sufficient to distinguish GHZ class from rest of the classes. It is also shown that it is possible to detect and classify other classes by performing a small number of measurements. We also show how to construct such observables in any basis. Furthermore, we consider the teleportation scheme of Lee *et.al*. and show that the partial tangles and hence teleportation _delity can be measured. We have also shown that these partial tangles can also be used to classify genuinely entangled state, biseparable state and separable state.

P. Agrawal, Satyabrata Adhikari, Chandan Datta, and Arpan Das.

2. Coherence of quantum channels.

We investigate the coherence of quantum channels using the Choi-Jamio lkowski isomorphism. The relation between the coherence and the purity of the channel respects a duality relation. This duality has been depicted via the Coherence-Purity (Co-Pu) diagrams. In particular, we study the quantum coherence of the unital and non-unital qubit channels and find out the allowed region of coherence for a fixed purity. We also study coherence of different incoherent channels, namely, incoherent operation , strictly incoherent operation, physical incoherent operation (PIO) etc. We find that if PIOs are coherence preserving operations, its coherence is zero otherwise it has unit coherence and unit purity. The unital channels generally do not create coherence whereas some nonunital can. All coherence breaking channels are shown to have zero coherence, whereas, this is not usually true for entanglement breaking channels. It turns out that the coherence preserving qubit channels have unit coherence. Although the coherence of the Choi matrix of the incoherent channels might have finite values, its subsystem contains no coherence. This indicates that the incoherent channels can either be unital or nonunital under some conditions. We also prove a complementarity relation between the relative entropy of coherence and the Holevo quantity of the quantum channel. This suggests that the coherence and the Holevo quantity of the channels cannot be arbitrarily large at the same time.

P. Agrawal, Chandan Datta, Sk Sazim, and Arun Pati

3. New Bell inequalities for three-qubit pure states.

We have introduced a set of new Bell inequalities for a three-qubit system. Each

inequality within this set is violated by all generalized GHZ states. Most well-known inequalities are not violated by all such states. Also, more entangled a generalized GHZ state is, more our inequalities will be the violated. This establishes a relation between nonlocality and entanglement for this class of GHZ states. Certain inequalities within this set are violated by pure biseparable states. We also present numerical evidence that at least one of these Bell inequalities is violated by any pure genuinely entangled state. These Bell inequalities, unlike other known inequalities, can distinguish between separable, biseparable and genuinely entangled pure three-qubit states. We also generalize this set to n-qubit systems which may be suitable to characterize the entanglement of n-qubit pure states. We also show the phenomenon of hidden nonlocality with respect to our inequalities.

P. Agrawal, Arpan Das and Chandan Datta.

2.5. Theoretical Condensed Matter Physics.

At IOP, the condensed matter theory group is involved in cutting edge research in the following branches of Condensed Matter Physics (CMP).

Quantum Condensed Matter Physics

In this field, we are actively involved in exploring the electronic, magnetic and quantum transport properties of various quantum materials.

We are performing an active research in this field with a special emphasis on quantum magnetism and spin liquid physics, strongly correlated electronic systems, quantum entanglement, water and hydrogen bonded systems, quantum transport through various mesoscopic systems, Dirac materials, topological insulator and topological superconductor, Floquet Dirac systems, interplay between topology and correlation etc.

Soft Condensed Matter and Biological Physics

Current activity in this field is mainly focused around developing physical understanding of different biological phenomena. Members are working on the following topics: formation of chromosomal structure, morphology and segregation of E.coli chromosome mediated by protein production and confinement, dynamics of cytoskeletal patterns, phase behavior of active colloids, ratcheting of colloidal dispersion, dynamics of semiflexible polymers in motor protein assay, DNA melting and associated vanishing of rigidity, role of topology in kinetoplast DNA, rheology of soft and active matter, etc.

Statistical Mechanics

The current interest of the group revolves around non-equilibrium stochastic thermodynamics, stochastic heat engines, fluctuation theorem, entropy production by active particles, stochastic pump of interacting particles and current reversal, collective motion driven by molecular motors, etc.

(A. M. Jayannavar, S. M. Bhattacharjee, G. Tripathy, A. Saha, S. Mandal, D. Chaudhuri).

1. Phase diagram of triple stranded DNA.

One of the odd results of quantum mechanics is the Efimov effect of three-particle bound-states in the absence of any pair-wise binding. He, with collaborators, have shown an analog of this effect, due to fluctuations, in triple-stranded DNA near the duplex melting point. A large scale Monte-Carlo simulation, based on PERM, is going on to explore details of the phases in the tripe stranded system, the phase diagram, and the nature of the transitions. This is on-going work involving both theoretical and numerical analysis of large chains with different types of polymeric interactions. The importance of this work is in the context of ongoing research on use of triplex DNA for therapeutic applications, like, gene therapy.

S. M. Bhattacharjee and D. Foster

2. Density profile of ASEP from Renormalization Group.

The totally asymmetric simple exclusion process along with particle adsorption and evaporation kinetics is a model of boundary-induced non equilibrium phase transition. In the continuum limit, the average particle density across the system is described by a singular differential equation involving multiple scales which lead to the formation of boundary layers (BL) or shocks. A re-normalization group analysis is developed here by using the location and the width of the BL as the renormalization parameters. It not only allows us to cure the large distance divergences in the perturbative solution for the BL but also generates, from the BL solution, an analytical form for the global density profile. The predicted scaling form is checked against numerical solutions for finite systems.

S. M. Bhattacharjee & Sutapa Mukherji.

3. Signature of tilted Dirac cones in Weiss oscillations of 8"Pmmn borophene.

Polymorph of 8-Pmmn borophene exhibits anisotropic tilted Dirac cones. In this work, we explore the consequences of the tilted Dirac cones in magnetotransport properties of a periodically modulated borophene. We evaluate modulation induced diffusive conductivity by using linear response theory in low temperature regime. The application of weak modulation (electric/magnetic or both) gives rise to the magnetic field dependent non-zero oscillatory drift velocity which causes Weiss oscillation in the longitudinal conductivity at low magnetic field. The Weiss oscillation is studied in presence of an weak spatial electric, magnetic and both modulations individually. The tilting of the Dirac cones gives rise to additional contribution to the Weiss oscillation in longitudinal conductivity. Moreover, it also enhances the frequency of the Weiss oscillation and modifies its amplitude too. Most remarkably, It is found that the presence of out-of phase both i.e., electric and magnetic modulations can cause a sizeable valley polarization in diffusive conductivity. The origin of valley polarization lies in the opposite tilting of the two Dirac cones at two valleys.

SK Firoz Islam and A. M. Jayannavar.

4. Stochastic heat engine powered by active dissipation.

Thermodynamics of nanoscale devices is an active area of research. Despite their noisy surrounding they often produce mechanical work (e.g. micro-heat engines), display rectified Brownian motion (e.g. molecular motors). This invokes research in terms of experimentally

quantifiable thermodynamic efficiencies. Here a Brownian particle is driven by a harmonic confinement with time-periodic contraction and expansion. The system produces work by being alternately (time-periodically) connected to baths with different dissipations. Here we analyse the system theoretically using stochastic thermodynamics. Averages of thermodynamic quantities like work, heat, efficiency, entropy are found analytically in the quasistatic limit. Simulations are also performed in various cycle-time limits. They show excellent agreement with analytical calculations in the large cycle-time (quasistatic) limit. Distributions of work, efficiency, and large deviation function for efficiency are studied using simulations. Experimentally realisable method to implement such novel technique is also discussed.

Arnab Saha, Rahul Marathe, P. S. Pal and A. M. Jayannavar.

5. Quantum thermodynamic properties of a cold atom coupled to a heat bath in non-Abelian gauge potentials.

In this work, we study different quantum thermodynamic functions (QTFs) of a cold atom subjected to an artificial non-Abelian uniform magnetic field and linearly coupled to a quantum heat bath through either usual coordinate coupling or through momentum variables. The bath is modelled as a collection of independent quantum harmonic oscillators. In each of the coupling scheme, the effect of the non-Abelian magnetic field on different QTFs are explicitly demonstrated for a U(2) gauge transformation. In each case, we show that the free energy has a different expression than that for the Abelian case. We consider two illustrative heat bath spectrum (Ohmic bath and Drude model) to evaluate explicit closed form expressions of free energy (F), specific heat (C), and entropy (S) in the low temperature limit for each of the above mentioned coupling scheme. The dependence of different QTFs on the non-Abelian magnetic field are pointed out even if the gauge potential is uniform in space.

Asam Rajesh, Malay Bandyopadhyay and A. M. Jayannavar.

6. Generalized Second Law and optimal protocols for nonequilibrium systems.

A generalized version of the Maximum Work Theorem is valid when the system is initially not at thermal equilibrium. In this work, we initially study the fraction of trajectories that violate this generalized theorem for a two simple systems: a particle in a harmonic trap (i) whose centre is dragged with some protocol, and (ii) whose stiffness constant changes as a function of time. We also find the optimal protocol that minimizes the average change in total entropy. To our surprise, we find that optimization of protocol does not necessarily entail maximum violation fraction.

Sourabh Lahiri, Arun M. Jayannavar and Anupam Kundu.

7. Probing the edge states in a zigzag phosphorene nanoribbon via RKKY exchange interaction.

Phosphorene is an anisotropic puckered two-dimensional (2D) hexagonal lattice of phosphorus atoms. The edge modes in a zigzag phosphorene nanoribbon (ZPNR) are quasi-flat

in nature and fully isolated from the bulk states, which are unique in comparison to the other hexagonal lattices like graphene, silicone etc. We theoretically investigate the Ruderman-Kittel-Kasuya-Yosida (RKKY) exchange interaction between two magnetic impurities placed on the nanoribbon, and extract the signatures of the flat edge states via the behavior of it. Due to the complete separation of the edge states from the bulk, we can isolate the edge mode contribution to the RKKY interaction from that of the bulk by tuning the external gate potential when both the impurities are placed at the same edge. The bulk induced RKKY interaction exhibits very smooth oscillation with the distance between the two impurities, whereas for edge modes it fluctuates very rapidly. We also explore the effect of tensile strain both in absence and presence of gate voltage and reveal that the RKKY interaction strength can be boosted under suitable doping, when both the impurities are within the bulk.

SK Firoz Islam, Paramita Dutta, A. M. Jayannavar and Arijit Saha.

8. Universal fluctuations in orbital diamagnetism.

Bohr–van Leuween theorem has attracted the notice of physicists for more than 100 years. The theorem states about the absence of magnetisation in classical systems in thermal equilibrium. In this paper, we discuss about fluctuations of magnetic moment in classical systems. In recent years, this topic has been investigated intensively and it is not free from controversy. We have considered a system consisting of a single particle moving in a plane. A magnetic field is applied perpendicular to the plane. The system is in contact with a thermal bath. We have considered three cases: (a) particle moving in a homogeneous medium, (b) particle moving in a medium with space-dependent friction and (c) particle moving in a medium with space-dependent temperature. For all the three cases, the average magnetic moment and fluctuations in magnetic moment have been calculated. Average magnetic moment saturates to a finite value in the case of free particle but goes to zero when the particle is confined by a 2D harmonic potential. Fluctuations in magnetic moment shows universal features in the presence of arbitrary friction in homogeneity. For this case, the system reaches equilibrium asymptotically. In the case of space-dependent temperature profile, the stationary distribution is non-Gibbsian and fluctuations deviate from universal value for the bounded system only.

P. S. Pal, Arnab Saha and A. M. Jayannavar.

9. Enhancement of crossed Andreev reflection in normal-superconductor-normal junction of thin topological insulator.

We theoretically investigate the subgapped transport phenomena through a normal-superconductor-normal (NSN) junction made up of ultra thin topological insulator with proximity induced superconductivity. The dimensional crossover from three dimensional (3D) topological insulator (TI) to thin two-dimensional (2D) TI introduces a new degree of freedom, the so-called hybridization or coupling between the two surface states. We explore the role of hybridization in transport properties of the NSN junction, especially how it affects the crossed Andreev reflection (CAR). We observe that a rib-

like pattern appears in CAR probability profile while examined as a function of angle of incidence and length of the superconductor. Depending on the incoming and reflection or transmission channel, CAR probability can be maneuvered to be higher than 97% under suitable coupling between the two TI surface states along with appropriate gate voltage and doping concentration in the normal region. Coupling between the two surfaces also induces an additional oscillation envelope in the behavior of the angle-averaged conductance, with the variation of the length of the superconductor. The behavior of co-tunneling (CT) probability is also very sensitive to the coupling and other parameters. Finally, we also explore the shot noise cross correlation and show that the behavior of the same can be monotonic or non-monotonic depending on the doping concentration in the normal region. Under suitable circumstances, shot noise cross correlation can change sign from positive to negative or vice versa depending on the relative strength of CT and CAR.

A. Saha & Collaborators

10. Amplification of Cooper pair splitting current in a graphene based Cooper pair beam splitter geometry.

Motivated by the recent experiments [Scientific reports 6, 23051 (2016), Phys. Rev. Lett. 114, 096602 (2015)], we theoretically investigate Cooper pair splitting current in a graphene based Cooper pair beam splitter geometry. By considering the graphene based superconductor as an entangler device, instead of normal (2D) BCS superconductor, we show that the Cooper pair splitting current mediated by Crossed Andreev process is amplified compared to its normal superconductor counterpart. This amplification is attributed to the strong suppression of local normal Andreev reflection process (arising from the Cooper pair splitting) from the graphene based superconductor to lead via the same quantum dot, in comparison to the usual 2D superconductor. Due to the vanishing density of states at the Dirac point of undoped graphene, a doped graphene based superconductor is considered here and it is observed that Cooper pair splitting current is very insensitive to the doping level in comparison to the usual 2D superconductor. The transport process of non-local spin entangled electrons also depends on the type of pairing i.e. whether the electron-hole pairing is on-site, inter-sublattice or the combination of both. The inter-sub lattice pairing of graphene causes the maximum non-local Cooper pair splitting current, whereas presence of both pairing reduces the Cooper pair splitting current.

A. Saha & Collaborators

11. Spin selective coupling to Majorana zero modes in mixed singlet and triplet superconducting nanowire.

Localized Majorana zero modes that appear at the end of one-dimensional topological superconductor are anticipated to be the building blocks of future topological quantum computers. In our recent study, we theoretically investigate the transport properties of a quasi one-dimensional ferromagnet-superconductor junction where the superconductor consists of mixed singlet and triplet pairings. We show that the relative orientation of the stoner field ($\tilde{\mathbf{n}}$) in

the ferromagnetic lead and the **d** vector of the superconductor acts like an on-off switch for the zero bias conductance of the device. In the regime, where triplet-pairing amplitude dominates over the singlet counterpart (topological phase), a pair of Majorana zero modes appear at each end of the superconducting part of the nano-wire. When **ñ** is parallel or anti-parallel to the **d** vector, transport gets completely blocked due to blockage in pairing while, when **ñ** and **d** are perpendicular to each other, the zero energy two terminal differential conductance spectra exhibits sharp transition from $4e^2/h$ to $2e^2/h$ as themagnetization strength in the lead becomes larger than the chemical potential indicating the spin selective coupling of pair of Majorana zero modes to the lead.

A. Saha & Collaborator

12. Classical ground states, spin-wave and PCUT analysis of rm H_2SQ system.

We are studying the confinement and deconfinement phase transition in certain hydrogen bonded network which can be modelled as some spin model. The theoretical and numerical tools that we employ include meanfield theory, Perturbative continuous unitary transformation(PCUT) and quantum montecarlo. The preprint is available here.

Vikas Vijigiri, Saptarshi Mandal.

13. Quantum theory of spin waves for Helical ground states in Hollandite lattice.

The finite temperature magnetic property of alpha-$Mn0_2$ is being studied by Atanu Maity. This study is being complicated by various competing exchange interaction and also a large physical unit cell. We have found the spin wave spectrum which shows a gapless phase which interpolates from linear to quadratic depending on the parameters. The low temperature susceptibility and specific heat shows unusual exponent depending on the helicity. The preprint is available here.

Atanu Maity and Saptarshi Mandal.

14. Magnetism of classical Keaev Model.

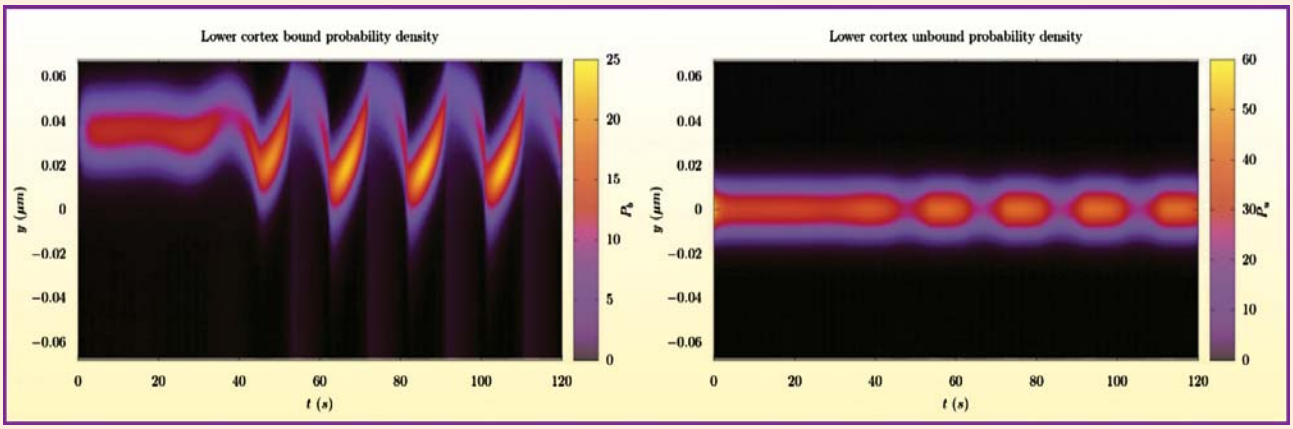
The magnetism of classical Kitaev model is being study with my student Dibyendu Rana. The classical Kitaev model has been studied earlier but inly in Jx=Jy=Jz case. Our aim is to study in anisotropic limit and see the effect of magnon-magnon interaction on it. We have also studied the edge states for various incarnation of extended Kitaev model and also studied quench dynamics for 3d Kitaev Model. The quench dynamics shows different characteristics owing to the existence of gapless contour. The two work will be ready for pre-print very soon.

Saptarshi Mandal and Dibyendu Rana.

15. Active filaments:

Based on our published study on active filament (Soft Matter **13**, 7129 (2017)), we extended its scope to study spindle oscillation, observed during mitotic cell division. Using a Fokker-Planck equation approach to describe probability distributions of cortical dynein, and Langevin dynamics of the centrosome under active forces, we identified a Hopf-bifurcation under enhancement of ATP fuel supply.

A kymograph of bound (left) and unbound (right) probability distribution of dynein in the limit cycle phase are shown in the above figure.

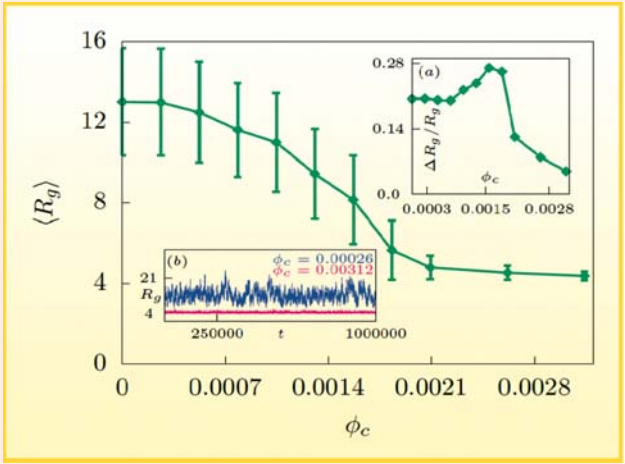


We are working on a full event based simulation to probe impacts of all components of stochasticity and non-linearity in their full glory. This is a work being done with my two PhD students, Amir Shee and VNS Pradeep.

D. Choudhuri, Biplab Bhattacharjee and Collaborators.

16. Bacterial Chromosome:

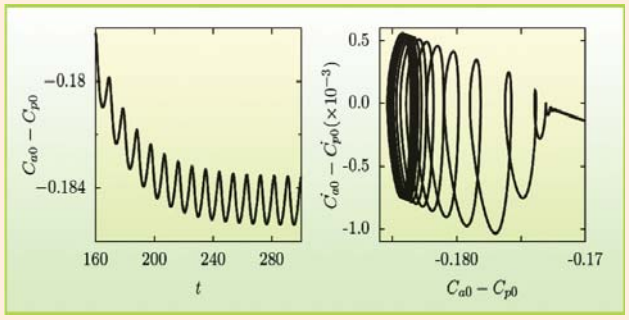
We have worked on two aspects of bacterial chromosome, namely their emergent morphology and dynamics. We have shown that the experimental results for live bacteria can be interpreted in terms of a structured polymer model that we proposed (papers to be communicated soon). In a separate study we probe the formation of the structured polymer that we assumed earlier. To this end, along with my PhD student Amit Kumar, we are studying dynamics of a model DNA in presence of cross-linkers with varying degrees of affinity and density. With increasing density, the polymer shows a coil-globule transition, associated with a clustering transition from gas-like to liquid-like phase of the crosslinkers. This transition occurs due to polymer mediated attraction between repulsive cross-linkers, thus being a classical reminiscent of Cooper-pair formation, albeit in real space. Thus this physics is successfully captured in terms of a dynamic Landau-Ginzburg theory. The loop formation is much more complex, with the density of simply connected loops showing a non-monotonic variation with cross-linker density. We are writing up one paper on this aspect. In immediate future, we shall study the impact of confinement in the loop formation dynamics.



D. Choudhuri, Biplab Bhattacharjee and Collaborators

17. Pulsatory phase in active fluid :

The cytoskeleton of a cell consists of filamentous proteins and molecular motors. This in actomyosin gives rise to contractile stress that can be tuned by local ATP concentration. Using a two component fluid model with a stress



dependent turnover, we investigate this system. It shows three different phases, uniform fluid, pattern formation, and active pulsatile fluid. See the phase

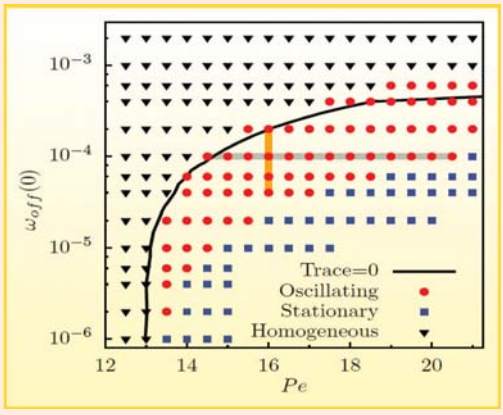
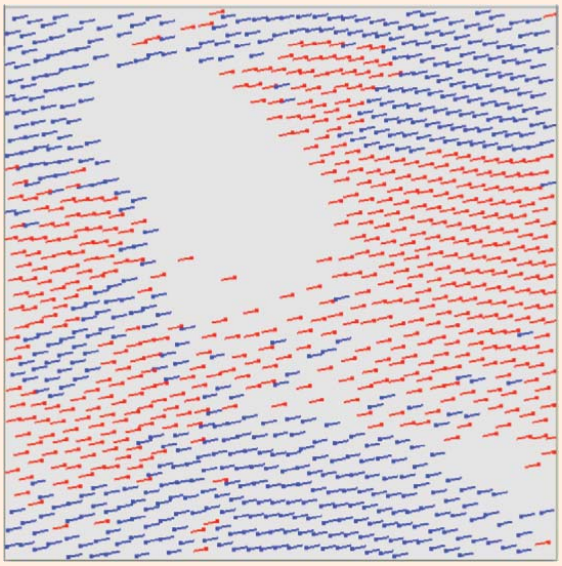


diagram on the right. This has implications for filopodial dynamics, pulsation seen in early embryo etc. The time scale of oscillations in the pulsatory phase grows with activity, and decays with increasing turnover rate. In the pulsatory phase how the two components of fluid change with time is shown in the figure on left.

18. Nematic alignment of polar active colloids:

Cytoskeletal filaments are polar active system that collide and align in a nematic fashion. In bacteria, this is the only activity that fluidizes the cell cytosol. Motivated by this, we are studying an agent based model using Brownian dynamics simulations. Depending on the activity expressed in terms of a Peclet number, and propensity in alignment the system shows three



different phases. In the low activity and propensity limit it is an isotropic fluid. With increase in activity we obtained a transition to nematic phase. At higher activity, steric repulsion generates jamming. A curious transition to lane formation leading to current carrying phase takes place at even higher activity, with clear signatures of intermittency identified. This work is being done with a post-doctoral visiting scientist, Dr. Biplab Bhattacharjee. We are writing up this part of the study, and probing associated liquid-hexatic- solid phase transition in the systems real space structure.

D. Choudhuri, Biplab Bhattacharjee and Collaborators.

2.6 Experimental Condensed Matter Physics.

The Experimental Condensed Matter Physics Group at IOP has active research programs in a wide range of areas including, accelerator based research activities, thin films, surface science, highly correlated electron systems, two-dimensional materials, quantum materials. Members of the group are also exploring advance functional materials for solar cell, memory and sensor applications. Our main goal is to investigate and understand the structure and properties of solids. We use different techniques such as ion implantation, pulsed laser deposition, molecular beam epitaxy and high temperature solid state reaction to prepare high quality novel materials. Various properties of the materials are investigated using sophisticated and advanced instruments that includes high resolution X-ray diffraction, transmission electron microscope, field emission scanning electron microscope, atomic force microscope, SQUID, physical properties measurement system, high resolution Raman spectrometer, Angle-resolved photoemission spectroscopy etc.

(S. Varma, B. R. Sekhar, P. V. Satyam, T. Som, D. Topwal, S. Sahoo, D. Samal).

1. Enzymeless metal doped ZnO glucose sensor.

Composite nanostructures have been grown via coelectrodeposition technique, by including a small concentration of metal in the growth cell, during deposition. Non- Enzymetic glucose sensing is demonstrated by the samples. Results have been compared with pure ZnO nanostructures. These nanostructures also display a band gap modification as well as enhanced absorption properties in the UV-Visible region.

S. Varma, A. Manna, S. Srivastava.

2. Resistive switching in TiO_2 films.

We have investigated the resistive switching behavior of ion implanted TiO_2 films. Implantation was carried out at IUAC, Delhi. All the films show development of nanostructures that display bimodal size distribution. These films also show bipolar resistive switching (RS) behavior. The switching behavior is explained based on the development of conducting filament by the migration of oxygen vacancies generated during ion implantation.

S. Varma, A. Manna, Aloke Kanjilal, D. Kanjilal

3. Ripple pattern formation on Rutile TiO2 (110) by low energy ion beam sputtering.

The formation of self-organized ripple patterns, on rutile TiO_2(110) single crystal, through Ar ion beam sputtering, has been investigated by Scanning Probe Microscopy (SPM) and Angle Resolved X-ray Photoelectron Spectroscopy (ARXPS). Implantation was carried out at IUAC, Delhi. The nanodot pattern, created at lower irradiation fluences transform to continuous ripple pattern at higher fluences. ARXPS results depict the distributions of higher amount of oxygen vacancies and elemental Ti, created due to preferential sputtering of lower mass oxygen atoms, at top irradiated surface rather than bulk TiO_2.

S. Varma, V. Solanki, I. Mishra, Shalik R. Joshi, D. Kanjilal

4. Aligned ZnO nanorods for enhancing UV-Visible absorption.

ZnO nanorods have been produced by hydrothermal method on various hetrostructure layers. These hetrostructures control the ZnO morphology. The morphology and photo absorption properties have been investigated. The Dye-catalysis results show that the ZnO-rods are acting as efficient photocatalytic unit.

S. Varma, P. Dash, A. Manna, P. K. Sahoo, N. C. Mishra.

5. Melting and Unzipping of DNA on SiO_x and TiO_2 Surfaces.

Melting and unzipping of DNA on ion beam modified SiO_x and TiO_2 Surfaces have been investigated. Ion beams induce patterning on the surfaces through the formation of nanodots. As these nanodots grow in size the DNA interaction increases leading to the melting of DNA as well as creation of features that indicate enhanced interaction. Changes in persistence length are also seen.

S. Varma, Indrani Mishra, Shalik Ram Joshi, S. M

6. Topological Insulators.

ARPES and DFT Band Mapping of BSTS

Using angle resolved photoelectron spectroscopic (ARPES) and density functional

theoretical studies on quaternary topological insulator (TI) BiSbTe1:25Se1:75 (BSTS) we confirmed the non-trivial topology of the surface state bands (SSBs) in this compound. We find that the SSBs, which are sensitive to the atomic composition of the terminating surface have a partial 3D character. Our detailed study of the band bending (BB) effects shows that in BSTS the Dirac point (DP) shifts by more than two times compared to that in Bi_2Se_3 to reach the saturation. The stronger BB in BSTS could be due to the difference in screening of the surface charges. From momentum density curves (MDCs) of the ARPES data we obtained an energy dispersion relation showing the warping strength of the Fermi surface in BSTS to be intermediate between those found in Bi2Se3 and Bi2Te3 and also to be tunable by controlling the ratio of chalcogen/ pnictogen atoms. Our experiments also reveal that the nature of the BB effects are highly sensitive to the exposure of the fresh surface to various gas species. These findings have important implications in the tuning of DP in TIs for technological applications.

H. Lohani et.al.

ARPES and DFT on a Week Toplogical Insulator

We reported the emergence of a weak topological insulator (WTI), BiSe, of the Bi-chalcogenide family with an indirect bandgap of 42 meV. Its structural unit consists of a bismuth bilayer (Bi2), a known quantum spin hall insulator sandwiched between two units of Bi2Se3 which are three dimensional strong topological insulators. Our density functional theory calculations confirm the WTI phase and angle resolved photo-emission spectroscopy measurements carried out on cleaved single crystal flakes show Rashba states that closely agree with our theoretical predictions. Further, we made a comparative study of the electronic and magneto-transport properties of single crystal flakes and thin films of BiSe.

K. Maji et.al.

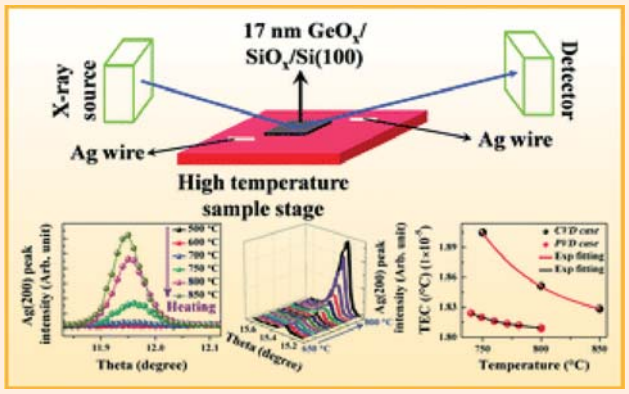
ARPES and DFT Studies of BiPd a Superconducting Topological Insulator.

We made a detailed electronic structure study of the non-centrosymmetric superconductor BiPd based on our angle resolved photoemission spectroscopy (ARPES) measurements and Density Functional Theory (DFT) based calculations. We observe a high intensity distribution on the Fermi surface (FS) of this compound resulting from various electron and hole like bands which are present in the vicinity of the Fermi energy (Ef). The near Ef states are primarily composed of Bi-6p with a little admixture of Pd-4d orbitals. There are various spin-orbit split bands involved in the crossing of Ef making a complex FS. The FS mainly consists of multi sheets of three dimensions which disfavor the nesting between different sheets of the FS. Our comprehensive study elucidates that BiPd could be a s-wave multiband superconductor.

H. Lohani et.al.

In situ synchrotron X-ray diffraction study of coherently embedded silver nanostructure growth in silicon.

We report on the *in situ* growth of coherently embedded Ag nanostructures using real time temperature dependent synchrotron X-ray diffraction (XRD) measurements. H″17 nm thick GeO_x film was grown on native oxide covered



silicon substrates ($GeO_x/SiO_x/Si$) using a physical vapor deposition (PVD) method, which were used as the substrates for Ag nanostructures growth. For growing Ag nanostructures, two different sources of silver were used. In one system, H"2 nm silver thin film was grown on the $GeO_x/SiO_x/Si$ substrates using a PVD method, while in another system, silver wires were kept on the specimen hot stage (chemical vapor deposition) along with the above substrates. All the *in situ* growth and real time XRD were done under atmospheric conditions. The lattice constant of the Ag nanostructures obtained from the *ex situ* growth specimens was used to compare with the real time high temperature XRD measurements. As the temperature is raised from room temperature to 850 °C while performing *in situ* growth, the evolutions of various diffraction peaks such as (111), (200) and (220), reflecting from the growth facets of Ag nanostructures, were monitored. By measuring the deviation of the Ag lattice parameter due to the shift in the diffraction peak positions as a function of temperature, the thermal expansion coefficients for the Ag nanostructures in a matrix have been determined. In one case, the thermal expansion coefficient was found to decrease from 1.9×10^{-5}/°C to 1.82×10^{-5}/°C with the increase of annealing temperature from 750 °C to 850 °C.

Mercury based drug in ancient India: The red sulfide of mercury in nanoscale

Mercury is one of the elements which had attracted the attention of the chemists and physicians of ancient India and China. Among the various metal based drugs which utilize

mercury, we became interested in the red sulfide of mercury which is known in ancient Indian literature as rasasindur (alias rasasindura, rasasindoor, rasasinduram, sindur, or sindoor) and is used extensively in various ailments and diseases. Following various physico-chemical characterizations it is concluded that rasasindur is chemically pure α-HgS with Hg:S ratio as 1:1. Analysis of rasasindur vide Transmission Electron Microscopy (TEM) showed that the particles are in nanoscale. Bio-chemical studies of rasasindur were also demonstrated. It interacts with Bovine Serum Albumin (BSA) with an association constant of $(9.76 \pm 0.56) \times 10^3$ M^{-1} and behaves as a protease inhibitor by inhibiting the proteolysis of BSA by trypsin. It also showed mild antioxidant properties.

Effect of Au thickness on AuAg bimetallic growth on reconstructed Si(5 5 12) surfaces.

Large, stable and single domain unit cell with row-like structures makes reconstructed Si(5

5 12) surface an important one-dimensional growth template of nanostructures. We report on the morphological aspects of the growth of AuAg bimetallic nanostructures on a reconstructed Si(5 5 12) surface that has been deposited with a 0.5 monolayer (ML) Ag and various Au thicknesses (0.5 to 5.0 ML) to determine the optimum gold thickness for a growth of high aspect ratio of AuAg nanostructures. The mean aspect ratio of AuAg nanostructures increases up to Au thickness of 3.0 ML and for larger thickness the mean aspect ratio decreases. The prior growth of 0.5 ML Ag on reconstructed surface result in the formation of one-dimensional Ag strips which are helping for preferential nucleation sites along Si⟨110⟩⟨110⟩ to form AuAg bimetallic long aspect ratio structures. Followed by these early processes of growth, for Au thickness >3.0 ML, excess Au ad-atoms begin to accumulate along Si⟨665⟩ ⟨665⟩ and consequences reduction of mean aspect ratio of bimetallic nanostructures. Nanostructures are grown using molecular beam epitaxy method under ultra-high vacuum conditions and in situ scanning tunneling microscopy has been used to investigate the morphological variations. Determination of structural aspects and compositional analysis has been carried out using Rutherford backscattering spectrometry and high-resolution (scanning) transmission electron microscopy methods.

A. Bhukta, A. Ghosh, P. Guha, Paramita Maiti, B. Satpati, P. V. Satyam

Surface protection coating material for controlling the decay of major construction stone.

Degradation of the building stones are creating instability in the old building and monuments which is to be protected. To investigate the characteristics of such a stones used for the construction in eastern India, we have collected the khondalite stones. The micro-structural and elemental composition analysis of the khondalite stones are analyzed by using SEM, EDX and PIXE trace elemental analysis. We have prepared surface protection coating material with grapheme oxide and cobalt ferrite as a base material along with other residuals. The prepared coating materials is coated on the galvanized iron substrate for further characterization. The surface morphology characteristics of the coating material is analyzed by SEM and AFM. The corrosion resistance characteristics of the prepared coating material is studied by the electrochemical impedance spectroscopy. The results suggests that the prepared coating material can be used as a surface protection materials to control the self-destruction of khondalite stones.

T. Arun, D. K. Ray, V. P. Gupta, S. S. Panda, P. K. Sahoo, J. Ghosh, P. Sengupta, and P. V. Satyam

Growth of large aspect ratio AuAg bimetallic nanowires on Si(110) substrate

Large aspect ratio bimetallic nanowire structures comprise potential applications in areas such as higher catalytic activity and surface Raman enhancement spectroscopy (SERS) substrates. By using the highly anisotropic ultra-clean Si(110) surface and with initial growth of sub monolayer (ML) Ag on such surface, a high aspect ratio AuAg bimetallic nanostructures can be formed. We report on the formation of large aspect ratio (>7.2 ± 0.8) AuAg nanowires on ultra-clean Si(110) surfaces using 0.5 ML Ag followed by 3.0 ML Au using molecular beam epitaxy

(MBE) at a growth temperature of 300 °C. Under similar growth conditions without pre-deposition of Ag and only with deposition of 3.0 ML of Au consequences smaller aspect ratio (2.1 ± 0.1) monometallic Au nanostructures. The enhancement in aspect ratio of the nanostructures is attributed to the formation of one dimensional Ag layer (prior to Au growth) and Au-Ag bimetallic intermixing at elevated temperature. Considering deposition of 3.0 ML Au, a regime of substrate temperature H" 270–330 °C is found to be optimum to growth some of high aspect ratio (>25.0) AuAg nanowires as well. Exterior of this regime, at lower temperature due to low mobility of the ad-atoms and at higher temperature due to probable inter-diffusion of Ag, such extremely high aspect ratio AuAg nanowires found to be infrequent to grow. For growth at substrate temperature 300 °C, mean aspect ratio of the AuAg nanostructures is gradually increased in accordance with Au thickness up to 3.0 ML due to preferential accumulation of ad-atoms (Au, Ag) along Si011 0 and thereafter reduces for adequate accumulation along Si0001 0.

A. Bhukta, P. Guha, B. Satpati, ParamitaMaiti, P. V.Satyam

Molecular dynamics simulation studies of gold nano-cluster on silicon (001) surface

Classical molecular dynamics simulations with modified embedded atom method model has been carried out to understand the interfacial behavior of a gold(Au) nano-cluster on a silicon(Si) surface. For illustration, a gold nano-cluster (NC) consisting of 108 atoms has been chosen on the Si (001) surface. We have investigated on the process of melting of this NC, the temperature dependent intermixing of Au and Si, and the diffusion of Au atoms into the Si substrate. It has been observed that the NC becomes semi-spherical around the room temperature and the melting process started around 450 K. In order to examine the substrate effect on the melting point temperature of the gold NC, a similar NC has been studied in vacuum. The melting point temperature of this free NC is found to be around 480 K. The observed suppression of melting temperature (by ~30 K) for the supported NC can be understood in terms of substrate induced change in morphology. We observe inter-diffusion between gold and silicon atoms for temperatures greater than 650 K.

S. S. Sarangi, P. V. Satyam, S. K. Nayak, S. D. Mahanti

Filled-carbon nanotubes: 1 D nanomagnets possessing uniaxial magnetization axis and reversal magnetization switching.

The present study aims to control the direction of magnetization in Fe3C, Co and Ni nanorods filled inside carbon nanotube (CNT). This control has been achieved during growth by modifying thermal chemical vapor deposition (CVD) system. As-grown in situ filled-CNTs were found to exhibit permanent magnetization. These CNTs have been characterized by using scanning electron microscopy (SEM), X-ray diffraction, Raman spectroscopy and transmission electron microscopy (TEM). Afterwards, direction of magnetization in Fe3C, Co or Ni nanorod filled inside CNT has been further probed by using magnetic force microscopy (MFM). MFM measurements reveal that nanorod exhibits single domain behavior and direction of magnetization,

instead of being controlled either by shape or magneto crystalline anisotropy, has been found to be influenced by magnetic field gradient, produced in modified thermal CVD system. Direction of magnetization has been found either along tube axis in vertical grown CNTs or in radial direction i.e. perpendicular to the tube axis in randomly grown CNTs. Besides investigated structural and magnetic properties, plausible growth model of in situ filling as well as mechanism to understand unique magnetization behavior has been proposed.

P. V. Satyam et.al.

Highly Active 2D Layered MoS_2-rGO Hybrids for Energy Conversion and Storage Applications.

The development of efficient materials for the generation and storage of renewable energy is now an urgent task for future energy demand. In this report, molybdenum disulphide hollow sphere (MoS_2-HS) and its reduced graphene oxide hybrid (rGO/MoS_2-S) have been synthesized and explored for energy generation and storage applications. The surface morphology, crystallinity and elemental composition of the as-synthesized materials have been thoroughly analysed. Inspired by the fascinating morphology of the MoS_2-HS and rGO/MoS_2-S materials, the electrochemical performance towards hydrogen evolution and supercapacitor has been demonstrated. The rGO/MoS_2-S shows enhanced gravimetric capacitance values ($318 \pm 14\ Fg^{-1}$) with higher specific energy/power outputs (44.1 ± 2.1 $Whkg^{-1}$ and $159.16 \pm 7.0\ Wkg^{-1}$) and better cyclic performances ($82 \pm 0.95\%$ even after 5000 cycles). Further, a prototype of the supercapacitor in a coin cell configuration has been fabricated and demonstrated towards powering a LED. The unique balance of exposed edge site and electrical conductivity of rGO/MoS_2-S shows remarkably superior HER performances with lower onset over potential (0.16 ± 0.05 V), lower Tafel slope ($75 \pm 4\ mVdec^{-1}$), higher exchange current density ($0.072 \pm 0.023\ mAcm^{-2}$) and higher TOF ($1.47 \pm 0.085\ s^{-1}$) values. The dual performance of the rGO/MoS_2-S substantiates the promising application for hydrogen generation and supercapacitor application of interest.

S. Kamila, B. Mohanty, A.K.Samantara, P.Guha, A.Ghosh, B.Jena, P.V.Satyam, BK.Mishra, BKJena.

Ag nanoparticle decorated molybdenum oxide structures: growth, characterization, DFT studies and their application to enhanced field emission

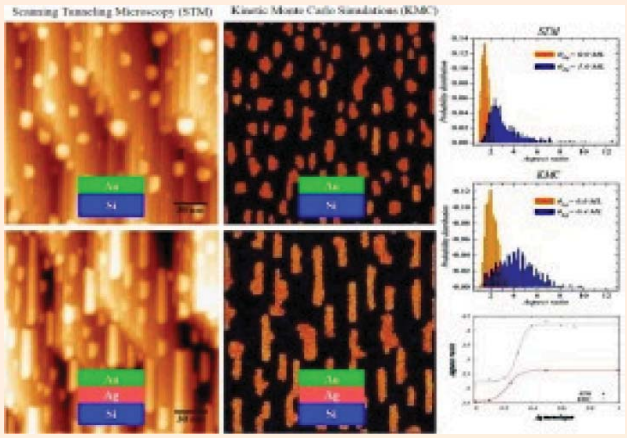
We report a simple single step growth of *á*-MoO_3 structures and energetically suitable site specific Ag nanoparticle (NP) decorated *á*-MoO_3 structures on varied substrates, having almost similar morphologies and oxygen vacancies. We elucidate possible growth mechanisms in light of experimental findings and density functional theory (DFT) calculations. We experimentally establish and verified by DFT calculations that the MoO_3(010) surface is a weakly interacting and stable surface compared to other orientations. From DFT study, the binding energy is found to be higher for (100) and (001) surfaces (~"0.98 eV), compared to the (010) surface (~"0.15 eV) and thus it is likely that Ag NP formation is not favorable on the MoO_3(010) surface. The Ag decorated MoO_3 (Ag-MoO_3) nanostructured sample shows enhanced field emission properties with an approimately 2.1

times lower turn-on voltage of 1.67 V ìm^{-1} and one order higher field enhancement factor (â) of 8.6 × 10^4 compared to the MoO_3 sample without Ag incorporation. From Kelvin probe force microscopy measurements, the average local work function (Ö) is found to be approximately 0.47 eV smaller for the Ag-MoO_3 sample (~5.70 ± 0.05 eV) compared to the MoO_3 sample (~6.17 ± 0.05 eV) and the reduction in Ö can be attributed to the shifting Fermi level of MoO_3 toward vacuum via electron injection from Ag NPs to MoO_3. The presence of oxygen vacancies together with Ag NPs lead to the highest â and lowest turn-on field among the reported values under the MoO_3 emitter category.

P.Guha, A.Ghosh, R.Thapa, E.M.Kumar, S. Kirishwaran, Ranveer Singh and P.V Satyam

Study of Ag induced bimetallic (Au–Ag) nanowires on silicon (5 5 12) surfaces: Experiment and theoretical aspects

The reconstructed vicinal (high index) silicon surfaces, such as, Si (5 5 12) composes row-like structures that can be used as templates for growing aligned nanowires. By using a sub-monolayers of Ag, prior to Au deposition on reconstructed Si (5 512) surface, intermixing of Au and Ag, enhancement of aspect ratio of bimetallic Au–Ag nanowires with tunable morphology is reported. This is attributed to a combined effect of pre-grown Ag strips as nucleation centers for incoming Au ad-atoms and anisotropic Au–Ag intermixing. To achieve optimum conditions for the growth of larger aspect ratio Au–Ag nanostructures, the growth kinetics have been studied by varying growth and annealing temperatures. At H"400°C, the Ag diffused into silicon substrate and the inter-diffusion found to inhibit the formation of Au–Ag bimetallic nanostructures. Controlled experiments under ultra-high vacuum condition in a molecular beam epitaxy system and in-situ scanning tunneling microscopy measurements along with ex-situ scanning transmission and secondary electron microscopy measurements have been carried out to understand the bimetallic nanostructure growth. Kinetic Monte Carlo (KMC) simulations based on kinematics of ad-atoms on an anisotropic template with a solid on solid model in which the relative ratios of binding energies (that are obtained from the Density Functional Theory) have been used and the KMC simulations results agree with the experimental observations. Advantage of having bimetallic structures as effective substrates for Surface enhanced Raman spectroscopy application is demonstrated by detecting Rhodamine 6 G (R6G) molecule at the concentration of 10^{-7} M.



A.Bhukta, T.Bagart, P.Guha, S.Ravulapalli, B.Satpati, B.Rakshit. P.Maiti, PVSatyam

Ion beam induced endotaxial silver nanostructures in silicon

Coherently embedded structures in a crystalline substrate are known as endotaxial

structures. In this paper, we report on the growth of silver (Ag) endotaxial structures in silicon using the aspects of both ion implantation and irradiation. In one case, endotaxial nanostructures of Ag at the Si interface are formed with 30 keV negatively charged silver ions (Ag^{-}) on GeO_x/SiO_x/Si system. In another case, 30 keV Ag^{-} ions are used to create defects in GeO_x, SiO_x and in silicon substrate. Further deposition of a thin layer of Ag on irradiated GeO_x/SiO_x/Si system yielded endotaxial Ag nanostructures relatively at lower temperature (700 °C) compared to the system without any irradiation effects. We also reveal that the irradiation effects with 1.8 MeV Ag^{+} ions do not influence the early onset temperature of endotaxial nanostructure formation (unlike low energy ions). We show that it is essential to have crystalline silicon substrate to form Ag endotaxial nanostructures to grow endotaxial structures.

P. Guha. R. R. Juluri, P.V. Satyam

Ion beam radiation effects on natural halite crystals

Halites are one of the interesting material due to its color variations. Natural halites whose color ranges from transparent to dark blue were studied by UV-VIS and Raman spectroscopy. The halite crystals were irradiated with 3 MeV proton micro-beam (~20 μm beam width with ~80 PA beam current) for 10 and 90 min to study the radiation damage. After 10 mins of irradiation, small spot developed on the surface of transparent halite crystal whereas after 90 mins of irradiation the spot spread inside the bulk leading to a brown coloration (20 μm initial size to ~2.0 mm final size). The irradiated portion and the un-irradiated portion of the halites was characterized by Raman spectroscopic technique. The variation in the population density was observed from the UV-Vis spectra. The change in the Raman band intensities was observed for transparent, blue colored and proton beam irradiation halites. Such variation of spectroscopic characteristics due to proton irradiation suggests that the halite can be used for the radiation monitoring.

T. Arun; S.S.Ram.; B.Karthikeyan; P. Ranjith; D.K.Ray.; B.Rout.; J.B.M.Krishna, ; P.Sengupta; P.V.Satyam

I. Ion beam induced surface nanostructuring of semiconductors and their applications

(i) Ion-beam induced synthesis of self-organized nanostructures

We are working on synthesis of self-organized nanostructures on semiconductor surfaces by using low-to-medium energy (0.1-100 keV) ions and trying to understand the underlying physical mechanisms in terms of various experimental parameters and the existing theories. Interestingly, usage of Au ions leads to fascinating ordering in the long nanowire-like patterns created on Ge surfaces. On the other hand, at low ion energies, ripples are formed on Si surface which undergoes a transition to facets (in the low energy regime) under specially chosen experimental parameters. Likewise, low energy Ar and Kr-ion bombardment at elevated temperatures and high fluences lead to ripples, dots, and nanowire-like pattern formation on several semiconductor surfaces like GaAs, GaSb, InP, InSb, Ge, and Si surfaces following *reverse epitaxy* process. As a matter of fact, different types of patterned surfaces are being fabricated and

being utilized by us for several fundamental but application oriented studies, viz. solar cells, spintronics, optoelectronics, plasmonics, magneto-plasmonic etc. where we use them as templates for deposition of thin films using various techniques.

(ii) Applications of self-organized (patterned) nanostructured surfaces

Tailoring optoelectronic properties of oxide thin films grown on patterned silicon templates

Low energy ion-beam fabricated nanofaceted Si substrates with various heights and widths show good anti-reflection property. An ion fluence-dependent anti-reflection (AR) performance is observed from these nanofaceted silicon surfaces. These nanofacets are successfully used by us for deposition of different oxide thin films. For instance, we have shown the efficacy of Al-doped zinc oxide (AZO) and Zn-doped tin oxide overlayers on ion-beam synthesized nanofaceted silicon for suppressing reflection loss. In addition, we have studied in detail the electric transport properties of these oxide overlayers and compared the same with those grown on pristine-Si substrates.

We have also carried out a large number of experiments on AZO and ZTO films grown on rippled- and faceted-Si substrates and observed surface morphology-driven anisotropy in their optoelectronic properties. Through these studies we are in the process of evaluating the possible improvements in AR property as well as reduction in electron-hole recombination towards using them as active layers in oxide-based solar cells. 6 Tailoring plasmonic properties of gold nanostructures grown on patterned silicon templates

Low energy ion-beam fabricated nanopatterned-Si substrates have anisotropic morphological nature which are being employed by us as templates to grow gold nanoparticles to tune their plasmonic property. In this case, we are growing Au nanoparticles (of different dimensions) on rippled- and faceted-Si substrates fabricated under different experimental parameters. Spectroscopic ellipsometry in conjunction with UV-Vis spectroscopic measurements show size (of Au nanoparticles)- and nanostructure-dependent shifts in the Au plasmonic peak. The results are compared with the Au nanostructures grown on pristine-Si substrates as well. As a next step, we plan to grow Au nanoparticles on pristine- and rippled- as well as faceted-Si substrates using molecular beam epitaxy (MBE) under ultra-high vacuum condition.

Thin film/nanoscale magnetism

Magnetic anisotropy in Co thin films on rippled substrates of Ge

Strong uniaxial magnetic anisotropy in Co thin films, of varying thicknesses, grown on nanowire-like rippled-Ge substrates are investigated. Thin films were deposited at different oblique angles of incidence by RF magnetron sputtering technique. The results are compared with the films deposited on pristine-Ge substrates as well. Co films grow conformally on patterned-Ge substrates and show a strong uniaxial magnetic anisotropy with the easy axis of magnetization parallel to the ripple directions. Complete spin orientation takes place in Co films depending on the angle between the applied

external magnetic field and orientation f the pattern wave vector.

P.V. Satyam and Collaborators

II. Growth and characterization of thin films for photovoltaics and resistive switching applications

(i) Oxide thin films using DC/RF magnetron sputtering and pulsed laser deposition techniques

We are studying growth of transparent conducting oxide (TCO) thin films, viz. MoO_3, TiO_2, $ZnO:Al_2O_3$ (AZO), and $ZnO:SnO_2$ (ZTO) on glass and silicon substrates. The main objective is to study growth of these materials by glancing angle deposition technique. All these films are utilized as active layers in oxide-based solar cells.

We are also working on resistive switching for which we regularly grow different oxide thin films like ZnO:Cu, Cu_2O, TiO_2, and MoO_3 using magnetron sputtering and pulsed laser deposition.

(ii) Local probe electrical transport property of aluminum-doped zinc oxide thin films

We demonstrate a polarization-mediated tunable nanoscale charge transport in Al-doped ZnO (AZO) thin film using conductive atomic force microscopy. In fact, we show that charge transport across an AZO film can be tuned by applying an external nano-Newton force, which confirms the presence of polarization in the film. In addition, we also demonstrate the role of polarization on the inhomogeneous work function using Kelvin probe force microscopy. The observed experimental result is attributed to defect-induced polarization in AZO film and will be a step forward to fabricate mechanical force tunable diode.

We also demonstrate that the work function of Al-doped ZnO (AZO) can be tuned externally by applying an electric field. Our experimental investigations using Kelvin probe force microscopy show that by applying a positive or negative tip bias, the work function of AZO film can be enhanced or reduced, which corroborates well with the observed charge transport using conductive atomic force microscopy. These findings are 1further confirmed by calculations based on first-principles theory. Tuning the work function of AZO by applying an external electric field is not only important to control the charge transport across it, but also to design an Ohmic contact for advanced functional devices.2#24 A 7

(iii) Hole-blocking property of MoO3 thin films

We investigate the hole-blocking properties of a MoO_3 layer when a heterostructure is grown on a chemically textured *p*-Si substrate. X-ray diffraction data reveal the amorphous nature of as-grown oxide films which undergoes a transition to a crystalline one after annealing. In addition, bulk current-voltage characteristics show that the leakage current increases after annealing which corroborates well with a change in the band gap due to a transition from amorphous to crystalline MoO_3. Moreover, MoO_3/Si heterojunction allows the transport of electrons but blocks the transport of holes. These results are compared with those obtained for MoO_3 films grown on pristine-Si substrates. The present findings are not only important for the fundamental understanding of the charge transport across the MoO_3/Si heterostructure but also to design hole-blocking solar cells. Recently, we have also started working on other hole and/or electron selective layers like WO_3, TiO_2, and $BiFeO_3$ for similar applications.

(iv) Resistive switching behavior in TiO_2, CuO, and Cu-doped ZnO thin films.

We have grown Cu-doped ZnO thin films on Si by pulsed laser deposition (PLD) technique. The films are found to be smooth and uniform over reasonably large surface areas and demonstrate bipolar resistive switching behavior. In addition, we have shown visible wavelength-dependent systematic change in the switching voltage at various current compliance values which adds up an extra control parameter in conventional resistive switching based memory devices.

We have also shown multimode resistive switching in copper oxide and titanium dioxide nanostructures using conductive atomic force microscopy. Resistive switching is observed in consecutive operation cycles from all around the sample. The different modes are interpreted in the framework of thermally induced defects. The model implies that the optimization of the conductive filament active region is crucial for the future application of nanoscale resistive switching devices.

(v) Fabrication of textured semiconductor surfaces for photovoltaic applications

Chemically textured Si with improved absorption in the complete range of solar spectrum is investigated by ultraviolet/visible/near-infrared (UV/Vis/NIR) spectroscopy, showing an average specular reflectance of ~0.4% in the wavelength of 500–3000 nm. The pyramidal structures on such solar-blind Si can reduce the reflectance further <0.1% in the UV region by conformal growth of granular Al-doped ZnO (AZO) films. Likewise, we have also demonstrated the efficacy of pyramidally textured Si surfaces as templates to grow Cu_2O, MoO_3, TiO_2, and other oxide materials (using DC/RF sputtering) towards achieving highly anti-reflecting surfaces for developing oxide-based solar cells.

Following the above studies, we have made textured surfaces of other semiconductors like Ge, GaAs, and InP where the above-mentioned oxide layers are being integrated now for applications in photovoltaic cells.

P. V. Satyam and Collaborators

III. Ion implantation induced modification of semiconductors

Ion beam modification of thin films

In our studies, ion irradiation is used to induce significant modification in electrical, optical, and structural properties of oxide thin films grown on different semiconductor substrates, viz. Si, Ge, GaAs, and InP. In addition, defect induced resistive switching is expected to take place in thin films of TiO2 and MoO3 followed by tunability in optical band gap, work function, and hole-blocking properties. For this purpose, low energy novel gas ions (few keV - tens of keV) are bombarded on the films at room temperature to yield controlled defect formation.

Temperature Dependent Photo-induced reversible Phase Separation in Mixed Halide Perovskite:

Tandem solar cells comprising of mixed halide perovskites $CH_3NH_3Pb(I_{1-x}Brx)_3$ were expected to have much higher efficiency, the observation that they undergo phase separation/demixing into low bandgap I-rich and high bandgap Br-rich domains under illumination put

forth a limitation to their possible utility. Using temperature dependent photoluminescence studies, we show that the stated photoinduced phase separation occurs only in a narrow temperature range and above a particular bromine concentration. Our observation of disappearance of phase separation at elevated temperatures suggests the possibility that these tandem solar cells may indeed work better at elevated temperatures. Further, we provide the first experimental proof for the demixing transition temperature as and also report that demixing and remixing temperatures are pinned to crystallographic phase transition temperatures. Longer carrier lifetime of iodide-rich clusters is observed confirming the strong electron-phonon interaction (polaronic effect) which is absent in the initial mixed states.

D. Topwal and Collaborators.

Fabricating solar cells:

Solar cells were fabricated based on new class of organic inorganic hybrid perovskite $CH_3NH_3PbI_3$ prepared by Ethyl acetate (EA); antisolvent treatment for the first time. This treatment results in new morphology for $CH_3NH_3PbI_3$ thin film. FESEM image shows microrod type structures of $CH_3NH_3PbI_3$ after EA antisolvent treatment. Energy band diagram was constructed using photoluminescence and photoemission studies. Power conversion efficiency of ~17% was achieved in EA treated film compare to without EA treated film.

D. Topwal and Collaborators

Ferro electricity in $GdCrO_3$

We performed detailed temperature dependent synchrotron powder x-ray diffraction studies, extended x-ray absorption fine structure (EXAFS) along with first-principles density functional theory based calculations, enable us to shed light on the origin of ferroelectricity in $GdCrO_3$. The actual lattice symmetry is found to be noncentrosymmetric orthorhombic P na21 structure, supporting polar nature of the system. Polar distortion is associated with the Gd displacements with respect to oxygen cage. Our study reveals an intimate analogy between $GdCrO_3$ and $YCrO_3$. However, a distinctive difference exists that Gd is less displacive compared to Y, which results in an orthorhombic P na21 structure in $GdCrO_3$ in contrast to monoclinic P 21 structure in $YCrO_3$ and consequently, decrease its polar property. It is found that magnetic coupling between Gd-4f and Cr-3d plays an important role in ferroelectric distortion. A strong magneto- electric coupling is also revealed using Raman measurements based analysis in the system below Cr-ordering temperature, indicating their relevance to ferroelectric modulation.

D. Topwal and Collagorators

Complex spin Glass behavior and defect induced polarization in $Ga_{2-x}Fe_xO_3$

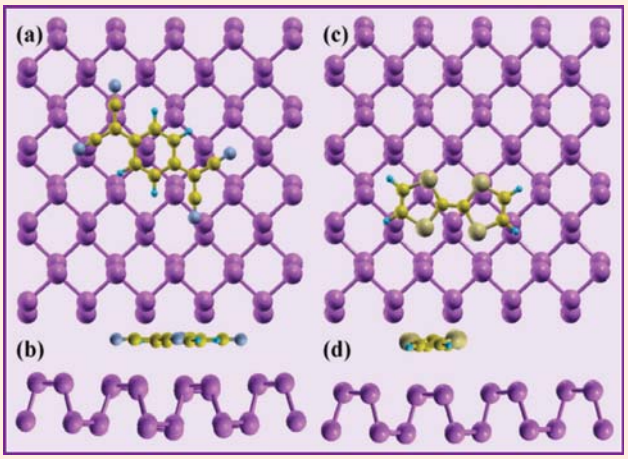
We carried out detailed investigation on sold solution of $Ga_{2-x}Fe_xO_3$ (with $x = 0.75, 1.0$, and 1.25) using dc magnetization, ac susceptibility, dielectric and pyroelectric response. Magnetic behavior in this series of compounds could broadly be explained by the molecular-field-approximation of a three-sublattice ferrimagnetic model considering three in-equivalent octahedral sites. Analysis of frequency dispersion of ac susceptibility reveals a transition from the cluster-glass-like phase to the spin-glass-like

phase with decreasing temperature for the x = 0.75 composition. Mentioned glassy behavior is found to gradually evolve with the composition (x) from the Ising type character to Heisenberg type behavior to unconventional glassy behavior for the x = 1.25 composition. $Ga_{2-x}Fe_xO_3$ can hence serve as an ideal system for modeling complex spin glasses. These systems were also found to exhibit combined relaxations (Maxwell-Wagner type relaxation and Debye relaxation) however, the dominating contribution was found be from extrinsic Maxwell-Wagner type relaxation. Further, emergence of polarization in these systems was understood in terms of thermally stimulated depolarization current (TSDC) effect caused by freezing of defect dipoles associated with charged oxygen vacancies rather than the intrinsic ferroelectric behavior.

D. Topwal and Collaborators

Modulating the electronic and optical properties of monolayer arsenene phases by organic molecular doping

Recently, arsenene monolayer structure of the arsenic with two phases has displayed semiconducting behavior. We have systematically investigated the electronic and optical properties of single-layer arsenene with two types of functionalized organic molecules; an electrophilic molecule [tetracyano-quinodimethane (TCNQ)] and a nucleophilic molecule [tetrathiafulvalene (TTF)], as an electron acceptor and electron donor, respectively. The interfacial charge transfer between the arsenene monolayer and TCNQ/TTF molecules extensively reduces the band gap of arsenene and accordingly resulted in a p- or n-type semiconducting behavior, respectively. We have



also performed the interfacial charge transfer from organic molecules to monolayer arsenene and vice versa. The interfacial surface molecular modification has established an efficient way to develop the light harvesting of arsenene in different polarization directions. Our theoretical investigation suggests that such n- and p-type arsenene semiconductors would broaden the applications in the field of nanoelectronic and optoelectronic devices such as photodiodes and it is also useful for constructing functional electronic systems.

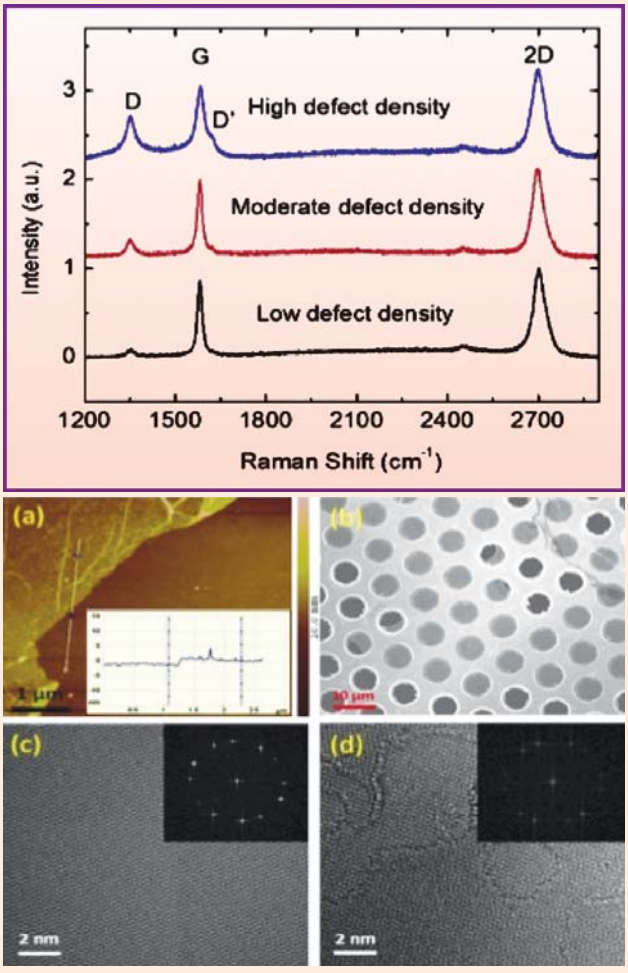
Optimized geometry structures of TCNQ and TTF on the arsenene surface: (a) top view and (b) side view of TCNQ with arsenene, (c) top view and (d) side view of TTF with α-phase of arsenene.

D. Singh, S.K Gupta, Y.Sonvane and Satyaprakash Sahoo

Grain size-dependent thermal conductivity of polycrystalline twisted bilayer graphene

We report the room temperature thermal conductivity of polycrystalline twisted bilayer graphene (tBLG) as a function of grain size measured by employing a noncontact optical technique based on micro-Raman spectroscopy.

Polycrystalline tBLG sheets of different grain sizes were synthesized on copper by hot filament chemical vapor deposition. The thermal conductivity values are 1305±122, 971±73, and 657±42 $Wm^{-1}K^{-1}$ for polycrystalline tBLG with average grain sizes of 54, 21, and 8 nm, respectively. Based on these thermal conductivity values, we also estimated the grain boundary conductance, $14.43±1:21X10^{10}$ $Wm^{-2}K^{-1}$, and the thermal conductivity for single crystal tBLG, 1510±103 $Wm^{-1}K^{-1}$. Our results show that the relative degradation of thermal conductivity due to grain boundaries is smaller in bilayer than in monolayer graphene. Molecular dynamics simulations indicate that interlayer interactions play an important role in the heat conductivity of polycrystalline bilayer graphene. The quantitative study of the grain size dependent thermal conductivity of poly- crystalline bilayer graphene is valuable in technological applications as well as for fundamental sci- entific understanding.

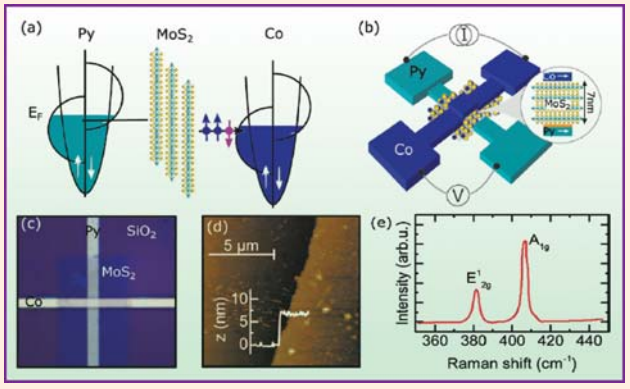


(left) Raman spectra of twisted bilayer graphene. (right) a. AFM image, b. FESEM Image, c and d. TEM image of twisted bilayer graphene.

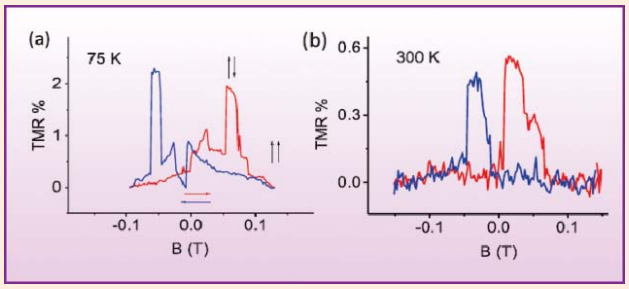
T. Limbu , K. R. Hahn, F. Mendoza, Satyaprakash Sahoo, J. J. Razink, R. S. Katiyar, B. R. Weiner, G.Morell

Spin-Polarized Tunneling through Chemical Vapor Deposited Multilayer Molybdenum Disulfide

The two-dimensional (2D) semiconductor molybdenum disulfide (MoS_2) has attracted



widespread attention for its extraordinary electrical, optical, spin and valley related properties. Here, we report on spin polarized tunneling through chemical vapor deposited multilayer MoS_2 (~7 nm) at room temperature in a vertically fabricated spin-valve device. A tunnel magnetoresistance (TMR) of 0.5 – 2 % has been observed, corresponding to spin polarization of 5 - 10 % in the measured temperature range of 300 – 75 K. First principles calculations for ideal



junctions results in a tunnel magnetoresistance up to 8 %, and a spin polarization of 26 %. The detailed measurements at different temperatures and bias voltages, and density functional theory calculations provide information about spin transport mechanisms in vertical multilayer MoS_2 spin-valve devices. These findings form a platform for exploring spin functionalities in 2D semiconductors and understanding the basic phenomenon that control their performance. Multilayer MoS_2 tunnel magnetoresistance device. **a,** Spin-dependent tunneling in magnetic tunnel junctions with multilayer MoS_2 barrier. **b,** Schematic representation of the multilayer MoS_2 vertical device with ferromagnetic contacts and MoS_2 spacer. **c,** Optical microscope image of a fabricated device consisting of large area multilayer MoS_2 junction of 7 nm thickness and ferromagnetic Co and $Ni_{80}Fe_{20}$ (Py) contacts as top and bottom electrodes, respectively. **d,** Atomic force microscope scan of MoS_2**e,** Raman spectra of MoS_2 measured at room temperature.

Temperature dependence of TMR in multilayer MoS2 MTJ.a, Tunnel magnetoresistance (TMR) measurements at 75 K. b. TMR measured at 300 K. The arrows indicate the up and down B field sweep directions.

A. Dankert, P.Pashaei, M. V.Kamalakar, A. P. S Gaur, Satyaprakash Sahoo, I.Rungger, A. Narayan, K.Dolui, M. A.Hoque, R. S. Patel, M. P. de Jong, R. S.Katiyar, S.Sanvito, S. P. Dash.

(a) Band Gap Engineering in SnO_2 by Pb doping

The band gap is an intrinsic character of a semiconductor and it governs the underlying electronic and optical properties. Tin oxide (SnO_2) is widely known as a direct wideband gap (3.6 eV) semiconductor crystallizing in rutile tetragonal structure. Due to its optical transparency in the visible range, high electrical conductivity, and long term stability, it is deemed to have potential application in optoelectronic devices including solar cells, flat panel displays and touch screen sensors.Despite all its alluring properties, the large band gap of SnO_2 limits its useful application. Therefore, there is a growing need to lower the band gap of SnO_2. The band

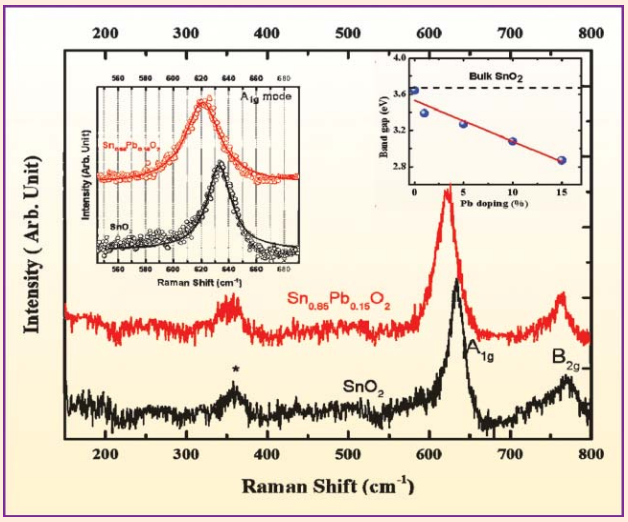


Fig.: Raman spectra of pure SnO_2 and 15% Pb doped SnO_2 samples. The spectra is background corrected and offset for clarity. The left inset shows the shift in A_{1g} peak position with 15% Pb incorporation The right inset shows the variation of band gap (determined from optical absorption) with Pb concentration. The dotted line represents the bulk band gap of SnO_2. The solid line is a guide to the eye for the band gap variation with Pb doping.

gap in semiconductors can dramatically be influenced by cationic substitution/chemical doping, strain engineering, applying external

pressure and lattice disorder. We have systematically investigated the effect of Pb doping on lowering the band gap of SnO_2. We demonstrate a significant reduction in its band gap to as much as ~ 0.8 eV (3.64 eV to 2.87 eV)upon 15% Pb doping. The observed band gap tunability with Pb-incorporation provides a direct and efficient approach to effectively tailor the band gap and is expected to open up applications inemerging oxide opto-electronic and energy applications.

S. N. Sarangi, G K Pradhan, and D Samal.

(b) Suppressed upper critical field in a Superconducting/Ferromagnetic bilayer

Singlet superconducting and ferromagnetic order are antagonistic to each other and generally they do not coexist in bulk materials. However, the fabrication of thin film heterostructures using thin film deposition techniques has made it possible to investigate the interplay between superconductivity and ferromagnetism in close proximity. The control over layer thickness provides an added opportunity to change the relative strength of competing order parameters by varying the layer thickness. The mutual interaction between the two competing order parameters at the superconductor/ ferromagnet (SC/FM) interface gives rise to a variety of novel electronic phenomena and has led to a wide study of such systems over last few decades.

We have investigated the influence of ferromagnetic $La_{0.7}Sr_{0.3}MnO_3$ (LSMO) layer on the upper critical field (B_{c2}) of $YBa_2Cu_3O_{7-\delta}$ (YBCO) in YBCO/LSMO bilayer. The upper critical field is estimated from magnetotransport data using WHH and GL formalism. We find that the upper critical of YBCO in YBCO/LSMO bilayer gets suppressed by a few tens of Tesla as compared to the single YBCO layer. Moreover, we also observe that the extent of suppression of Bc2 increases with increasing LSMO layer thickness. We have provided a comprehensive discussion to account for the suppression based on spin

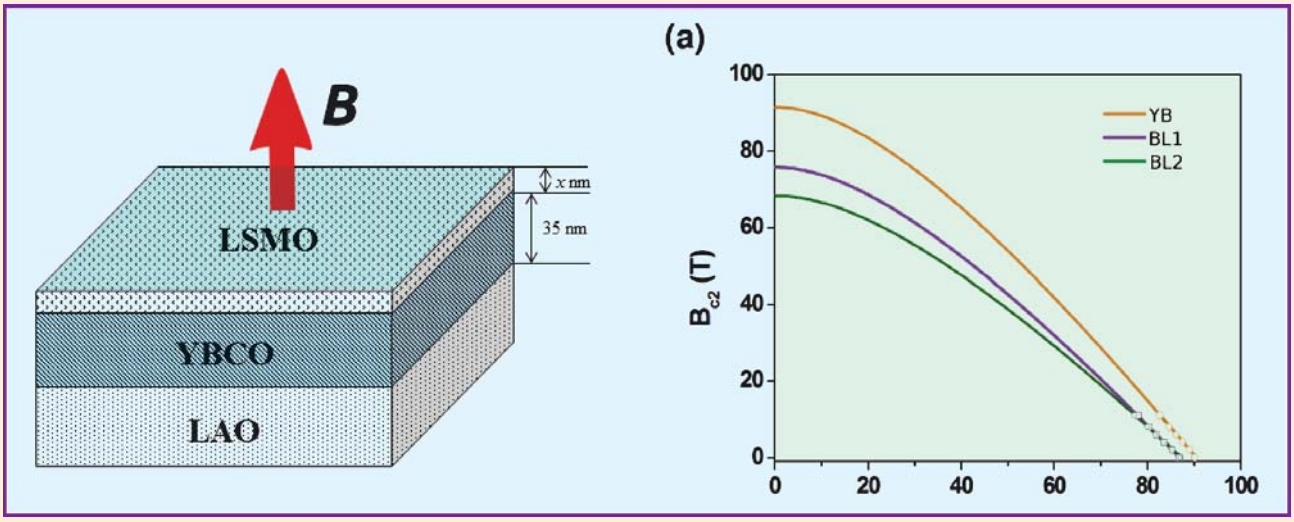


Fig. : Schematic of the superconducting (YBCO)/ferromagnetic (LSMO) bilayer with varying LSMO thickness grown on $LaAlO_3$ (LAO). x= 0,16 and 28 for single layer YBCO, bilayer BL1 and bilayer BL2 respectively. B-T phase diagrams for YBCO (YB) and bilayers (BL1, BL2) constructed from magneto-transport data using WHH formalism.

polarized quasiparticle injection induced cooper-pair breaking, magnetic proximity effects and finally local magnetic field emanating from the ferromagnetic LSMO layer, which increases with the increasing LSMO layer thickness.

A Gaurav, B R Sekhar, P S Anil Kumar, D Samal.

(c) Spin-orbit coupled $SrIrO_3$ thin films: Structural stability and related electrical transport properties.

Metastable orthorhombic $SrIrO_3$ (SIO) is an arch-type spin-orbit coupled material. We tailor the growth of relatively thick SIO films that transform from bulk "6H-type" structure with monoclinic distortion to an orthorhombic lattice by controlling growth temperature. Extensive studies based on high resolution X-ray diffraction and transmission electron microscopy infer a two distinct structural phases of SIO. Electrical transport reveals a weak temperature dependent semi-metallic character for both phases. However, the temperature dependent Hall-coefficient for the orthorhombic SIO exhibits a prominent sign change, suggesting a multiband character in the vicinity of E_F. Our findings thus unravel the subtle structure-property relation in SIO epitaxial thin films.

S. G. Bhat, N. Gauquelin, N. K. Sebastian, A. Sil, J. Verbeeck, D Samal, P S Anil Kumar.

(d) Manipulating the superconducting properties by atomic layer engineering.

Realisation of high-T_c superconductivity in atomically enginneered heterostructures provides a unique platform to manipulate its behavior in a controlled way and understand the

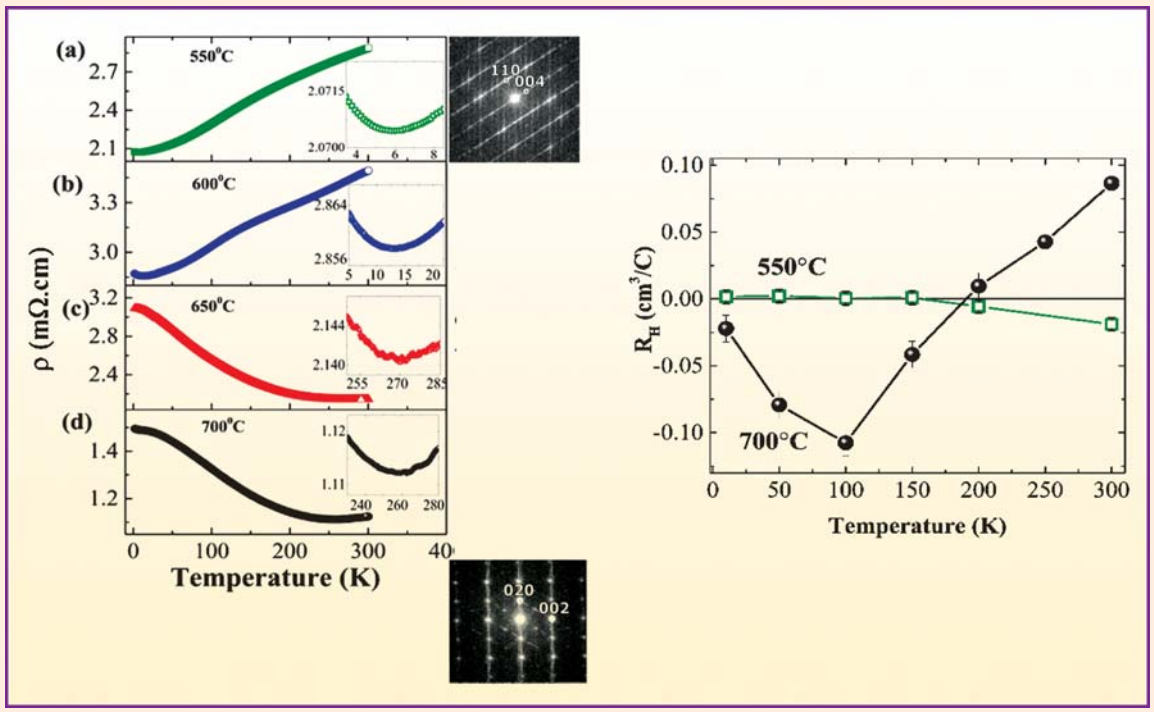


Fig. (a) - (d) are the plots of resistivity as a function of temperature for SIO films grown at different conditions. Insets to each figure show the transition from insulating-like to metal-like trend as the temperature is increased. Respective STEM images reveals distinct hexagonal and orthorhombic phases for films grown at 550°C and 700°C respectively. The right side plot shows the Hall coefficient (R_H) vs. temperature of SIO thin films grown at 550°C and 700°C respectively.

underlying complex structure-property relationships. Despite the fact that a fundamental understanding of the mechanism for high-T_c superconductivity in cuprates remains elusive, experimental data from the view point of crystal structure reveals that the underlying crystal-lattice structure plays a key role. In a simple picture, the structural model of high-T_c cuprate superconductors is built on a *natural superlattice*, where the current carrying CuO_2 planes are interleaved with the charge-reservoir blocking/balance layers. *What if we mimic layered superconductors by using atomic-scale LEGO blocks? The assembly using atomically thin layers with some intelligently guessed differences seems worth a try, especially when the mechanism of high-T_C superconductivity remains unknown!* Such an approach tends to be more flexible and can possibly harbour high-T_c superconductivity without resorting to any chemical substitution leading to uncontrolled disorder. In this project, we conceive, design, and demonstrate a model infinite-layer based cuprate hybrid that hosts superconductivity by manipulating the sub-layer characteristics at unit cell level and subsequently elucidate the possible mechanism. We investigate infinite layer-based cuprate hybrids where 7-8 unit cells of $Sr_{0.6}Ca_{0.4}CuO_2$ layer are sandwiched between ultra-thin non-superconducting spacer layers of $SrTiO_3$ (STO), $SrRuO_3$, or $BaCuO_2$ (BCO) forming three distinct types of heterostructures. We observe that the hole content of the $Sr_{0.6}Ca_{0.4}CuO_2$ layer is present in all studied cases, but superconductivity is uniquely observed in the

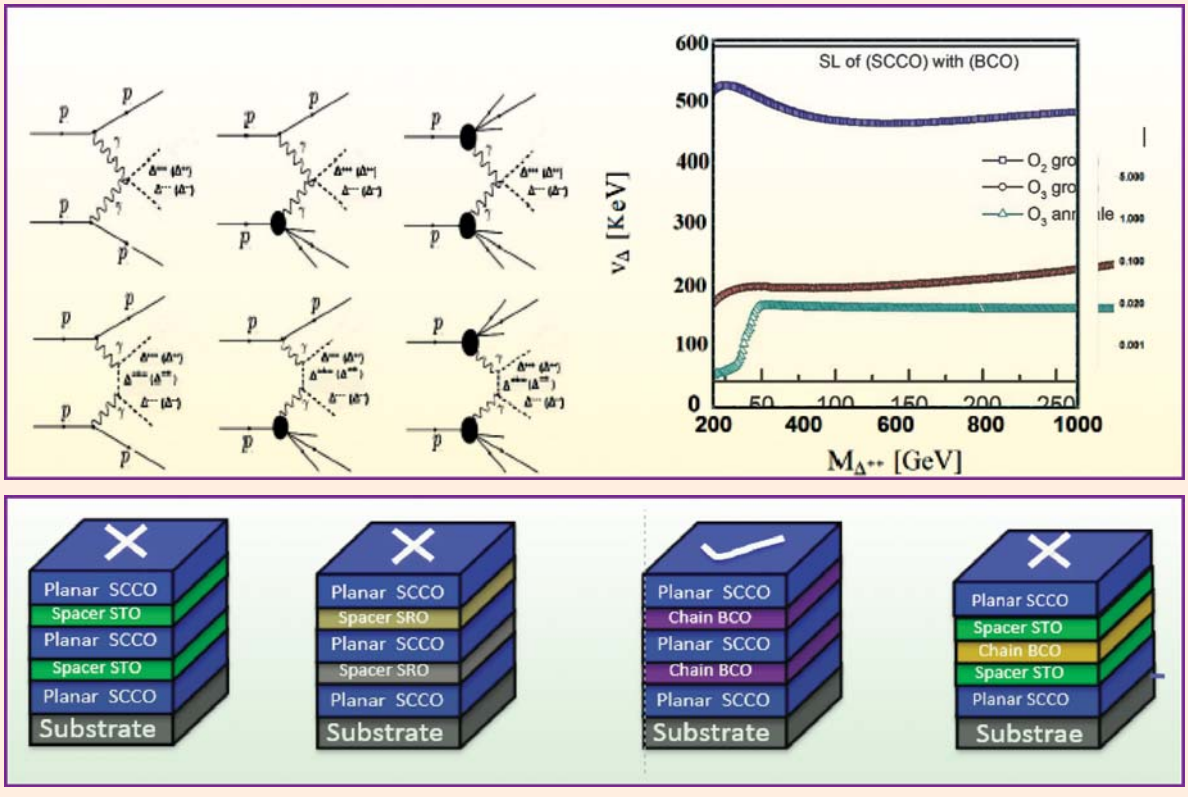


Fig. (a)Temperature-dependent sheet resistance for **(a)** $[(SCCO)_8/(STO)_4]_{10}$, $[(SCCO)_8/(SRO)_4]_{10}$ and **(b)** $[(SCCO)_8/(BCO)_1]_{10}$SLs under various conditions (O_2-grown, O_3-grown, and O_3-annealed, respectively squares, circles and triangles). In the schematic, tick mark indicates the occurrence superconductivity and the cross indicates the non-occurrence of superconductivity.

$Sr_{0.6}Ca_{0.4}CuO_2$/BCO stacking. Insertion of an additional STO spacer layer in the latter heterostructure results in suppression of the superconductivity in SCCO /BCO heterostructure. Indeed, our investigation unfolds the possibility to realize high-T_c superconductivity in a designed superlattice (SL) that entangles two IL-based cuprate blocks (SCCO) and (BCO)) having different attributes in terms of their oxygen sublattice structure and atomic polarisability.

D. Samal et al..

(e) The effect of Sn intercalation on the superconducting properties of 2H-$NbSe_2$.

2H-$NbSe_2$ is known to be an archetype layered transitional metal dichalcogenide superconductor with a superconducting transition temperature of 7.3 K.We have investigated the influence of Sn intercalation on the superconducting properties of 2H-$NbSe_2$. Sn has been successfully intercalated up to 4 molar% in the $NbSe_2$. Magnetic and transport studies reveal a significant reduction of both superconducting transition temperature and upper critical field [T_c and B_{C2} (0)] upon Sn intercalation. With a mere 4 mole% Sn intercalation, it is observed that T_c and B_{C2} (0) get suppressed by ~3.5K and 3T, respectively. Werthamer-Helfand-Hohenberg (WHH) analysis of magneto-transport data is performed to estimate B_{C2} (0). From the low temperature Raman scattering data in the normal phase of intercalated $NbSe_2$, it is inferred that the suppression of superconductivity cannot be ascribed to strengthening of charge density wave (CDW)ordering. The effects such as electron-doping induced Fermi surface change and/or disorder scattering upon intercalation are speculated to be at play for the observed phenomena.

S Naik, G. K. Pradhan, S. G. Bhat, B. Behera, P.S. Anil Kumar, S.L. Samal, D Samal.

(f) Experimental observation for unconventional exchange bias in $SrCoO_3$/ $SrCoO_{2.5}$ natural bilayer with $T_N > T_C$.

A precise control and tuning of interfacial magnetic properties in thin film heterostructures is crucial for engendering exotic functionalities that is highly relevant for technological applications such as magnetic field sensors,

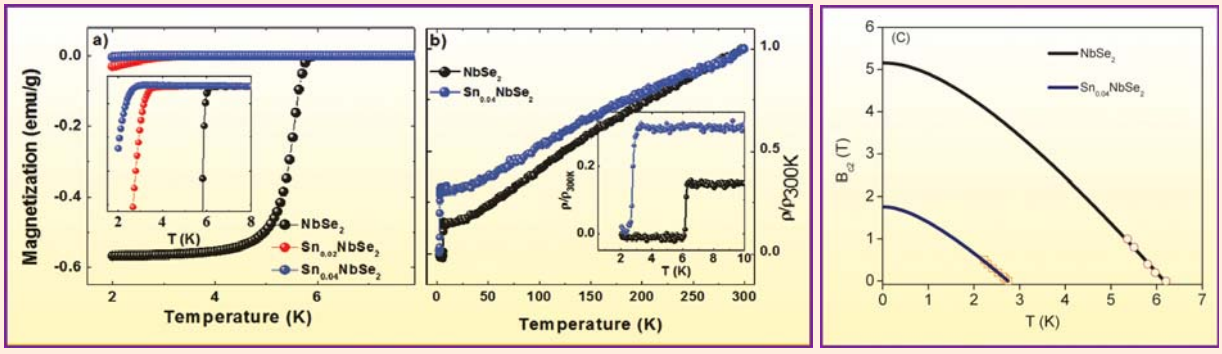
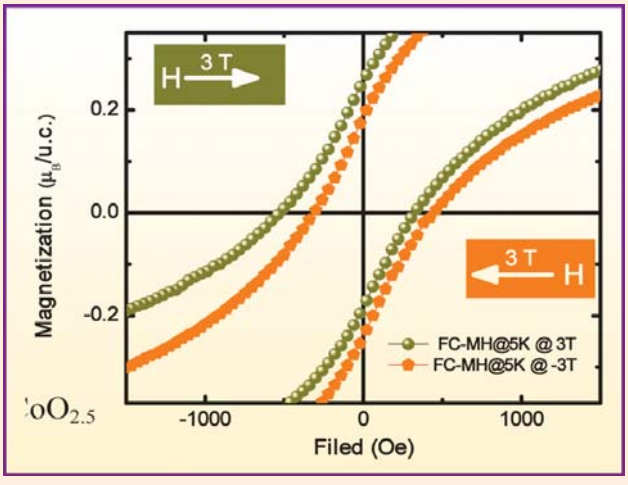


Fig. (a) Temperature dependent zero field cooled (dc field 50 Oe) magnetization for Sn_xNbSe_2 (0 d" x d" 0.04) revealing superconducting transition. The inset shows the magnified view of superconducting transition. (b) Normalized temperature dependent resistivity for Sn_xNbSe_2 with x = 0 and x = 0.04. The inset shows the magnified view of superconducting transition (c) $\mathbf{B_{C2}}$–$\mathbf{T_c}$ phase diagrams for $NbSe_2$ and $Sn_{0.04}NbSe_2$ extracted using WHH formalism. The inset shows the slope dB/dT in the vicinity of T_c.

memories or magnetic recording read heads. A great deal of attention in this regard is focussed on the effect called "exchange bias" that occurs due to interfacial magnetic exchange interaction in a coupled ferromagnetic/antiferromagnetic system. Traditionally, in order to observe the exchange bias in a bilayer, a combination of a ferromagnet (FM) with higher Curie temperature (T_C) than an antiferromagnet (AF) with lower Néel temperature (T_N) is used.

We present a design scheme to fabricate perovskite oxide based FM/AF ($SrCoO_3$/$SrCoO_{2.5}$) natural bilayer and demonstrate the evidence for unconventional exchange bias with $T_N > T_C$. The term natural bilayer is coined categorically to emphasize that an interface involving perovskite $SrCoO_3$ and $SrCoO_{2.5}$ is formed spontaneously by a structural transformation.It has to be noted that bulk



$SrCoO_3$ hosts a metallic ferromagnetic state with Tc ~ 305 K, whereas $SrCoO_{2.5}$ exhibits an insulating antiferromagnetic state with T_N~ 570K (Fig1. Left panel), thus rendering an ideal platform to investigate the possible occurrence of unconventional interfacial exchange coupling

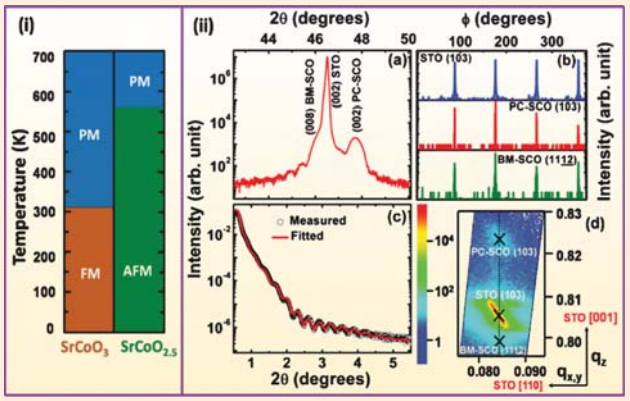


Fig. (i)A schematic showing the temperature dependent magnetic phase of $SrCoO_3$ and$SrCoO_{2.5}$ in bulk. (ii) Detailed structural investigation revealing the formation of a natural thin film bilayer $SrCoO_3$/$SrCoO_2$ grown on $SrTiO_3$ by PLD. The right hand side field-cooled M-H plot measured on $SrCoO_3$/$SrCoO_2$ bilayer manifests the exchange bias effect.

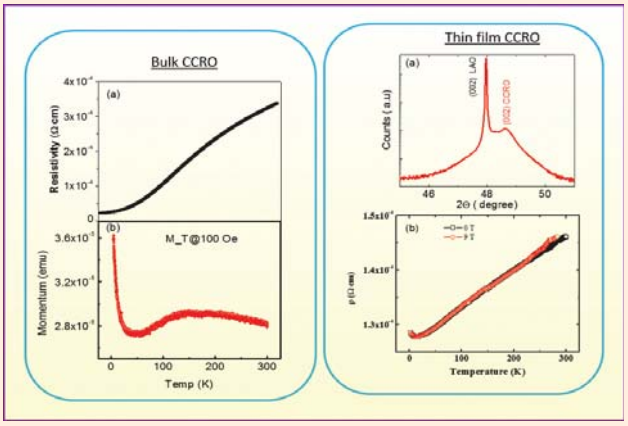
in $SrCoO_3$/$SrCoO_{2.5}$ bilayer. The present revelation of spontaneous stabilization of $SrCoO_3$/$SrCoO_{2.5}$ natural bilayer without any additional caveats testify a novel method to design innovative interfaces and offers the opportunity and new insight to examine the elusive exchange coupling persisting at a perovskite oxide based FM/AF interface with $T_N > T_C$.

B. Behera, Subhadip Jana, Shwetha Bhat, P.S. Anil Kumar, D Samal.

(g) Dimensional effect on heavy-fermion character in $CaCu_3Ru_4O_{12}$ thin films.

Electrons in solids, by coupling with spins and lattices, form dressed particles called quasiparticles (QPs). The mass of such QPs can in some cases be extremely heavy, 100-1000 times the bare electron mass. Heavy-fermionic QP signature are generally found in systems with f-electron systems containing rare earth or actinide ions (for example CeSn). Those systems are conventionally known as heavy-fermionic systems, and show a rich variety of phenomena

such as the coexistence of superconductivity and ferromagnetism. The f-electrons, which are localized at high temperatures, hybridize with the conduction electrons at low temperatures through Kondo interaction, thereby forming a very narrow conduction band and, therefore the QP effective mass of the narrow band is substantially enhanced. In the case of d-electron metals, it is not that obvious to identify the same kind of physics. Interestingly certain "d" transition metal oxides such as LiV_2O_4 and$CaCu_3Ru_4O_{12}$ are reported to exhibit remarkable heavy-fermion electronic character, and these systems are under investigation to unveil the microscopic underlying physics. The formation of heavy QP in d-electron system opens a new way to understand the heavy-fermion related physics beyond f-electron systems. Generally, in low spatial dimensions, many-body correlation effects originating from the Coulomb interaction between electrons become more prominent and complex. Moreover, both thermal and quantum fluctuations are largely enhanced with a reduction in dimensionality.. Thus, many body effects that do not exist in three dimensions are expected to prevail in low-dimensional systems. Indeed, two-dimensional systems exhibit exciting properties such as high-T_c superconductivity in cuprates and iron pnictides and metallic conduction in transparent oxides. If heavy fermionic systems can be made 2D, even more fascinating ground states are expected to result, and thus such studies are very much desirable. We have put our efforts to fabricate $CaCu_3Ru_4O_{12}$ (CCRO) thin films by PLD and to study the dimensional effect. Preliminary results on successful growth of CCRO films are shown below.



Subhadip Jana, B. Behera, S. N. Sarangi, Shwetha Bhat, D Samal.

(h) Towards arresting co-operative Jahn-Teller effect in $Ni_{1-x}Cu_xO$

The structure of bulk CuO as found in nature is unique and at variance with other 3d transition-metal monoxides (TMMOs). While MnO, FeO, CoO, and NiO all crystalize in the rock-salt crystal,CuO crystalizes itself in a non-centrosymmetric monoclinic structure possibly due to strong Jahn-Teller distortion. To arrest such co-operative Jahn-Teller distortion at Cu site and investigate about the local structure, we diluted NiO with Cu to form Ni1-xCuxO. We observe that Cu substitutes the Ni up to x= 20%. Higher concentration of Cu leads to phase separation. Interestingly, the rocksalt structure is retained upto 20% from XRD investigation. Though XRD gives an average rocksalt- type macroscopic structure, we are more interested to look for the local structure surrounding Cu-ion in Ni_{1-x}CuxO and the evolution of its magnetic properties. The results of structural findings based on XRD investigation are given below. We also performed Raman investigation on Ni1-xCuxO that shows the phonon and magnon modes. The two-magnon (2-M) mode shows a

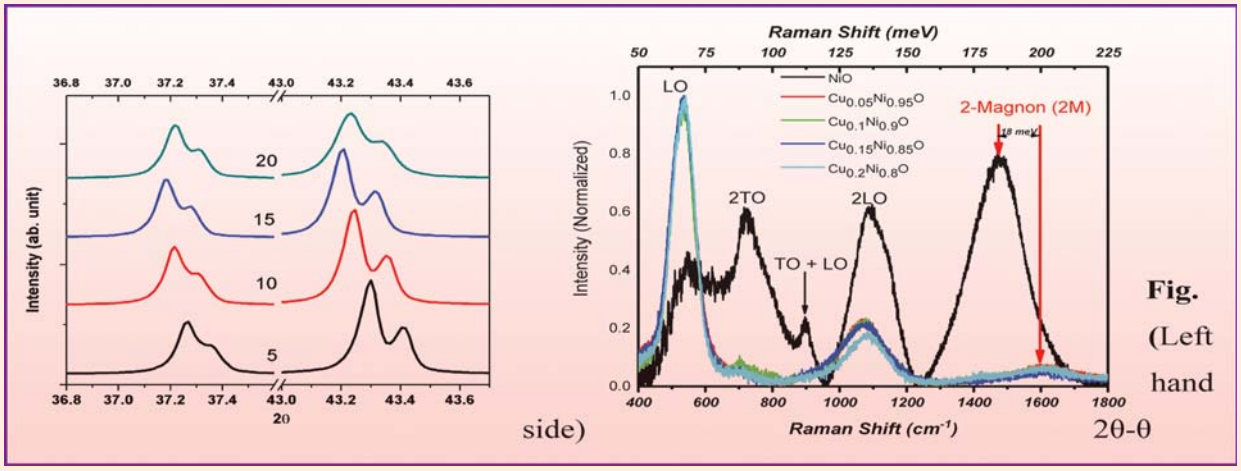


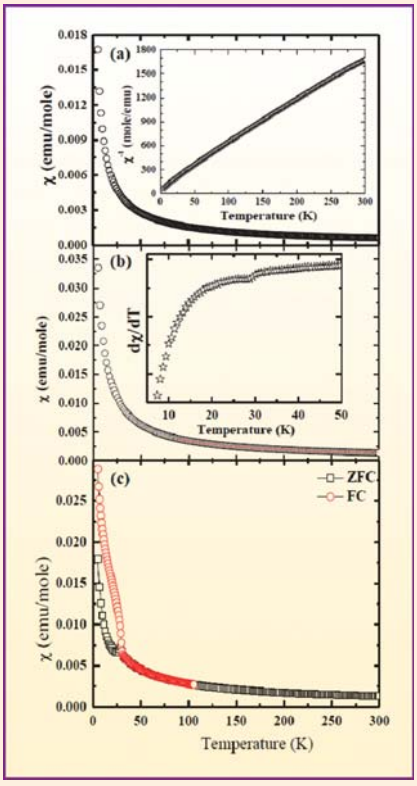
Fig.- (Left hand side) 2è-è XRD scan for $Ni_{1-x}Cu_xO$ with x =5,10,15,20. (Right hand side) Raman spectra showing a shift in 2-magnon peak upon Cu substitution in NiO.

strong shift (~ 18 meV) upon Cu doping indicating a significant modification of the magnon dispersion relation. The anti-ferromagnetic magnetic ordering appears to be modified due to substitution of copper. Neutron scattering is being carried out to elucidate the exact magnetic order upon copper doing. Also we are trying to perform EXAFS to delve into local struture surrounding Cu in Ni1-xCuxO.

B. Behera, Subhadip Jana, G K Pradhan S. N. Sarangi, D Swain, D Samal.

(i) Magnetic character of $Sn_{1-x}Mn_xS$ (x = 0.0, 0.05, 0.10, and 0.20)

The compound with x = 0.10 shows the signature of antiferromagnetic ordering with



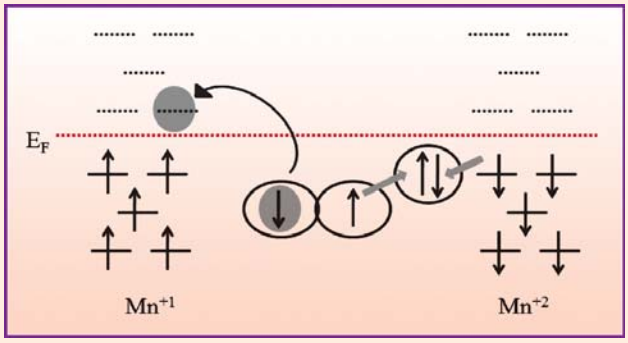


Fig. (a) Temperature dependence of magnetic susceptibilibity ÷(T) of $Sn_{0.95}Mn_{0.05}S$ under an applied field of 100 Oe. The inset shows the temperature dependent inverse susceptibility. (b) Temperature dependendence of magnetic susceptibility ÷(T) of $Sn_{0.90}Mn_{0.10}S$ under an applied field of 100 Oe. The solid line shows the Curie Wiess fit from 80 K to 300 K. The inset shows the d÷(T)/dT with respect to temperature. (c) Temperature dependence of zero-field-cooled (ZFC) and field-cooled (FC) magnetic susceptibilities ÷(T) of $Sn_{0.8}Mn_{0.2}S$ measured under an applied field H = 100 Oe. The right hand side image shows schematic representation of the electronic configuration of super exchange mechanism for antiferromagnetically ordered Mn doped SnS.

Neel temperature around 28 K. With increase in Mn concentration to x = 0.20, the antiferromagnetic ordering gets more prominent marked by the bifurcation in ZFC and FC curve around the magnetic transition. The origin of observed antiferromagnetic behavior in $Sn_{1-x}Mn_xS$ is attributed to superexchange interaction which couples the neighboring Mn ions through the intervening S-anions.

C.Behera, D. Samal, S G Bhat, P S Anilkumar, S. Samal

(j) Spin-momentum locking in a cubic Dirac material probed by quantum interference

The presence of both inversion (P) and time-reversal (T) symmetries in solids leads to well-known double degeneracy of electronic bands (Kramers degeneracy). The lifting of degeneracy makes spin or chirality to mani-fest in the form of (pseudo)spin texture in momentum space, such as in topological insulators or in strong Rashba materials. Non-trivial cases are when the double degeneracy remains in exotic materials. Three-dimensional (3D) Dirac material is a remarkable example of this case, in which spin could have non-trivial dependence to momentum, but difficult to resolve because all the states are degenerate with time-reversal pairs. We use quantum interference effects in magnetoconductance to detect hidden entanglement of spin and momentum in antiperovskite-type 3D Dirac materials. We find robust weak antilocalization (WAL) when the Fermi energy (E_F) is tuned close to the Dirac nodes, whereas clear signature of weak localization (WL) develops when EF shifts by doping. Notably, the mixing of different Dirac valleys does not suppress WAL, pointing to contrasting interference physics compared to graphene. These results are explained by an axial spin-momentum locking of real spin at each Dirac pocket, which, via scattering among six Dirac valleys that originates from cubic symmetry, effectively rotates spin and restores WAL. The finding points to a novel way to control spin/chirality dynamics by tuning chemical potential and disorder in multi-valley Dirac materials.

H. Nakamura, J. Merz , E. Khalaf , P. Ostrovsky, A. Yaresko , D. Samal , H. Takagi

CdS nanowires formed by chemical synthesis using conjugated single-stranded DNA molecules.

CdS nanowires were successfully grown by chemical synthesis using two conjugated single-stranded (ss) DNA molecules, poly G (30) and poly C (30), as templates. During the early stage of the synthesis with the DNA molecules, the Cd^{2+} interacts with Poly G and Poly C and produces the (Cd^{2+})–Poly GC complex. As the growth proceeds, it results in nanowires. The structural analysis by grazing angle x-ray diffraction and transmission electron microscopy confirmed the zinc-blende CdS nanowires with the growth direction of< 220>. Although the nanowires are well surface-passivated with the DNA molecules, the photoluminescence quenching was caused by the electron transfer from the nanowires to the DNA molecules. The quenching can be used to detect and label the DNAs.

S. N. Sarangi, S. N. Sahu, S. Nozaki

Band gap engineering in SnO_2 by Pb doping

There is a growing need to lower the band gap of the transparent conductive tin oxide (SnO_2) in view of its potential application in photo-

electronic technology. Here, we systematically investigated the effect of Pb doping on lowering the band gap of SnO_2. We demonstrate a significant reduction in its band gap to as much as<" 0.8 eV (3.64 eV–2.87 eV) upon 15% Pb doping. The observed band gap tunability with Pb-incorporation provides a direct and efficient approach to effectively tailor the band gap and is expected to open up applications in emerging oxide opto-electronic and energy applications.

S.N. Sarangi, GK Pradhan, D Samal

ZnO-nanorods: A possible white LED phosphor

The white light-emitting diodes (LEDs) have drawn much attention to replace conventional lighting sources because of low energy consumption, high light efficiency and long lifetime. Although the most common approach to produce white light is to combine a blue LED chip and a yellow phosphor, such a white LED cannot be used for a general lighting application, which requires a broad luminescence spectrum in the visible wavelength range. We have successfully chemically synthesized the ZnOnanorods showing intense broad luminescence in the visible wavelength range and made a white LED using the ZnOnanorods as phosphor excited with a blue LED. Their lengths and diameters were 2 – 10 ìm and 200 – 800 nm, respectively. The wurtzite structure was confirmed by the x-ray diffraction measurement. The PL spectrum obtained by exciting the ZnOnanorods with the He-Cd laser has two peaks, one associated with the near band-edge recombination and the other with recombination via defects. The peak intensity of the near band-edge luminescence at 388 nm is much weaker than that of the defect-related luminescence. The latter luminescence peak ranges from 450 to 850 nm and broad enough to be used as a phosphor for a white LED. A white LED has been fabricated using a blue LED with 450 nm emission and ZnOnanorod powders. The LED performances show a white light emission and the electroluminescence measurement shows a stiff increase in white light intensity with increasing blue LED current. The Commission International de1'Eclairage (CIE) chromaticity colour coordinates of 450 nm LED pumped white emission shows a coordinate of (0.31, 0.32) for white LED at 350 mA. These results indicate that ZnOnanorods provides an alternate and effective approach to achieve high-performance white LEDs and also other optoelectronic devices.

S. N. Sarangi, Arun T., D. K. Ray, P. K. Sahoo, S. Nozaki, N. Sugiyama, and K. Uchida.

PUBLICATIONS

3.1	Papers Published in Refereed Journals	:	71
3.2	Papers Submitted to International Refereed Journals	:	87
3.3	Conference Proceedings	:	92
3.4	Books	:	94
3.5	Papers published by External Users	:	94

3.1. Papers Published in Refereed Journals

1. **Bubble-bound state of triple-stranded DNA: Efimov Physics in DNA with repulsion,**
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J. Stat. Mech. (2017) 073203.

2. **Probing the edge states in a zigzag phosphorene nanoribbon via RKKY exchange interaction**
SK Firoz Islam, Paramita Dutta, A. M. Jayannavar and Arijit Saha
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3. **Signature of tilted Dirac cones in Weiss oscillations of 8''Pmmn borophene**
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4. **Amplification of Cooper pair splitting current in a graphene based Cooper pair beam splitter geometry**
SK Firoz Islam and Arijit Saha
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5. **Enhancement of crossed Andreev reflection in normal-superconductor-normal junction of thin topological insulator**
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6. **Rotational Brownian motion: Trajectory, reversibility and stochastic entropy**
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7. **Bidirectional motion of filaments: Role of motor proteins and passive cross Linkers**
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Sayantan Choudhury, Sudhakar Panda
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Arpan Das, Shreyansh S. Dave, Somnath De, Ajit M. Srivastava,
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11. **Setting Initial Conditions for Inflation with Reaction-Diffusion Equation**
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18. **Addressing Neutrino Mixing Schemes with DUNE and T2HK**
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Accepted in Journal of High Energy Physics

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JHEP 1804 (2018) 039

21. **Null-Infinity and Unitary Representation of Poincare Group**
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Preprint Number : arXiv:1801.10171 [hep-th]

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Preprint Number : arXiv: 1705:10333

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Sanjoy Mandal, Manimala Mitra, Nita Sinha
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Debottam Das, Kirtiman Ghosh, Manimala Mitra,Subhadeep Mondal
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26. **Constraining the right-handed gauge boson mass from lepton number violating meson decays in a low scale left-right model**
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27. **Probing sterile neutrinos in the framework of inverse seesaw mechanism through leptoquark productions**,
Debottam Das, Kirtiman Ghosh, Manimala Mitra, and Shubhadeep Mondal
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28. **Singlet-Triplet Fermionic Dark Matter and LHC Phenomenology**
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3. **Generalized Second Law and optimal protocols for nonequilibrium systems**
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4. **Quantum thermodynamic properties of a cold atom coupled to a heat bath in non-Abelian gauge potentials**
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5. **Extracting work from a single heat bath using open-loop protocol**
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6. **Probing the edge states in a zigzag phosphorene nanoribbon via RKKY exchange interaction**
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7. **Spin selective coupling to Majorana zero modes in mixed singlet and triplet superconducting nanowire**
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e-Print Archives (1707.01988)

9. ***Article of General Interest :*** Publication of non-science article: Scratching the Surface with Shikha- A conversation with a condensed matter physicist about surface science and making change in Indian science: In conversation with Dr. Nandita Jayaraj of Life of Science.com (also in www.wire.com)

10. **Confinement and crowding control the morphology and dynamics of a model bacterial chromosome**
Pinaki Swain, Bela M. Mulder, Debasish Chaudhuri
to be submitted

11. **Chromosome sizing and positioning through cell-size sensing**
Fabai Wu, Pinaki Swain, Louis Kuijpers, Xuan Zheng, Kevin Felter, Margot Guurink, Debasish Chaudhuri, Bela Mulder, Cees Dekker
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12. **Quantum entanglement in de Sitter space from Stringy Axion: An analysis using á vacua**
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13. **Distinguishing different classes of entanglement of three-qubit pure states in an experimentally implementable way**
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14. **Coherence of quantum channels**
Chandan Datta, Sk Sazim, Arun Pati and Pankaj Agrawal
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15. **Probing the Type-II Seesaw Mechanism through the Production of Higgs Bosons at a Lepton Collider**
Pankaj Agrawal, Manimala Mitra, Saurabh Niyogi, Sujay Shil, and Michael Spannowsky
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16. **Signatures of a Light Sterile Neutrino in T2HK**
Sanjib Kumar Agarwalla, Sabya Sachi Chatterjee, Antonio Palazzo
Submitted in Journal of High Energy Physics

17. **Sub-TeV Quintuplet Minimal Dark Matter with Left-Right Symmetry**
Sanjib Kumar Agarwalla, Kirtiman Ghosh, Ayon Patra
Submitted in Journal of High Energy Physics

18. **Can we measure q_{23}octant in 3+1 scheme?**
Sanjib Kumar Agarwalla, Sabya Sachi Chatterjee, Antonio Palazzo
Contribution to XXII DAE-BRNS HEP Symposium, University of Delhi, Delhi, India, 12-16 December, 2016

19. E**xploring LFV processes in presence of Non-Holomorphic soft SUSY breaking terms** in MSSM-Utpal Chattopadhyay, Debottam Das, Samadrita Mukherjee

20. **Dirac Seesaw and related phenomenology-**
Debottam Das , Bibhabasu De, Nirakar Sahoo, Manimala Mitra

21. **A TTL Fast Pulse Counter for Detector Signals;**
Swain S., Sahu S., Sahu P.K., Biswas S.; (2018)

22. **A Simulation Model for Triple GEM Detector;**
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23. **A Simulation Model for Triple GEM Detector;**
Swain S., Mondal M.M., Sahu P.K., Nayak S.N.; (2018)

24. **Preliminary results of Ion Backflow study for a single GEM detector**
D. S. Bhattacharya, P. K. Sahu, S. Swain and S. K. Sahu; (2017):
arXiv:1708.02118.

25. **Formation of Anisotropic Nanostructures on Rutile TiO2(110) Surfaces and Their Photo-Absorption Properties,**
Vanaraj Solanki, Shalik R. Joshi, Indrani Mishra, D. Kanjilal and Shikha Varma,
Metallurgical and Materials Transactions A (2018), in press

26. **Investigation of Optical, Electrical and Magnetic Properties of hexagonal $NiTiO_3$ Nanoparticles Prepared via Ultrasonic Dispersion Techniques for high power applications,**
Subrata Karamkar, Ashis Manna, Shikha Varma, and D. Behera,
Material Research Express (2018) in press.

27. **Temporal evolution on SiO2 surface under low energy Ar+ -ion bombardment: Role of sputtering, mass distribution and shadowding**
M. Kumar, D. P. Dutta, Tanmoy Basu, S. K. Garg, H. Hofsäss, and Tapobrata Som
Journal of Physics: Condensed Matter

28. **Revealing multimode resistive switching in Cu-O nanostructures using conductive atomic force microscopy**
M.Kumar, B. Satpati, Tapobrata Som
Appl. Surf. Sci. (Under review).

29. **Broadband antireflection property of conformally grown zinc tin oxide thin films on nanorippled- and nanofaceted-Si substrates**
M.Saini, R. Singh, S.K. Srivastava and Tapobrata Som
J. Phys. D: Appl. Phys. (Under review).

30. **Experimental and simulation studies on temporal evolution of chemically etched Si surface: Tunable light trapping and cold cathode electron emission properties**
R. Singh, S. A. Mollick, M. Kumar, M. Saini, P. Guha, and Tapobrata Som
Phys, Status Solidi (a) (Under review).

31. **A Fast and facile deposition of PTFE based superhydrophobic and ultra wideband angle insensitive anti-reflection coatings**
Rajnarayan De, J, S. Misal, D. D. Shinde, S. R. Polaki, Ranveer Singh, Tapobrata Som, N. K. Sahoo, and K. Divakar Rao
Physica Status Solidi (RRL) (Under review).

32. **Structural, Optical and Morphological Properties of N Ion Implanted SrTiO3 Thin Films**
Anuradha Bhogra, Anha Masarrat, Ramchanran Meena, Manju Bala, Dilruba Hasina, Tapobrata Som, and Asokan Kandasami
Metall. Mater. Trans. A (under review).

33. **Structural properties of Fe ion Implanted CoSb3 Thin Films**
Anha Masarrat, Anuradha Bhogra, Ramchanran Meena, Manju Bala, Ranveer Singh, Vineet Barwal, Chung Dong, Chi-Ying Lu, Chi Chen, Tapobrata Som, Asad Niazi, and Asokan Kandasami
Metall. Mater. Trans. A (under review).

34. **Role of local structural distortion in driving ferro-electricity in $GdCrO_3$**
arXiv:1803.08318, Accepted in PRB

35. **Temperature Dependent Photo-induced reversible Phase Separation in Mixed Halide Perovskite**
under review in, Nano letters

36. **Self-immobilized Pd nanowires as an excellent platform for a continuous flow reactor: Efficiency, stability and regeneration**
under review in ACS nano

37. **Angle dependent LSPR from Ag nanoparticles embedded in SiO2 thin film**
under review in APL, arXiv1805.10576

38. **$GdCrO_3$: Potential candidate for low temperature magnetic refrigeration**
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39. **Multifunctional Sn1-xMnxS (0 d″ x d″ 0.20) Nanocrystals: Magnetic and Photocatalytic Applications**
C.Behera, D. Samal, S G Bhat, P S Anilkumar, S. Samal
under revision in New Journal of Chemistry-2018

40. **The effect of Sn intercalation on the superconducting properties of 2H-NbSe2**
S Naik, G. K. Pradhan, S. G. Bhat, B. Behera, P.S. Anil Kumar, S.L. Samal, D Samal (submitted to Euro Physics Letter-2018).

41. **Interfacial conditions for superconductivity in epitaxial hetero-structures with infinite layer cuprates**
D Samal et al. (under revision in Advanced Functional Materials-2018).

42. **Spin-momentum locking in a cubic Dirac material probed by quantum interference**
H. Nakamura, J. Merz , E. Khalaf , P. Ostrovsky, A. Yaresko , D. Samal , H. Takagi
Submitted to Physical Review X

43. **Searching for Leptoquarks at IceCube and the LHC**
Ujjal Kumar Dey, Deepak Kar, Manimala Mitra, Michael Spannowsky and Aaron C. Vincent
arXiv:1709.02009 (accepted in Phys. Rev. D),

44. **Long-lived Heavy Neutrinos from Higgs Decays**
Frank Deppisch, Wei Liu, Manimala Mitra
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45. **Neutrino and Collider Implications of a Left-Right Extended Zee Model**
Sarif Khan, Ayon Patra and Manimala Mitra
arXiv: 1805.09844,

3.3 Conference Proceedings

1 **Tidal deformability of neutrons and hyperons stars**
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2 **A comparative study: Clustering within microscopic and macro-scopic approaches**
Manpreet Kaur, BirBikram Singh, S K Patra and Raj K. Gupta, DAE Symp. on Nucl. Phys. 62 (2017).

3 **Temperature profile of thermile fissile nuclei**
A. Quddus, K. C.Naik, S. Ahmad and S K Patra, DAE Symp. on Nucl. Phys. 62(2017).

4 **Alpha decay chains of 302122 using relativistic mean field model**
Mamina Panigrahi, R. N. Panda, M. Bhuyan and S K Patra, DAESymp. on Nucl. Phys. 62 (2017).

5 **A comparative study of spin-orbit interaction in nuclei and hyper-nuclei**
M. Ikram, Asloob A. Rather, M. Imran and S K Patra,DAE Symp. on Nucl. Phys. 62 (2017).

6 **Prediction of decay modes of Z=119 superheavy nuclei within themass range 286 d" A d" 310**
Asloob A. Rather, M. Ikram and S KPatra, DAE Symp. on Nucl. Phys. 62 (2017).

7 **Re-visit of neutron-rich thermally fissile Th and U isotopes**
KishorChandra Naik, A. Quddus, R. N. Panda and S K Patra, DAESymp. on Nucl. Phys. 62 (2017).

8 **Ground state properties of Z=118 nuclei**
R. R. Swain, B. B. Sahuand S K Patra, DAE Symp. on Nucl. Phys. 62 (2017).

9 **Band structures and K isomers of 178Hf**
A. B. Sahu, Z. Naik, S.K. Ghorui S K Patra and C. R. Praharaj, DAE Symp. on Nucl.Phys. 62 (2017).

10 **Structure and reaction dynamics of Al-isotopes using Glauber model and relativistic mean field theory**
Mahesh K Sharma, R. N. Panda, Manoj K. Sharma and S K Patra, DAE Symp. on Nucl. Phys.62 (2017).

11. **Effective relativistic mean field model for finite nuclei and neutronstars**, *Bharat Kumar, B. K. Agrawal and S K Patra, DAE Symp.on Nucl. Phys. 62 (2017).*

12 **Advanced Detectors for Nuclear, High Energy andAstroparticle Physics. Springer Proceedings in Physics**,
S., Das S., Ghosh S.
vol 201. Springer, Singapore, 147-156.

13 **Advanced Detectors for Nuclear, High Energy andAstroparticle Physics. Springer Proceedings in Physics**,
S., Das S., Ghosh S.
vol 201. Springer, Singapore, 211-216.

14 Optical and low temperature magnetic properties study on sol-gel derived misfit calcium cobaltite
Avinna Mishra, Sudipta Mahana, Dinesh Topwal, U. Manju, Sarama Bhattacharjee
AIP Conference proceedings, 2017 1832 (1), 030019

15 **Thermoelectric properties of ternary half-Heuslar LuPdBi**
A. Mukhopadhyay, S. Mahana, S. Chowki, D. Topwal, N. Mohapatra
AIP Conference proceedings, 2017 1832(1), 110024

16 **Complex magnetic behavior in $GdCrO_3$**
Sudipta Mahana, U. Manju, D. Topwal,
AIP Conference proceedings, 2017 1832 (1), 130046

17 **$CH_3NH_3PbI_3$ based solar cell: Modified by antisolvent treatment**
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AIP Conference proceedings, 2017 1832 (1), 080065

18 Looking for Galactic Diffuse Dark Matter in INO-MagICAL Detector
Sanjib Kumar Agarwalla, Amina Khatun, Ranjan Laha
Proceedings of the 19th International Workshop on Neutrinos from Accelerators(NUFACT 2017)

19 **ZnO-nanorods: A possible white LED phosphor**
S. N. Sarangi, Arun T., D. K. Ray, P. K. Sahoo, S. Nozaki, N. Sugiyama, and K. Uchida
AIP Conference Proceedings 1832, 060022 (2017); doi: 10.1063/1.4980427

20. Recent inclusive tt cross section measurements
Aruna Kumar Nayak
9th International Workshop on the CKM Unitarity Triangle; POS(CKM 2016)117

21. Development of a High-Energy Transmission Laue Diffraction setup using a medical LINAC
Mallick, K. S. Jena, S. K. Biswal, A. K. rath and S. Behera
Proc. of Indian Particle Accelerator Conference (InPAC- 2018), January 09-12, 2018.

22. **Status report of 3MV Pelletron Accelerator at Institute of Physics, Bhubaneswar**
S. Sahoo, A. K. Behera, R. R. Dash, M. Majhi, K. C. Patra, B. Mallick, A. Sahoo, P. K. Biswal
Proc. of Indian Particle Accelerator Conference (InPAC- 2018), January 09-12, 2018.

23. **Injector Magnet of IOP Pelletron: Maintenance and Repair of DANFYSIK System**
Mallick, A. K. Behera, R. Das, M. Majhi, P. K. Biswal, K. C. Patra, A. Sahoo, P. C. Marndi, R. K. sahoo, S. Mishra and S. Sahoo
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24. **Ion beam based characterization of Triple GEM Detector**
P. K. Sahu, S. Sahu, B. Mallick, D. S. Bhattacharya, S. Swain, and S. Dani
Proc. of Indian Particle Accelerator Conference (InPAC- 2018), January 09-12, 2018.

3.4. Books Edited

1. **Prof. S. M. Bhattacharjee :** Topology and Condensed Matter Physics with Mahan Mj and A. Bandhyopadhaya) (published by Hindustan Book Agency/Springer)

2. **Prof. S. M. Bhattacharjee :** "What is dimension?", and "Use of Topology in physical problems"

3.5. Papers published by External User

1. Growth and Characterization of Au nanoparticles embedded In_2O_3 composite films, M.R. Ananthan, P. Malar, T. Osipowicz, Shikha Varma and S. Kasiviswanathan, Thin Solid Films, 622 (2017) 78.

2. Investigation of Optical, Electrical and Magnetic Properties of hexagonal $NiTiO_3$ Nanoparticles Prepared via Ultrasonic Dispersion Techniques for high power applications, Subrata Karamkar, Ashis Manna, Shikha Varma, and D. Behera, Material Research Express (2018) in press.

COLLOQUIA AND SEMINARS

4.1	Colloquia	:	97
4.2	Seminars	:	98
4.3	Lectures delivered by IOP members	:	105
4.4	Conference / Symposium attended by IOP Members	:	112
4.5.	Awards / Honours and Recognitions	:	115

4.1 COLLOQUIA & POPULAR TALK

4.1.1. COLLOQUIUM

Sl. No.	Date	Name and address of Speaker	Ttitle
1	14.07.2017	Prof. Samir Mathur,OSU, USA	Resolution of the Black Hole Information Paradox
2	04.09.2017	Prof. R. Rajaraman	What is inside a Pulsar?
3	25.10.17	Prof. P. K Mohanty, SINP, Kolkata	Can current decrease with increasing bias: onset negative response in non-equilibrium systems.
4	13.11.17	Prof. Sreerup Raychaudhuri TIFR, India	The early history of particle physics research in India
5	15.11.17	Prof. Gobinda Majumder TIFR, India	Past, present and future of the CMS experiment
6	22.11.17	Professor Amol Dighe TIFR, India	Looking at the sky with neutrinos
7	24.11.17	Prof. Rohini M. Goldbole CHEP, IISc, Bangalore	Whither with Colliders?
8	29.11.17	Prof. Rajiv V. Gavai TIFR, India	Exciting Odyssey in the Femto-world: QCD Critical Point
9	01.12.17	Prof. M. P.Das, Dept. of Theoretical Physics, The Australian National University,	"Photoelectric Effect: Truth vs. Hype"
10	06.12.17	Prof. Sumathi Rao	Spin mode switching in the quantum Hall effect
11	19.12.17	Dr. Alain Claverie,CEMES-CNRS and University of Toulouse, France	The Physics behind the Smart Cut TM Process for thin film transfer
12	11.01.2018	Dr. Deepak Kar Univ. of Witwatersrand, Johannesburg	Not a jet all the way: discovery prospects using substructure
13	26.01.2018	Prof. Jogesh C. Pati	unity in particle physics: *why choose the path of four colors and left-right symmetry?*
14	29.01.2018	Prof. Bala Iyer, ICTS-TIFR, Bengaluru	The detection of gravitational waves and the two body problem in general relativity
15	06.02.2018	Prof. Jogesh C. PatiSLAC, USA	unity in particle physics: "why choose the path of four colors and left-right symmetry"?
16	20.02.2018	Prof. P. Jena, Physics Dept., Virginia	Commonwealth University, Richmond, VA,

			USA Super-Ion Inspired Materials for Energy Storage and Conversion
17	27.02.2018	Prof. Debashish Chowdhury, IIT-Kanpur	Cyclic Molecular Machine: wandering in a landscape or hopping on a network?
18	01.03.2018	Prof. Milind DiwanBNL, USA	Sterile Neutrino Experimental Status*
19	12.03.2018	Prof. Sandhya Choubey HRI, Allahabad, India	The Oscillating Neutrino
20	09.03.2018	Dr. K. N. Vyas, Director, BARC Mumbai	"Nuclear Science Societal Applications and Relevance"

4.1.2 POPULAR TALK

1.	23.06.17	Prof. Ashok Das, Rochester University, USA	IPA-DAE C.V. Raman Lecture : The Amazing Integrable Models
2.	15.05.17	Dr. Sanjib K. Agarwalla and Collaborators	Indo-Japan Collaboration Meeting on Neutrino and Particle Physics
3.	16.05.17	Dr. D. Samal and Collaborators	Max plan Panther Group Workshop
4.	16.05.17	Dr. D. Samal and Collaborators	Kick-off Workshop for MPG-India Partnership group
5.	09.03.2018	Dr. K. N. Vyas, Director, BARC Mumbai	"Nuclear Science Societal Applications and Relevance"
6.	26.03.2018	Dr. Safiul Alam Mollick, Department of Physics, IIT Roorkee	Seminar of General Interest (Expt. Condensed Matter Physics) : Ion-beam Patterning of Ge and Its Application

4.2 SEMINARS

4.2.1. SEMINAR OF GENERAL INTEREST

1	24.04.17	Dr. Surajit Ghosh, BHU	Study of Magneto-transport and Verwey transition in Fe3O4
2	28.04.17	Prof. Maitree Saha Sarkar, SINP	Our Adventures in Nuclear Structure and NuclearAstrophysics with light-ions and low energy beams
3	04.05.17	Triparno Bandyopadhyay (Univ. of Calcutta)	The darkness within: Unification, and revival of the right
4	29.05.17	Ms. Kalpana Sharma, Journalist, consulting Editor, Economic and Political weekly	Should Indian Men Worry about Indian Women?
5	30.05.17	Ms. Kalpana Sharma, Journalist, consulting Editor, Economic and Political weekly	The Other Half of the Story
6	03.08.2017	Y.L. Jeyachandran	Understanding Ionic Hydration in Aqueous salt solution.

7	08.09.2017	Er. Sanjib Kumar Sahu	LabView and its interface to experimental instruments
8	19.09.2017	Dr.Helder Marchetto, Germany	Introduction and applications of low energy electron microscopy and photoemission electron microscopy
9	27.12.17	Dr. Mrutyunjaya Bhunya	The surface properties of neutron-rich exotic nucleiA source studying the nuclear symmetry energy
10	16.01.2018	Preeti Manjari Mishra,Postdoctoral Researcher, Max Planck Institute for Nuclear Physics, Heidelberg, Germany	Photoexcitation spectroscopy of cold molecules in the Cryogenic Storage Ring "CSR"
11	13.02.2018	Sushanta Dattagupta Bose Institute, Kolkata*	Quantum phase and its measurable attributes a la theAharonov-Bohm effect
12	19.02.2018	Partha Ghose	Unifying Classical and Quantum Electrodynamics
13	21.02.2018	Partha Ghose	Entanglement in LIGO!

4.2.1. LECTURE SERIES

1	05.12.17	Prof. M. P. Das.	General theory of transport.
2	07.12.17	Prof. M. P. Das.	Quantum transport in mesoscopic systems
3	11.12.17	Prof. M. P. Das.	Quantum transport in mesoscopic systems

4.2.2. SYNOPSIS / ANNUAL REVIEW TALK

1	20.04.2017	Ms. Bidisha Chakrabarty	Non-BPS D1-D5-P solutions and gravitational instantons
2	04.07.17	Mr. Soumyabrata chatterjee	Field theory on cosmological spacetime: some results from ads/cft.
3	05.07.17	Mr. Bharat kumar	new parameterization of extended relativistic mean field model
4	06.07.17	Mahesh Saini	Ion-beam Patterning of materials & their application in solar cell research.
5	07.07.17	Mr. Ganesh c. paul	Novel transport phenomena in silicene hybrid junction
6	07.07.17	Mr. Paras Koundal IISER Mohali	Neutrino Oscillation in Three Flavor Paradigm
7	28.06.17	Amina Khatun	The study of Long-Range Force in INO-ICAL detector
8	11.07.2017	vijigiri vikas	Analytical and Numerical studies ofHydrogen bonded system with gauge symmetry.

9	19.07.2017	Sabya Sachi Chatterjee	Can we measure octant of 2-3 mixing angle in 3+1 scheme?
10	20.07.2018	Shreyansh Shankar Dave	Magneto hydrodynamics for Heavy-ion collisions.
11	21.07.2017	Partha Paul	Linearized Einsteins's Equation from Entanglement Thermodynamics
12	24.07.2017	Dibyendu Rana	Spin Wave analysis of Kitaev and extended Kitaev model
13	25.07.2017	Amit Kumar	Role of cross-linking in Morphology of chromosome.
14	25.07.2017	Amir Shee	Pattern Formation in a fluid switching between active and Passive Fraction.
15	26.07.2017	Atanu Maity	The Study of Spin Wave Spectrum & Finite Temperature MagneticBehavior of $\alpha-MnO_2$ (Hollandite Lattice).
16	01.08.2017	Subhajit Sarkar	Flux phase at the half filling in absence of reflection symmetry.
17	04.08.2017	Chaitra Hegde	"Diffusion in one dimension: large deviations and some universal features"
318	22.08.2017	SK Firoz Islam	Cooper pair splitting in a graphene based beam splitter geometry
19	25.08.2017	Subhadip Ghosh	Active maintenance of structures and transport due to molecular motors.
20	17.10.17	Arpan Das	Consequences of phase transition dynamics inNeutron stars and in Inflation
21	14.11.17	Sudipta Mahana	Magnetic and Ferroelectric studies of advanced functionaloxides and related Phenomena
22	16.06.17	Dr.M.M Mondal	"Physics at forward rapidities at RHIC and LHC
23	02.11.17	Dr. Sangram Das	"Understanding some exciting optical properties ofgraphene-semiconductor hybrid structure"
24	03.11.17	Sabya Sachi Chatterjee	Exploring Light Sterile Neutrinos and Long-Range Forces inLong-Baseline Experiments
25	28.11.17	Bidisha Chakraborty	Non-BPS D1-D5-P solutions and Gravitational Instantons.
26	12.12.17	Puspendu Guha	Silver Nanostructures on Oxide Surfaces: Growth,Characterizations and Applications

27	12.01.2018	Mr. Atanu Maity,	Bond operators and triplon analysis for spin s dimerantiferromagnet (PRB 82, 054404 (2010)),
28	25.01.2018	Dr. Paramita Dutta,	Probing topological edge states by time-periodic drive,

4.2.3. SEMINAR OF HIGH ENERGY PHYSICS GROUP

1	18.05.17	Dr. Haresh Raval, IITB	Implications of a quadratic gauge in non-perturbative QCD
2	25.05.17	Prof. Narendra Sahu, IIT Hyd	Singlet-Doublet fermion dark matter, neutrino mass and collider signatures
3	25.05.17	Prof. Hiranmaya Mishra , PRL, Ahmedabad	Estimation of transport coefficients of hot and dense Quark matter
4	26.05.17	Sarif Khan, HRI	Neutrino Mass, Dark Matter (WIMP + FIMP) and Muon (g-2) in a U (1) Model.
5	1.06.17	Dr. Subhadeep Mondal, HRI	Looking for a compressed Supersymmetric spectrum at the LHC
6	9.06.17	Prof. Sudip JanaOklahoma State University, USA	Minimal left-right symmetric model Higgs phenomenology at the LHC for photon initiatedprocesses"
7	29.06.17	Siba Prasad Das (Universidad de los Andes, Colombia)	A brief discussion on NMSSM Higgs phenomenology at LHC and LHeC
8	30.06.17	Dr. Ujjal Kumar Dey, IIT KGP	Quark mixing in an S_{3}-symmetric 2HDM
9	10.07.2017	Dr.Sanmay Ganguly	Boosted Top QuarkAn Experimental Probe toStandard Model & Beyond
10	29.08.2017	Ambresh Shivaji,	Determination of trilinear Higgs self-coupling in single Higgs processes at the LHC
11	13.10.17	Dr. Saurabh Niyogi	Constraining compressed scenarios using soft track at theLHC (arXiv:1704.07048

4.2.4. SEMINAR OF HIGH ENERGY PHYSICS GROUP (TPSC)

1	16.10.17	Mr. Nirakar Sahoo (IIT Hyderabad)	Mixed Singlet-Doublet Fermionic Dark Matter, Neutrino Mass and Collider Signatures
2	08.11.17	Tapoja' Jha (University of Calcutta)	Phenomenology of Universal Extra Dimensional Models
3	18.12.17	Dr. Swagata Mukherjee RWTH Aachen University, Germany	'Search for exotic new physics in CMS'

4	03.01.2018	Dr. Shilpi Jain (National Central University, Taiwan)	Reviewing the rare Higgs decays at CMS.
5	09.02.2018	T.R Govindarajan,IMSC Chennai	"Is Photon Mass Less?"
6	14.03.2018	Prof. Sandhya Choubey (Harish-Chandra Research Institute (HRI), Allahabad, India)	'Dark Matter- Experimental Evidences'
7	15.03.2018	Prof. Sandhya Choubey (Harish-Chandra Research Institute (HRI), Allahabad, India	'Dark Matter- Theory Aspects'
8	22.03.2018	Samadrita Mukherjee (IACS, Kolkata)	Exploring Non-Holomorphic Soft Terms in the Framework ofphenomenological MSSM and in Gauge Mediated Supersymmetry Breaking
9	20.07.2017	Dr.Sayantan Choudhury	Inflation to Structures EFT all the way
10	17.10.17	C. Soumya (University of Hyderabad)	Phenomenological Aspects of Neutrino Oscillation
11	20.11.17	Dr. Poonam Mehta (JNU, New Delhi)	Long baseline neutrino experiments and leptonic CP violation
12	12.01.2018	Dr. Deepak Kar (University of Witwatersrand, Johannesburg)	Hand-on introduction to Monte Carlo generators and Rivet
13	19.03.2018	Dr. Reetanjali Moharana (The Hebrew University, Israel)	Angular correlation of cosmic neutrinos with astrophysical cosmic-ray and ã-ray sources
14	21.03.2018	Mr. Abhishek Mohapatra (The Ohio State University)	Nonrelativistic Effective Field Theory of Axion Dark Matter
15	23.03.2018	Ankita Budhraja (IISER, Bhopal)	Factorized and Resummed Angularity Distributions
16	26.03.2018	Dr. Suratna Das (IIT Kanpur)	Cosmology as a testing ground of Quantum Mechanics
17	27.03.2018	Dr. Moon Moon Devi (Tezpur University)	Extensive Air Showers: Study of the muon component to find UHECR > primary

4.2.5 ASTROPHYSICS SEMINAR

1	16.03.2018	Prof. Sarira Sahu	What can be told about the astrophysical sources on the non-detection of Glashow resonance in Ice Cube?
2	21.03.2018	Prof. Sarira Sahu	TeV flaring of Blazars:Possible mechanism and observational Constraint
3	22.03.2018	Prof. Sarira Sahu	TeV flaring of Blazars:Possible mechanism and observational Constraint

4.2.6 SEMINAR OF CONDENSED MATTER PHYSICS GROUP

1	02.05.2017	Dr. Bhaskar Sen Gupta, Max Planck Institute for Polymer Research, Mainz	Amorphous Materials with Magnetic Degrees of Freedom
2	08.05.2017	Debolina Misra, IIT KGP	Density Functional Theory based Study of Lanthanum Nickelate
3	16.05.17	Dr. Avinna Mishra, IMMT, BBSR	Transition metal oxide based thermoelectric materials
4	31.05.2017	Dr. Rakesh Kumar Sahoo, IMMT, BBSR	Perspectives of 1D and 2D carbon Nano materials growth using chemical vapor deposition
5	5.06.2017	Dr. Arnab Saha, Savitribai Phule Pune University	Dynamical Density Functional Theory of Microswimmers
6	9.06.2017	Prayas Chandra Patel, BHU	Understanding Magnetism in Sulfide based nanoparticles
7	15.06.2017	Jayakrishna Khatei, Technion-Israel Institute of Technology	Dark excitons and intervalley coherence in MoS2 monolayers by two photon luminescence
8	10.07.2017	Nayana Narayanan,	Bose Einstein condensation of magnon
9	10.07.2017	Rajesh Shasani	Electron Microscopy: Imaging and compositionalanalysis of ZnO nanoparticles and plant leaf
10	21.07.2017	Priyadarsini Swain,	Exploring Quantum Phase Transition in metallic nanoalloys"
11	17.07.2017	Dr. G.K Pradhan	Science under Pressure
12	14.08.2017	Dr.Priyanka Mohan	Floquet topological transitions in spin-orbit coupled materials: A B-W approach
13	16.08.2017	Dr. Kumud M Tripathi	"Green nano carbons: Synthesis and their application"
14	18.08.2017	Dr.Tamoghna Das	What is the structure of a Simple Liquid?
15	16.10.2017	Arnab Roy, Dept. of Physics, Bar-Ilan University Ramat-Gan, Israel	Quantum fluctuations at the super conductor insulatortransition probed by the Nernst effect
16	15.12.2017	Dr.P.K MuduliIIT Delhi	Electrical and optical detection of spin currents
17	08.01.2018	Sakshath S. TU Kaiserslautern, Germany	Ultrafast demagnetisation dynamics in multicomponent systems
18	09.01.2018	Dr.Mayukh Majumder	In search of Quantum Spin Liquid: A microscopic insight

19	22.01.2018	Pankaj Bhalla, PRL, Ahmedabad	Electronic transport properties of materials: The memory function approach
20	24.01.2018	Vijay SinghCEA-Liten, Grenoble, France	In-silico Material Modelling: From Advanced Functional Materials to Next-Generation Photovoltaics and beyond
21	31.01.2018	Prof S. D.Mahanti, Michigan State University	Amplitude Modes in Quantum Spin-dimer systems; are they Higgs modes?
22	08.02.2018	Biplab Bhattacharjee (S N Bose Center, Kolkata)	Dynamics and phase behavior of active particles
23	15.02.2018	Dr. Sudeshna SenShanghai Jiao Tong University, China	Understanding the role of disorder in strongly interacting systems using effective medium approaches
24	06.03.2018	Soumyaranjan Mohapatra	Substitution induced modifications in structural, magneticand magneto dielectric properties of $Bi_2Fe_4O_9$.
25	26.03.2018	Dr. Maheswar Nayak, RRCAT, Indore	X-ray multilayer reflective optics
26	28.03.2018	Tridev Mishra (BITS, Pillani)	Some studies on modifications of low dimensional systems under the application of periodic driving

4.2.7 EXPERIMENTAL NUCLEAR PHYSICS SEMINAR

1	04.05.2017	Sathi Sharma, JRF, SINP	Interests in low-energy proton induced reactions in nuclear structure and astrophysics
2	04.05.2017	Arkabrata Gupta, Inspire Fellow, IIEST Shibpur	Interests in low-energy proton induced reactions in nuclear structure and astrophysics

4.2.8 QUANTUM INFORMATION SEMINAR

1	22.05.2017	Mr. C. Jebaratnam	Superlocality as an operational definition of nonclassicality going beyond nonlocality.

4.3 LECTURES DELIVERED BY THE INSTITUTE MEMBERS

4.3.1 POPULAR TALKS

TITLE OF TALK	EVENT / PLACE & DATE
From bonds to bands and atoms to solids: Physics and chemistry of electrons	**Prof. D. Samal :** Indian Science Congress Association National Seminar on Reaching the Unreached through Science and technology" 18-19 December, 2017, KIIT University, Bhubaneswar
Physics and Chemistry of electrons in solid	**Prof. D. Samal :** Workshop on mystery of Science, 3rd January 2018, KIIT University Bhubaneswar
Physics at the Large Hadron Collider	**Prof. A. K. Nayak :** SOA University, Bhubaneswar, 15th September 2017.
	Prof. A. K. Nayak : IANCAS program at IOP, 7th July 2017
Learning science, doing research, Three Idiot's way	**Prof. A. M. Srivastava :** HBCSE, Mumbai, 15 June, 2017
Learning science, Three Idiot's way	**Prof. A. M. Srivastava :** at the camp "Science Movement", held in Bhubaneswar for 100 selected students from across Odisha, 25 Dec. 2017
Chief Speaker talk	**Prof. A. M. Srivastava :** students on Republic day at Carmel English Medium School, Khordha-Odisha, 26 Jan. 2018
Our Universe, Elementary Particles and Dark Energy	**Prof. A. M. Srivastava :** at IMMT, Bhubaneswar on National Science Day, 28 Feb. 2018
Universe, elementary particles and dark energy	**Prof. A. M. Srivastava :** at NISER (arranged by the Science Activity Club), 22nd March, 2018
Black holes	**Prof. A. M. Srivastava :** at the Xaviers school Khandagiri for school students 8-10 class in memory of Steven Hawking. March, 2018

4.3.2. SEMINARS/TALKS DELIVERED

TITLE OF TALK	EVENT / PLACE & DATE
Prof. S. M. Bhattacharjee	
What is dimension?	Institute lecture, IIT Roorkee, March 2018
Prof. A. M. Srivastava	
Seminar on Power spectrum and flow	Physics Dept. Univ. of Illinois, Urbana

fluctuations in relativistic heavyion collisions	Champaign, USA, 5th April 2017
Effect of magnetic field on flow fluctuations in relativistic heavy-ion collisions	Brookhaven National Lab, Upton, NY, USA, April 14, 2017
Cosmology	OCSC HBCSE meeting for the selection of Indian team for the International Olympiad in Astronomy and Astrophysics (held in Thailand in Nov. 2017), May 2-8, 2017
Failure of geometrical optics in the Mirage phenomenon, and determination of acid rain content by rainbow parameters	NIUS camp at HBCSE, Mumbai, 15 June, 2017
CMBR power spectrum and flow anisotropies in relativistic heavy-ion collisions	the International Conference, "Light Cone meeting LC 2017" "Frontiers in Light Front Hadron Physics- Theory and Experiment" held at the University of Mumbai from September 18-22, 2017
Setting Initial Conditions for Inflation with Reaction-Diffusion Equation	the Working group on Astroparticle Physics at the International Conference, "Workshop on High Energy Physics Phenomenology", held at IISER Bhopal, 14-23 Dec. 2017
Chiral Magnetic and Chiral Vortical effects in relativistic heavy-ion collisions	In the Working group on QCD and QGP at the International Conference, "Workshop on High Energy Physics Phenomenology", held at IISER Bhopal, 14-23 Dec. 2017
Entanglement of neutrinos from supernova	In the Working group on neutrinos at the International Conference, "Workshop on High Energy Physics Phenomenology", held at IISER Bhopal, 14-23 Dec. 2017
High density QCD phase transitions inside neutron stars : Glitches and Gravitational waves	at Physics Dept. IISER Kolkata, 7th March, 2018
Thermal history of the universe *(Two Lectures)*	At the "IUCAA sponsored workshop on Astronomy and Astrophysics in NIT Rourkela, 9th March, 2018.
Topological Structures in QCD phases at high baryon density	At PRL Conference on Condensed matter physics, PRL, Ahmedabad, 15th March, 2018

PROF. S. VARMA

DNA Sensing of Nanoparticles by Scanning Probe Microscopy	At International Conference on Electron Microscopy and Allied Techniques and XXXVIII Annual Meeting of the Electron Microscope Society of India (EMSI-2017), held at Mahabalipuram (July, 2017).

Sensing of Nanoparticles with DNA	at National Conference on Physics at Small Scales and Advanced Materials (PSAM) at the School of Physics, University of Hyderabad (Sept 2017).
Enhanced Photoabsorption, Super-	at Meeting on Emerging Trends in the Physics of
Paramagnetism and DNA Biocompatibility in ion implanted TiO_2 (110)	Surfaces, Interfaces and Nanostructures (ET-PSIN) at Indian Association for the Cultivation of Science (IACS) and S. N. Bose National Center for Basic Sciences (SNBNCBS),Kolkata (Nov. 2017)
DNA as a Sensor of nanoparticles : Unzipping of DNA	at the International workshop on Advanced Materials (IWAM-2017) at the National Institute of Science and Technology (NIST), in Berhampur (Dec. 2017)
Photoabsorption, Magnetism and DNA Biocompatibility on Nanostructured TiO_2(110)	at the ninth Vidyasagar-Satyendranath Bose National workshop (SMCP-2018) at Vidyasagar University, Midnapore, West-Bengal (Jan. 2018).
DNA as a Sensor of Nanoparticles : Unzipping and changing Persistence Length of DNA	at IISER Kolkata (March 2018)
Academic Activities of Institute of Physics in	During centennial meeting of Governing Council
last 40 years : Experimental Program	of the Institute, at IOP, Bhubaneswar, April 2017)
Experimental Academic Activities of Institute of Physics	During the visit of UGC team, at IOP, Bhubaneswar (Nov. 2017).
Prof. P. Agrawal	
Nonlocality and Multiqubit States	International Symposium on New Frontiers in Quantum Correlations (ISNFQC18), S. N. Bose National Centre for Basic Sciences, Kolkata, India, January 29 - February 2, 2018.
Prof. B. R. Sekhar	
Band Structure of Some Topological Insulators	Invited talk in Optics-2017, NIT, Calicut
Topological Insulators	Invited talk at CMDAYS-2017, Tezpur, Assam.

Surface States in Topological Insulators	Invited talk at NCES-2017, IISER, Bhopal.
Band Structure of Insilators (ARPES Perspective)	Invited talk at Frontiers in Condensed Matter, NISER
Band Structure of Quantum Materials	Talk at UN College, Cuttack
Speech as a Chief Guest	Talk at EDEN School, Khurda

Prof. P. V. Satyam

Studying Interfaces across bimetallic Au-Ag system grown under ultra clean surfaces	International Conference on Electron Microscopy and Allied techniques atMammalapuram, organized by IGCAR and IIT Madras, 17 – 19 July 2017
Electron Microscopy For Studying Thin Film Surface and Interfaces	Recent Trends in Condensed matter physics, JC Bose Institute, 1 – 3 November, 2017.
Emerging Trends on Physics of Surfaces, Interfaces and Nanostructures	Conference title: ", IACS/SNBose, Kolkata, 24 – 25 November 2017
Three decades of Surface Science work: from dirty to ultra clean surfaces	

Prof. T. Som

Strong uniaxial magnetic anisotropy in Co films on highly ordered grating-like nanopatterned-Ge	10th National Conference on Solid State Chemistry and Allied Areas (ISCAS-2017), Delhi Technological University, New Delhi. 1st July, 2017.
Surfing ion-beam fabricated silicon nanofacets for cold cathode electron emission sites	4th International Conference on Nanostructuring by Ion Beams (ICNIB-2017), Devi Ahilya University, Indore. 12th December, 2017.
Nanoscale functionalization of ion-beam induced self-organized nanostructures	17th International Conference on Thin Films (ICTF-17), National Physical Laboratory, New Delhi. 15th November, 2017.
ECR plasma-based surface nanostructuring of materials and their nanoscale functionalization	*Faculty Development Programme (FDP)* at C.V. Raman College of Engineering, Bhubaneswar. 22nd December, 2017.

Prof. S. K. Patra

Tidal deformity of neutrons and hyperons stars with relativisticmean field theory, DAE Symposium on Nuclear Physics	Thapar University, Patiala. 20th – 24th December, 2017.
Gravitational waves	Centurian University, Bhubaneswar. 27th July, 2017.

Tidal deformity of neutron and hyperon star with relativistic mean field theory	Ravenshaw University. 12th April, 2017.
Prof. S. K. Agarwalla	
Atmospheric Neutrinos: Status and Prospects	Invited talk given at the Nu HoRIzons VII Conference, HRI, Allahabad, India,21st February, 2018
Recent Developments in Neutrino Oscillations and Future Outlook	Invited Plenary talk given at WHEPP XV workshop, IISER Bhopal, Bhopal, India,20th December, 2017
Indirect Searches of Galactic Diffuse Dark Matter in INO-MagICAL Detector	Talk given at the NuFact 2017 Conference, Uppsala University, Uppsala, Sweden,28th September, 2017
Can New Physics spoil the measurement of Octant of θ_{23}?	Seminar given at ICTP, Trieste, Italy, 21st September, 2017
Can we probe Octant of θ_{23} in presence of New Physics?	Seminar given at the Laboratori Nazionali del Gran Sasso (LNGS), Assergi, Italy,8th September, 2017
Non-Standard Interactions in Borexino and Daya Bay	Invited talk given at the workshop on Recent Developments in Neutrino Physicsand Astrophysics, LNGS, Assergi, Italy, 5th September, 2017
Prof. A. Saha	
Cooper pair splitting in a Graphene based beam splitter geometry	S. N. Bose National Centre for Basic Sciences, Kolkata, September (2017).
Cooper pair splitting in a Graphene based beam splitter geometry	IISER Kolkata, September(2017).
Cooper pair entangler device based on Graphene superconductor	Young Investigator Meet in Quantum Condensed Matter Theory, SNBNCBS, Kolkata, October(2017). 62nd DAE Solid State Physics Symposium, BARC, Mumbai, December(2017). Annual Condensed Matter Physics Meeting, NISER, Bhubaneswar, 27th February (2018).
Few transport phenomena through Superconducting hybrid junctions of Dirac materials	Indian Institute of Science (IISc), Bangalore, 18th January (2018).
Few transport phenomena through Superconducting hybrid junctions of Dirac materials	Indian Institute of Technology (IIT), Kanpur, 07th March (2018).

Prof. A. K. Nayak

Tau lepton as a probe for New Physics at LHC	Seminar on Contemporary Physics, Utkal University, 12th August 2017.

Prof. S. Banerjee

Null-Infinity and Unitary Representation of Poincare Group	Tata Institute of Fundamental Research (TIFR), Mumbai , 15th January, 2018.
Saha Theory Workshop : Modern Aspects of String Theory	Saha Institute of Nuclear Physics (SINP), Kolkata, 22nd February, 2018.
Celestial sphere and unitary representation of the homogeneous Lorentz group	HRI Allahabad, 6th September, 2017. ICTS - TIFR, Bengaluru, 27th September, 2017. NISER Bhubaneswar, National Strings Meeting 2017 , 05th December, 2017.
Holographic RG flow and black brane (hole) in AdS	IISER Pune, 10th – 13th July, 2017 (Four Lecture)
First Spring Meeting on Strings : Null-Infinity, Unitary Representation of Poincare Group and Soft Theorems	NISER Bhubaneswar, Date : 24th March, 2018.

Prof. D. Samal

Atomic layer engineering : A viable approach to manipulate the electronic properties of transition metal oxides at unit cell level	Kick-off Workshop for MPG-India Partnership group**, 15-May, 2017**, IoP Bhubaneswar
Tailoring Dirac semi-metallic state in inverse-perovskite (Sr_3PbO) and perovskite ($SrIrO_3$) epitaxial thin films	International workshop on advanced materials (IWAM-2017), 19-21 December, National Institute of Science and Technology (NIST), Berhampur, Odisha. National Conference on Electron Spectroscopy (NCES-2017), December 27-29, 2017, IISER Bhopal
Thin-film heterostructures of quantum materials and novel phenomena	23rd January 2018, IACS Kolkata.
Exploring Dirac semi-metallic state in designer oxide thin-films	IoP-NISER meeting in Condensed Matter Physics, 26-27, January 2018, NISER, Bhubaneswar

Prof. Debottam Das

Probing sterile neutrinos in the framework of inverse-seesaw through lepto quark productions	WHEPP15, Dec17

Dr. S. N. Sarangi

DNA Assisted Synthesis of CdS Nanowires : A Nano-bioelectronic Device	International workshop on "Advanced Materials"" (IWAM-2017) at National Institute of Science & Technology (NIST), Berhampur during December 19-21, 2017
Nuclear Techniques &Nano-Science	DAE-IOP Awareness-cum-Workshop on " Nuclear Technologies for Betterment of Tribal's Social Life" at Ekalavya Model Residential School, Mahasingi, Kandhamal district of Odisha during 18th and 19th March, 2017.
Nanostructures and Nanotechnology : Fundamentals and Applications	Workshop on Mystery of Science, organized by Kalinga Institute of Industrial Technology(KIIT) Deemed to be University in collaboration with Indian Association of Nuclear Chemists & Allied Scientists-Eastern Region Chapter(IANCAS-ERC), Institute of Physics(IOP), Bhubaneswar during 3rd January 2018.

4.4. CONFERENCE / WORKSHOP ATTENDED BY IOP MEMBERS

Name	Conference/Workshop details
Prof. S. M. Bhattacharjee	1. RTCMP, Bose Institute, Kolkata, Oct 20172. ISI-PU Conference on Statistical Physics, Feb 2018
Prof. A. M. Jayannavar	**1. Large deviation theory in statistical physics: Recent advances and future challenges** organised by ICTS from 27 September - 27 October, 2017.
Prof. A. M. Srivastava	2. Attended the International Conference, "Light Cone meeting LC 2017" "Frontiers in Light Front Hadron Physics- Theory and Experiment" held at the University of Mumbai from September 18-22, 2017. 3. Attended the International Conference, "Workshop on High Energy Physics Phenomenology", held at IISER Bhopal, 14-23 Dec. 2017. 4. Attended the "PRL Conference on Condensed matter physics", PRL, Ahmedabad, 14-16th March, 2018. 5. Academic team member for the selection and preparation of the Indian Team for the International Olympiad in Astronomy and Astrophysics (IOAA-2017), held in Nov., 2017 in Phuket, Thailand. Selection camp held during 2-8 May, 2017. 6. Scientific Observer with the Indian Team, Nov. 2017, in IOAA-2017 at Phuket, Thailand 7. Participated in the Resource Generation Camp for Astronomy Olympiad at HBCSE -TIFR, 17-18 March, 2018.
Prof. S. Varma	1. International Conference on Electron Microscopy and Allied Techniques and XXXVIII Annual Meeting of the Electron Microscope Society of India (EMSI-2017), held at Mahabalipuram (July, 2017). 2. National Conference on Physics at Small Scales and AdvancedMaterials (PSAM) at the School of Physics, University of Hyderabad (Sept 2017). 3. Meeting on Emerging Trends in the Physics of Surfaces, Interfaces and Nanostructures (ET-PSIN) at Indian Association for the Cultivation of Science (IACS) and S. N. Bose National Center for Basic Sciences (SNBNCBS), Kolkata (Nov, 2017) 4. International workshop on Advanced Materials (IWAM-2017) at the National Institute of Science and Technology (NIST), in Berhampur (Dec. 2017) 5. Ninth Vidyasagar-Satyendranath Bose National workshop (SMCP-2018) at Vidyasagar University, Midnapore, West-Bengal (Jan. 2018).
Prof. P. V. Satyam	1. International Conference on Electron Microscopy and Allied techniques atMammalapuram, organized by IGCAR and IIT Madras, 17 – 19 July 2017.

2. Imaging the Biomolecules, Noble Prize in Chemistry at Institute of Mathematical Applications, Bhubaneswar, 27 October 2017.
3. Recent Trends in Condensed matter physics, JC Bose Institute, 1 – 3 November.
4. Noble prize in Chemistry, Indian Institute of Technology Bhubaneswar, 14 November 2017.
5. Conference title: Emerging Trends on Physics of Surfaces,Interfaces and Nanostructures", IACS/SNBose, Kolkata, 24 – 25 November 2017.

Prof. T. Som

1. 10th National Conference on Solid State Chemistry and Allied Areas (ISCAS-2017), Delhi Technological University, New Delhi.
2. 4th International Conference on Nanostructuring by Ion Beams (ICNIB-2017), Devi Ahilya University, Indore.
3. 17thInternational Conference on Thin Films (ICTF-17), National Physical Laboratory, New Delhi.

Prof. S. K. Agarwalla

1. Nu HoRIzons VII Conference, HRI, Allahabad, India, 21st to 23rd February, 2018
2. Workshop on High Energy Physics Phenomenology (WHEPP XV), IISER Bhopal, India, 15th to 21st December, 2017.
3. NuFact 2017 Conference, Uppsala University, Uppsala, Sweden, 25th-30th September, 2017
4. Workshop on Recent Developments in Neutrino Physics and Astrophysics, LNGS and GSSI, Assergi and L'Aquila, Italy, 4th to 7th September, 2017
5. Indo-Japan Neutrino Meeting at Institute of Physics, Bhubaneswar, 15th May, 2017

Prof. A. Saha

1. Annual Condensed Matter Physics Meeting, NISER, Bhubaneswar, 26-27February (2018).
2. 62nd DAE Solid State Physics Symposium, BARC, Mumbai, 26-30 December (2017).
3. Young Investigator Meet in Quantum Condensed Matter Theory, SNBNCBS, Kolkata, 26-27 October (2017).
4. Tailoring quantum materials using Thin Film Techniques, IOP, Bhubaneswar, 15-16 May (2017).

Prof. A. K. Nayak

1. India CMS Collaboration meeting, 4—6th August, 2017, IIT – Madras.
2. India CMS Collaboration meeting, 26—28th November 2017, IOP, Bhubaneswar.
3. India CMS Collaboration meeting, 16—18th March 2018, TIFR, Mumbai

Prof. S. Banerjee

1. First Spring Meeting on Strings, NISER Bhubaneswar , 23/03/2018 – 25/03/2018
2. NISER Bhubaneswar, National Strings Meeting 2017

3. Saha Theory Workshop : Modern Aspects of String Theory, Saha Institute of Nuclear Physics, Kolkata

Prof. D. Samal

1. *Atomic layer engineering: A viable approach to manipulate the electronic properties of transition metal oxides at unit cell level*, Kick-off Workshop for MPG-India Partnership group, 15-May, 2017, IoP Bhubaneswar (Invited Talk) (Also I was the organizer for this workshop)
2. *Tailoring Dirac semi-metallic state in inverse-perovskite* (Sr_3PbO) *and perovskite* ($SrIrO_3$) *epitaxial thin films*, International workshop on advanced materials (IWAM-2017), 19-21 December, National Institute of Science and Technology (NIST), Berhampur, Odisha. (Invited Talk)
3. *Tailoring Dirac semi-metallic state in inverse-perovskite* (Sr_3PbO) *and perovskite* ($SrIrO_3$) *epitaxial thin films,* National Conference on Electron Spectroscopy (NCES-2017), December 27-29, 2017, IISER Bhopal (Invited Talk)
4. Thin-film heterostructures of quantum materials and novel phenomena, 23rd January 2018, IACS Kolkata. (Invited Talk)
5. Exploring Dirac semi-metallic state in designer oxide thin-films, IoP-NISER meeting in Condensed Matter Physics, 26-27, January 2018, NISER, Bhubaneswar.

Prof. Manimala Mitra

1. 'Physics at CLIC', CERN, Geneva, july, 2017,
2. WHEPP XV, December 2017, IISER Bhopal,
3. NuHoRIzon VII, HRI, Allahabad, 21-23rd Feb, 2018
4. BSM Direct Searches at CLIC on March 23rd, 2018

Dr. Sachin N. Sarangi

1. **DNA Assisted Synthesis of CdS Nanowires: A Nano-bioelectronic Device"** at International workshop on "Advanced Materials"" (IWAM-2017) at National Institute of Science & Technology (NIST), Berhampur during December 19-21, 2017.

4.5. AWARDS / HONOURS AND RECOGNITIONS

Prof. Sudhakar Panda

Prof. Sudhakar Panda has been awarded J.C. Bose National Fellowship on July 2017.

Prof. S. Varma

1. Editorial Board Member of International Journal: Journal of Physics Condensed Matter
2. Member Executive committee, Joint Secretary (East), Ion Beam Society of India (for Second term)

Prof. P. V. Satyam

1. President, Electron Microscope Society of India (EMSI) (2017 – 2020)
2. Sectional Committee – Andhrapradeh Science Academy
3. Editorial Board Member, Transactions of the Indian Ceramic Society (Taylor & Francis)
4. Guest Faculty at IIT, Bhubaneswar (*Chemistry group*)

Prof. Sanjib Kumar Agarwalla

1. Awarded with Young Scientist Research Grant for three years (2018 to 2021) from Indian NationalScience Academy (INSA)
2. **Professional Memberships of Dr. S. K. Agarwalla**
   (a) Member of the India-based Neutrino Observatory (INO) collaboration(Actively involved in the physics and detector simulation studies) http://www.ino.tifr.res.in/ino/
   (b) Member of the International Design Study for the Neutrino Factory https://www.ids-nf.org/wiki/Front Page.

CONFERENCES AND OTHER EVENTS

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5.1. Alumni Day:

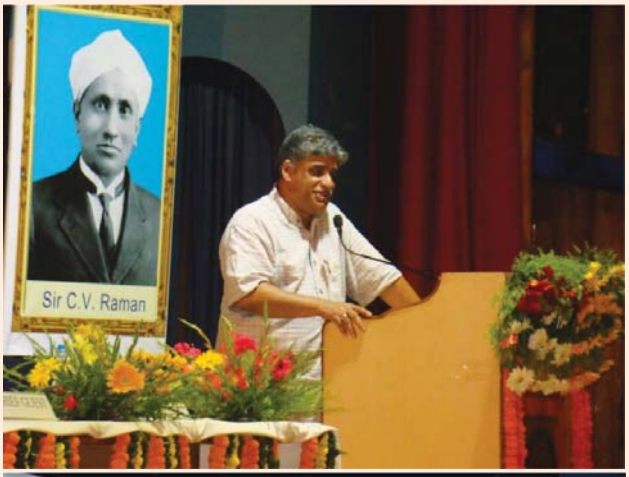
The 38th Alumni day was celebrated on 12th April, 2017. It was chaired by Prof. S. Panda, Director, and Institute of physics and President Alumni Association, IOP. The programme started with an academic session consisted of a series of lectures by alumni members of IOP and followed by colloquium by invited distinguish physicist Prof. Sayan Kar, IIT Kharagpur. The topic of his colloquium was **"HOW WELL DO WE KNOW THE GRAVITATIONAL CONSTANT?".**

Prof. Soumitro Banerjee, IISER Kolkata delivered colloquium talk entitled "Bifurcation in piecewise smooth dynamical system".

There was a scientific discussion among the students of the institute and the experts. Around 180 students from different colleges of the state participated in this event.

Prof. Kuntala Bhatacharjee, IIST Trivandrum delivered Alumni day talk on "Tailored nano-structures of MoS_2:A simple liquid phase exfoliation method,

The evening program started with the talk delivered by chief guest Shri. Jagadananda, social activist, leader of Centre for Youth and Social Development, Bhubaneswar.



It was followed by prize distribution to the winners of science modelling competition among school students of various group. This was followed by evening cultural programme.

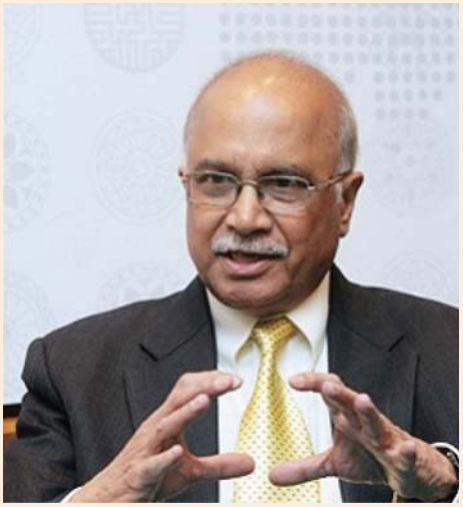
Office Bearers of Alumni Association :

Secretary : Mr. MB. Vinayakrishnan

Faculty Advisor : Dr. D. Samal

5.2. Foundation Day

Institute of Physics celebrated 43rd Foundation Day on September 4, 2017. This is one of the most important events of the Institute, where a large number of persons from academia, media, and administration of the Odisha Government and DAE were invited. Members of the Institute family took active part in the proceedings. A function was arranged in the Auditorium of the Institute. Prof. R. Rajaraman, an Emeritus Professor of Theoretical Physics at the School of Physical Sciences at Jawaharlal Nehru University, the co-Chairman of the International Panel on Fissile Materials and a member of the Bulletin of the Atomic Scientists's Science and Security Board graced the occasion as Chief Guest and delivered the key note address on the Foundation Day talk entitled "What is inside a Pulsar (nickname for Pulsating Sources of Radio)?". In the lecture, *Prof. Rajaraman* emphasized the importance of collaborative scientific work among the different institute of India and abroad, as science becomes more collaborative and multidisciplinary approaches are needed to solve problems that are significant at this time. The importance ensuing that the pursuit of science as a career is kept open to all. Many steps have been taken over the years – and many more are still required – to encourage women scientists to pursue their careers and to enhance the gender sensitivity of the work environment in our academic and scientific institutions. *After a brief introduction to Pulsars and their formation, Prof. Rajaraman had focused on what is likely to be their internal composition and why they are also called "Neutron Stars". The talk was introductory, meant for students from all branches of Physics. At the end of the talk their was a briefly discussion about some very fundamental concepts of elementarily, that play a role in the equation of state of the pulsars.*



The session was chaired by Prof. Sudhakar Panda, Director, Institute of Physics. Vote of thanks was given by Prof. B. R. Sekhar, Chairman of the Foundation Day Celebration Committee. The programme was concluded by a cultural programme 'DRAMA' entitled "Bhala Manisha Khoja Chalichi (ଭଲ ମଣିଷ ଖୋଜା ଚାଲିଛି / in search of good person)" by IOP staff.

5.3. Indo-Japan Collaboration Meeting on Neutrino and Particle Physics.

An Indo-Japan collaboration meeting on Neutrinos and Particle Physics was organized at the Institute on 15th May. The purpose of this meeting was to seek opportunities of collaboration between India and Japan on neutrino and other emerging areas in particle physics. Important delegates from Japan (four persons) and Canada (one person) who are working on various world class neutrino experiments attended this meeting. The Director of J-PARC Center/KEK, Prof. Naohito Saito was the chief guest of this meeting who informed about the various scientific activities which are being pursued at the J-PARC Center/KEK during the meeting. He also briefed about the opportunities that are available to students to work with the scientists from Japan. The other delegates from Japan were Prof. Takashi Kobayashi (Head of Particle and Nuclear Physics Division of J-PARC and Deputy Director of Institute of Particle and Nuclear Studies, KEK), Prof. Takeshi Nakadaira (T2K Project Coordinator and Neutrino Section Leader of J-PARC, KEK), and Prof. Masashi Yokoyama (T2K Near Detector Upgrade Project Leader, Member of T2K and Hyper-K Steering Committee from University of Tokyo). Prof. Sampa Bhadra from the York University, Canada who is an important member of the T2K experiment also took part in this meeting. The delegates discussed about the neutrino experiments in which they are involved and making pioneering discoveries. Dr. Sanjib Kumar Agarwalla from IOP talked about the research work on neutrinos which is being carried out at IOP and also discussed the future plans. The faculty members, students, and post-doctoral fellows from our Institute who are working on various issues related to particle physics participated in this meeting. Many enthusiastic students from IOP and surrounding Universities and Institutes took part in the meeting and they asked very relevant questions after each talk. The students were quite eager to know that how can they participate in the various scientific activities

which are being pursued at the J-PARC Center and KEK.

This collaboration meeting provided a platform to learn about the particle physics program at J-PARC and neutrino physics program in Japan. Indian scientists who are doing research in these related areas will be immensely benefitted from this Indo-Japan collaboration and it will provide us an opportunity to take part in the world class neutrino experiments in Japan and learn from them. This will be also quite useful for our own homegrown India-based Neutrino Observatory project.

The detailed agenda of this meeting and all the talks which were delivered during this meeting can be found at the following link: http://www.iopb.res.in/ijnm2017.

5.4. Kick-off Workshop for MPG-India Partnership group

A workshop on "Tailoring quantum materials using thin film techniques" was organized at Institute of Physics (IoP), Bhubaneswar during 15-16 May, 2017 as the joint venture of Max Planck Institute of Solid State Research and IoP through Max Planck partner Group Programme. The main aim of this workshop was to strengthen the research ties between MPI Stuttgart and IoP through scientific discussion on relevant research topics of common interest and possible future collaborations. Many distinguished scientists including Prof. Hidenori Takagi, Director of the Department of Quantum Materials from Max Planck Institute of Solid State Research represented the German side. The major topics covered during the workshop were

(i) novel functionality of materials produced by the interplay between strong electronic correlation, spin-orbit interaction and the band-topology

(ii) Dirac and Weyl semimetals

(iii) exotic thin film design and characterization (iv)oxide heterostructures.

The workshop started with a formal inaugural function on 15th may 2017, in which Prof. Sudhakar Panda, Director, IoP Bhubaneswar, welcomed the delegates and participants and offered all support towards the MPG-India Partnership programme at IoP. Then Prof. Hidenori Takagi, Director, MPI Stuttgart talked about the research activities at MPI FKF, Stuttgart. He also mentioned the future strategy to continue with the collaborative research work

between MPI FKF and IoP. Finally, Dr. Debakanta Samal from IoP briefed about the research activities and the facilities available at IOP.

Technical session had eight invited speakers from Germany and India. There were about thirty five participants including faculties, post-docs, and PhD students from India.

On the second day of the workshop (16th May 2017), a business meeting was organized. In this meeting there was a detailed discussion on the possible research projects to be carried out through Max Planck partner Group pogramme at IoP. It was decided that the planned research activities will be carried out through an extensive interaction with the scientists from both the places. Prof. Takagi agreed that he will arrange the necessary collaborative support from MPI.

After the business meeting, the German Scientists were given a tour to various experimental facilities at IoP and could interact with the concerned faculties of each lab.

5.5. IPA-DAE C.V. Raman Lecture

For the first time, the Institute of Physics organized C. V. Raman IPA-DAE Lecture under the banner of "Indian Physics Association (IPA)-Department of Atomic Energy (DAE) on 23rd of June, 2017 at 4.00 p.m. The lecture entitled "***The Amazing Integrable Models***" was delivered by Prof. Ashok Das, University of Rochester, USA. More than 100 scientists, researchers and students from nearby universities, and educational institutions (Utkal University, NISER, SOA University, OUAT and CET) attended this lecture.

During this talk Prof. Das illustrated about integrable models that have many unusual features. Integrable model defines nonlinear differential/partial differential equations that are exactly solvable. Examples include lattice model, spin chains etc. He also described about the integrable models in various dimension. In particular, he discussed about KdV equation, solitary wave (shallow water wave), and nonlinear Schrödinger equation. The KdV equation has a colourful history, which began in 1832 with John Scott Russell's celebrated pursuit on horseback of a solitary wave along the Edinburgh- Glasgow canal. It is the prototypical example of an exactly solvable model. The KdV equation represents the simplest combination of nonlinearity and dispersion in the absence of dissipation. Owing to its nonlinearity, the KdV equation resisted analysis for many years, and it did not come under serious scrutiny until 1965, when Zabusky and Kruskal obtained numerical solutions while investigating the Fermi-Pasta-Ulam problem of masses coupled by weakly nonlinear springs. KdV can be solved by means of the inverse scattering transform. The mathematical theory behind the KdV equation is a topic of active research. If two localized solution of KdV equation collide with each other, remarkably after the collision they move out maintaining their shape. These solutions which are because of the nonlinear interactions, behave

as if there exists no interaction at all. Such solutions are called Soliton solution. Solitons are defined as travelling wave solution that are localized, non dispersive and those maintain their shape even after the collision. KdV equation yielded a startling new type of wave behavior. Soliton solutions are now discovered for a large number of nonlinear equations, including equations of particle physics, laser physics, and magneto hydrodynamics.

Finally, Prof. Das mentioned that the physics related to integrable model (KdV equation) has several connections to physical problems and shows up in fluid dynamics, astrophysics, biophysics, plasma, high energy and even in defense studies. These are very special models and describes some of the beautiful features. P.S: The complete video lecture of Prof. A. Das on this occasion is available in the following link. https://www.youtube.com/watch?v=qtxpl5xEz78.

5.6.India-CMS collaboration Meeting at Institute of Physics

The India-CMS collaboration meeting was held at Institute of Physics, Bhubaneswar, from 26th November to 28th November 2017. Faculty members, post-docs, and students from Indian institutes and universities participating in CMS experiment at CERN-LHC attended the meeting. Delegates were from TIFR, Mumbai, SINP, Kolkata, NISER, Bhubaneswar, University of Delhi, IIT Madras, IIT Bhubaneswar, Panjab University, IISc, Bengauru, Viswa Bharati University, Shantiniketan, IISER Pune. About 50 participants attended the meeting. The director, Prof. Sudhakar Panda welcomed the guests and inaugurated the meeting. The meeting was

chaired by the India-CMS spokesperson, Prof. Brajesh Choudhary, University of Delhi. Senior faculty members of the collaboration were assigned to chair various sessions of the meeting. The first day of the meeting was devoted for the presentation of students and post-docs on physics analyses using proton-proton collision data recorded by the CMS detector. The talks from various groups on detector R&D and CMS detector upgrade proposals were presented on 2nd day. Many discussions happened on the possible contributions by Indian Institutes to the future (phase-II) upgrade of the CMS detector. The last part of the 2nd day and the 3rd day were devoted to the faculty meeting. The meeting ended with vote of thanks.

5.7. Centennial Function Governing Council of Institute of Physics.

Institute of Physics celebrated the 100th Meeting of the Governing Council of the Institute on 21st April, 2017. The function also has brought culmination to the year long scientific activities of the 40th academic year. The GC met in the morning and took stock of the overall achievements and contributions made by the institute. The evening function was presided over by Dr. Sekhar Basu, Chairman, GC (Secretary, DAE and Chairman AEC). Former Directors; Prof. T. Pradhan (Founder Director), Prof. V. S. Ramamurthy, Prof. Y. P. Viyogi and Prof. A. M. Jayannavar graced the occasion and were felicitated by Dr. Basu. Former Directors shared their memories, experiences and blessed the Institute more success and fame. Director, Prof. Sudhakar Panda gave an overall view. Senior faculty members gave presentations on the various research activities undertaken by the Institute and the contributions in last 40 years. Distinguished members of the present Governing Council were also present on the occasion.

OTHER ACTIVITIES

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6.1 OutreachProgramme

6.1.1National Science Day Celebration-2018

Institute of Physics, Bhubaneswar has organized National Science Day 2018 Celebrations on 28th February 2018 at its Auditorium. The program began with the welcome address by Dr. Debakanta Samal, Convener of the Program. Dr. Anil Bhardwaj, Director, Physical Research Laboratoy, Ahmedabad was the Chief Speaker of the program. Prof. Sudhakar Panda, Director inaugurated the function. About 250 students and 25 teachers were participated from different colleges/Schools from 30 districts of Odisha. Three eminent scientist had been invited to deliver their scientific talk. They presented their seminar before the audience. Sri R. K. Rath, Registrar presented the vote of thank.

Sri R. K. Rath, Registrar, Dr. Anil Bhardwaj, Chief Guest, Prof. Sudhakar Panda, Director and Dr. Debakanta Samal, Convener on dias during the inauguration of the function)

LIST OF SCIENTIST AND TITLE OF THEIR SEMINAR TALK IN SCIENCE DAY

S.N.	SPEAKER	TITLE OF TALK DELIVERED
1.	Prof. Anil Bharadwaj, Director, PRL	INDIAN PLANETARY EXPLORATION PROGRAM
2.	Prof. S. Tripathy, TIFR, Mumbai	THE FOUNTAIN OF LIFE
3.	Prof. Milind Diwan, Dept. of Physics, BNL, NY	COMPUTERS FOR SUSTAINABLE FUTURE

6.1.2. IANCAS Activities

IOP is also actively involved in spreading the awareness about the basic science among common people through its own Outreach Program and those organized through ***Indian Association of N uclear Chemists and Allied Scientists*** **(IANCAS).**The Indian Association of Nuclear Chemists & Allied Scientists -Eastern Regional Chapter (IANCAS-ERC), office is at IOP campus, Bhubaneswar

6.1.2.1. The IOP-IANCAS Workshop on Nuclear Sciences was organized at IOP Auditorium, Institute of Physics, Bhubaneswar on 7th July, 2017 under the joint sponsorship of IOP-IANCAS-ERC, Bhubaneswar.

Delegates & Participants of workshop held o 7th July, 2017 at IOP Auditorium

6.1.2.2. IOP-KIIT-IANCAS workshop on "Mystery of Science" on 3rd January, 2018Venue: Convention Centre, Campus-6 of Kalinga Institute of Industrial Technology *(KIIT)*, Deemed to be University, Bhubaneswar.

Workshop Class on Fun Science Experiments

6.1.2.3. Dr. K. N. Vyas, Director, BARC Mumbai has deliver a popular talk entitled "Nuclear Science Societal Applications and Relevance" in IOP Lecture Hall under IANCAS-ERC special Lecture on 09.03.2018.

Dr. K. N. Vyas, Speaker of IANCAS-ERC Special Lecture

6.2 Sky watch Programme

Several Night sky observations sessions were conducted at IOP. The observations were carried out using two telescopes and two binoculars. Brief detailsof the two telescopes are as follows:

A. 8" Schmidt-Cassegrain 2 meter focal length telescope, computer controlled with GPS system, 2 inch eye piece kit. This is a sophisticated telescopefor viewing sessions at the Institute.

B. 4" refractor telescope, manual controls with fine adjustment knobs. Thisis a robust, user friendly telescope, which everyone was allowed to handle.

Various night sky sessions were:

a. Night sky observation sessions with telescopes at IOP Bhubaneswar forIOP members and general public, 27 Oct. 2017.

b. Night sky observation session with telescopes at IOP Bhubaneswar for100 selected student participants from across Odisha in the camp "ScienceMovement", 24 Dec. 2017.

c. Night sky watch program with telescopes for school students (participants of the telescope making workshop) and for IOP members at IOP, 21st Jan, 2018.

d. Night sky watch program for general public and for IOP members andtheir families at IOP to watch the Lunar Eclipse using additional telescopesfrom SCAA. 31st Jan. 2018.

Various night sky objects which were seen during these sessions includedMoon (generally sessions were held when there was good viewing condition forcraters), Saturn, Uranus and Neptune, Andromeda galaxy and Orion nebula.Telescope making workshop:A telescope making workshop was organized for 40 school students (class9-12) at IOP, with lecture on ray-diagram and optics. 40 telescopes assembled (which were given to those students), 21st Jan, 2018.

6.3. Activities of Official Language

Hindi Section of the Institute is committed to comply with various guidelines issued by the

Department of Official Language to promote the usage of Hindi language in the office. The main goal is to render Hindi translation of the works given by various sections/officers of the Department and implementation of the official language Policy, which mainly include compilation of quarterly reports received from various sections of the Institute and send it in an integrated form to the Department of Atomic Energy, which organizing quarterly meeting to discuss these reports.

6.3.1. Winning of DAE Rajbhasha Shield

Institute of Physics, Bhubaneswar has been awarded with "Rajbhasha Shield" for the year of

2016-2017 by the Department of Atomic Energy for its excellent implementation of the Official Language **"Hindi"** in the Institute. This award was given on 22 March, 2018 during the All India Official Language Conference held at Madras Atomic Power Plant, Kalppakam, Tamilnadu.

6.3.2. Celebration of Hindi Pakhwada

Hindi Pakhwada was organized in the Institute during September 14-28, 2017 wherein various competitions were held which include Essay writing competition, Noting- drafting competition, Dictation Debate, Handwriting, etc. Members of the institute participated in these competitions and awarded on 31st September, 2017 accordingly

6.3.3. Celebration of World Hindi Day

Institute celebrated the World Hindi Day on 1st October, 2018. Prof. Anup Kumar, HoD, Hindi Department, Regional Institute of Education, Bhubaneswar had the Chief Guest of the

function. All staff members were participated in this function.

6.3.4. Organising Joint Hindi Workshop

Institute of Physics, Bhubaneswar, NISER and Heavy Water Plant, Talcher jointly organized the Hindi Workshop on 23.06.2017 on the title of

"Use of Hindi in Technical Fields" at Heavy Water Plant, Talcher. Ten Employees and two officers were participated in the said workshop.

For December, 2017 ending quarter, a Joint Hindi Workshop organized in the Institute on 27th December, 2017 at Institute by IOP, NISER and HWP, Talcher on "New Technical Facilities for use of Hindi". Thirteen officials were participated in this workshop on behalf of the Institute. Sri Hariram Pansari, Sr. Manager (Rajbhasha), NALCO, Bhubaneswsar was the Chief Speaker of the workshop. Sri Alok Kumar Chaturvedi, Chief Manager (OL), State Bank of India, Local Head Office, Bhubaneswar was delivered a talk on "Hindi Grammar" to the participants.

6.3.5. Organizing Scientific Seminar in Hindi

The Scientific Seminar in Hindi on "Role of Scientific and Technical Institutions in Skill

Development" Jointly Organised at NISER, Jatani on 20.03.2018. Two Officers and fourteen employees were participated in this seminar on behalf of the Institute.

6.4. Observation of International Yoga Day at the Institute

The Institute of Physics celebrated the 3rd International Day of Yoga on 21st June, 2017 with

fervor and warmth amid numerous events organized to mark the International Yoga Day across the globe. Mass Yoga demonstrations were

organized between 7- 8 am in the campus, where all officials participated in different Yoga Performances in tranquil morning hours under guidance of Yoga Experts. The activities have helped the members in spreading awareness and also set a platform for their future involvement in Yoga and other health activities. The Yoga Day Event was marked with motivating speeches by Sister Durgeshnandini, Prajapati Brahma Kumari Iswariya Viswavidyalaya, Unit-8, Bhuabneswar who shared the benefits of yoga for physical, mental and spiritual well - being and encouraged the entire staff for embracing the same in their daily activities.

6.5. Swachhata Pakhwada

Institute has celebrated Swachhta Pakhwada during 16th-28th February 2018 on the occasion of World Science Day on 28th February, 2018. During the Pakhwada different swachhata program conducted in the Institute as well as near by villages. A workshop on "Housekeeping Services" was organized for Housekeeping Workers deployed by the contractor at IOP Site.

(Swachhata Program at Village-Daruthenga)

6.6 Women Cell Activities

Women cell, lOP, had arranged talks by Ms. Kalpana Sharma as a part of its ongoing activities to carry out awareness programs on women related issues and gender diversity. Ms. Kalpana Sharma is an independent journalist and writer. She is currently Consulting Editor with the Economic & Political Weekly. In her career of over four decades, she has worked with The Hindu, Times of India, Indian Express and Himmat Weekly. For 22 years, she wrote a regular column from a gender perspective, "The Other Half", first in Indian Express and later in The Hindu. For this she received the Chameli Devi Jain Award for Outstanding Woman Journalist. She is the author of "Rediscovering Dharavi: Stories from Asia's largest slum" and has edited three other books.

The talks were held on 29 May (4:00 pm) and on 30th may (10:30 am) in the main lecture hal,10P. These talks were respectively titled 'Should Indian Men Worry about Indian Women?' and 'The Other Half of the Story'. In

the first talk she emphasized - though there is greater visibility of women in all walks of life from sport to science, from business to politics, from the media to the military, we are compelled to acknowledge that much remains unchanged and steps to change the same. In the second talk she mainly discussed about writings in her columns 'The Other Half', which she wrote first in Indian Express and thereafter in The Hindu. Here she discussed many contemporary issues from a gender perspective with common threads and the disruption and changes in the lives of Indian women.

Both the talks were very well received and had very good participation of Institute members as well as members from NISER and civil society. There was an extensive discussion of members with Ms. Sharma during as well as at the end of the talks. Both the talks were recorded and will be made available in the institute for furthering the awareness. Many positive suggestions were received from the participants including preparing of a homepage with many relevant information, rules as well many links to Ms. Kalpana Sharma's articles as well as other such articles. There were also suggestions of starting discussion group of such activities, and many other related relevant issues, periodically within the institute and other members. The full talk available in the following link

Part – 1 : https://www.youtube.com/watch?v=tW8UiHc4EsA

Part – 2 : https://www.youtube.com/watch?v=UrrsTYWXlek

6.7. Sports and Cultural Activities

Along with the research activities, the sports and cultural activities have been promoted through different sports and cultural programs to keep all the members physically fit under the chairmanship of Prof. S. K. Patra.

6.7.1. Sports

a. A Football match was conducted on 15th August, 2017. This was a friendly match between Director's Team (Faculties and Doctoral) and Registrar's Team (Staffs of the Institute). Registrar's Team won the match. Around 110 spectators were there to enjoy the football match.

b. A friendly Cricket match was also conducted on the occasion of 26th January, 2018. This match was played between Director's Team (Faculties & Doctoral) and Registrar's Team (Staffs). Director's Team won the match. It was a very interesting match. Around 80-viewers joined and made the event successful.

c. Institute also organized the Annual Sports and Cultural Meet in the month of August, 2017. These events started on 12.08.2017 and got completed on 25.08.2017. The total number of events was 17. Around 55 staff members participated in men's events, 30 family members participated in the women's events, and 40 children participated in children's event. Among staffs, 20 volunteers coordinated for a successful completion of the Annual day. The winners of different events were awarded in the Annual day program. Also few staffs were rewarded, those who had completed 25 years of service in IOP.

6.7.2. Celebration of Children's Day :

Institute has celebrated National Children's Day celebration on 14th November, 2017 on the

birth day of Pandit Jawahar Lal Neheru. Sri Ram Kishore Sharma, Rehabilitation Officer of Vocational Rehabilitation Centre for Handicapped (VRCH), Bhubaneswar, Ministry of Labor and Employment, Government of India was the Chief Guest of the program. Staff members, their family members and children were participated in this program.

6.8. Zonal selection matches for DAE Sports and cultural meet :

a. In the year 2017-18, Institute conducted two events of zonal selection matches for DAE Sports and cultural meet i.e. Drama, Poetry and Painting on 04.11.2017 and Kabaddi on 18th Nov.2017.

b. For DAE Cultural meet, the cultural groups from different DAE units were participated. The teams were (1) UCIL, Jaduguda (2) HWPB, Talcher (3) SINP, Kolkata and (4) IOP-NISER Bhubaneswar. Among these four teams in Drama, HWPB, Talcher was selected to participate in RRCAT, Indore to play in the final competition. In Poetry, Dr.

S. N. Sarangi (IOP, Bhubaneswar), Dr. A. K. Nayak (NISER, Jatni) and in Painting Sri Jaideo Sen (UCIL, Jaduguda), Sri Sunil Mali (UCIL, Jaduguda) were selected to participate in the final at RRCAT.

c. For another DAE Sports and cultural meet i.e. Kabaddi, it was jointly organized by IOP and NISER. Around 20 volunteers of the IOP employees' welfare society coordinated for the successful completion of the matches. IOP team also participated in the competition. From IOP team Sri Brundaban Mohanty was selected for Konark team to play in the final match.

Fig: The Photo of Zonal selection match for Kabaddi.

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Fig: The Photo of Zonal selection match for Drama.

6.9. Fire Safety awareness Programe at IOP

FIRE Safety Awareness Programme at Institute and FIRE Service Week 2018 (14th-20th April 2018)

Inaugural Function of "FIRE Service Week 2018": Er Sanjib Sahu, Coordinator, Prof. B. R. Sekhar, Chairman Fire Safety committee, IOP, Bhubaneswar , Sri M. Swain, Principal, Odisha Fire and Disaster Rescue Academy, Bhubaneswar as Chief Guest and Sri R. K. Rath, Registrar, IOP Bhubaneswar.

Fire Safety and Public Awareness camping.






Fire Safety and Training activity at IOP, Bhubaneswar.

FACILITIES

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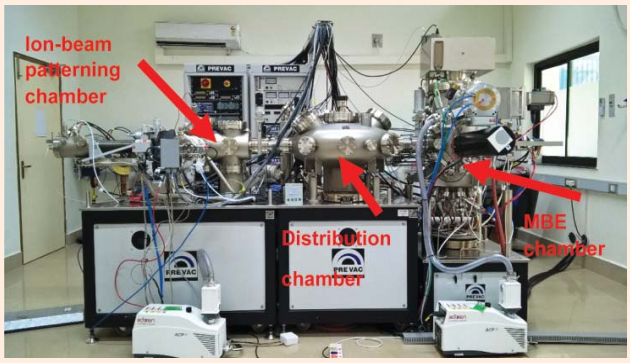
1.1 MAJOR EXPERIMENTAL FACILITIES

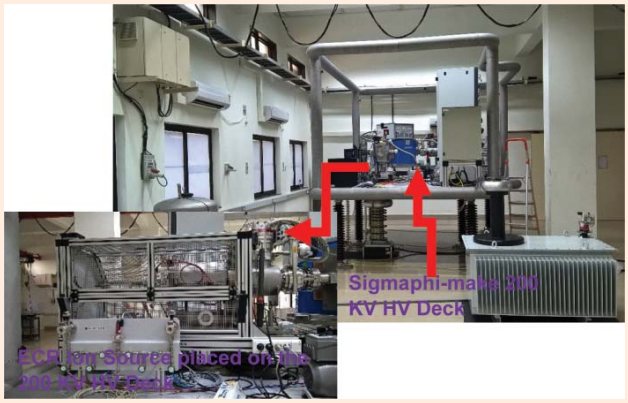
Integrated Low Energy Ion Patterning and UNV Growth System

Recently, we have installed and commissioned a low energy ion patterning unit



integrated with molecular beam epitaxy system for fabrication of self-organized patterned susbstrates, *in-situ* ultrathin films and self-assembled nanostructures to achieve nanoscale functionalities, viz. plasmonics, magnetism and optical properties. This facility is having structural characterization module and we are in the process of adding the in-situ compositional module as well which will make it a unique system in the country.

Development of an ECR ion Source-based low-to-medium energy ion-beam facility

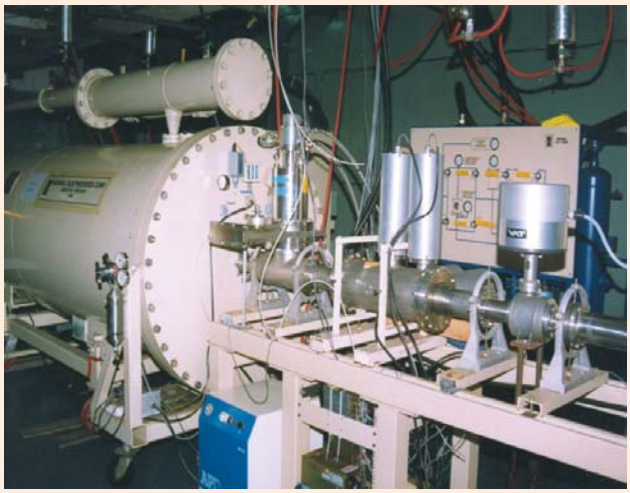


We installed electron cyclotron resonance (ECR) ion source on a 200 KV high voltage deck. This will enable us to accelerate ions to hundreds of keV to a few MeV energy for ion implantation, nanoscale patterning, ion-beam induced epitaxial crystallization, ion-beam mixing, ion-beam shaping, synthesis of embedded nanostructures and so on. This facility will help us bridging the gap of not being able to use inert gas ions (other than helium) and energies below 1 MeV from the existing Pelletron accelerator.

ION BEAM FACILITIES

Ion Beam Laboratory

The Ion Beam Laboratory houses the NEC 3 MV tandem Pelletron Accelerator which is one



of the major facilities used by researchers from all over the country. The accelerator provides ion beams of energies typically 1-15 MeV starting from protons and alphas to heavy ions. Commonly used ion beams are that of H, He, C, N, Si, Mn, Ag and Au. Multiple charge states are possible for the MeV energy positive ion beams. Argon is used as the stripper gas to produce positive ions. The most probable charge state for

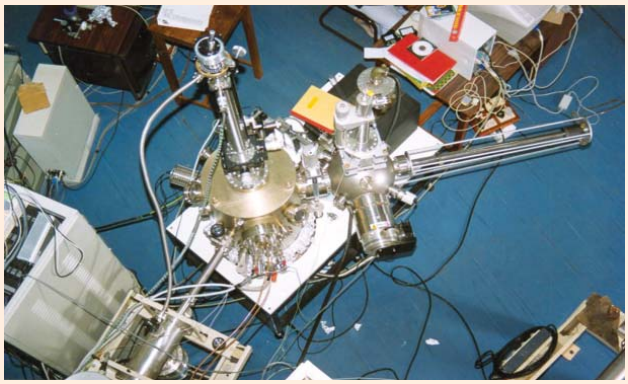
heavy ions (carbon or above) is 3+ for terminal potentials above 2 MV.

The beam hall has six beam lines. The beam line at -45° is used for Rutherford Backscattering (RBS), Elastic Recoil Detection Analysis (ERDA), Proton induced X-ray Emission (PIXE), Ultra high vacuum (UHV) and ion channeling. Radiocarbon AMS is carried out in the -15° beam line. A general purpose scattering chamber suitable for PIXE experiments is available in the 0° line. This beam line also has the potential to perform external PIXE experiments in atmosphere. The 15° beam line is equipped with a raster scanner and is being used for ion implantation. There is a UHV chamber for surface science experiments in the 30° beam line. The 45° beam line houses the micro-beam facility.

The types of experiments that are being carried out in the IBL are mainly ion beam modification and ion beam analysis. These include ion implantation, irradiation, channeling, Rutherford backscattering, and particle induced X-ray emission. The accelerator is also being used for radiocarbon dating by Accelerator Mass Spectrometry (AMS) . The facilities for research in surface sciences include an ultra-high vacuum chamber on the surface physics beam line at IBL which is equipped with a thin film deposition facility, Auger spectroscopy and the low energy electron diffraction (LEED) units.

Ion Beam Analysis Endstation

We have also added an ion beam analysis endstation in the general-purpose beam line at the Ion Beam Laboratory. This endstation is unique one in the country which is dedicated for user experiments based on ion beam analysis



techniques, viz. Rutherford backscattering spectrometry (RBS), RBS-channeling, and elastic recoil detection analysis (ERDA). While RBS is meant for depth profiling of heavy elements, RBS-channeling is capable of analysis of single crystals and epitaxial layers to determine crystalline quality, amorphous layer thickness, degree of disorder and atomic site. In addition, it can be used for accurate determination of thickness of an amorphous thin film, consisting of light elements, deposited on a single crystalline substrate of a relatively heavier element. On the other hand, low-energy ERDA helps in absolute determination of hydrogen and its isotopes in a simultaneous fashion and in a non-destructive way. The system can be upgraded to add proton induced x-ray emission (PIXE) technique for trace elemental analysis in materials. The endstation is equipped with a slam load lock chamber and a rectangular sample holder, which can accommodate more than ten samples at a single go. These eliminate the need for exposing the scattering chamber to the ambient and frequent disruption in experiments. The samples can be precisely positioned in front of the ion beam with the help of XYZ motors and monitored by a CCD camera. All gate valves and the vacuum pumps are coupled to the interlocking system which

rules out meeting a vacuum related accident. In addition, the chamber is equipped with two surface barrier detectors – one dedicated for RBS measurements and the other one for ERDA measurements. They are coupled to the respective set of electronic modules and the data acquisition system is interfaced with a computer.

Ion beam etching induced surface nanostructuring

At Surface Nanostructuring and Growth (SUNAG) Laboratory, we have facilitated a low energy (50 eV – 2 keV), broad beam (I in. diameter) electron cyclotron resonance (ECR) source based ion beam etching facility for creating self-organized surface nanostructures. The source is equipped with a differential pumping unit for working at a better chamber vacuum during the ion etching process. The ion source is coupled with a UHV compatible sample processing chamber which is equipped with a load lock chamber and a 5-axes sample manipulator. The sample stage has both low (LN2) and high-temperature (1000°C) stages for creating nanostructures at different sample temperatures. One can measure the target current from the sample stage itself, while the ion current is measured by bringing in a shutter in front of the ion beam path.

MICROSCOPY FACILITEIS

HRTEM Laboratory :

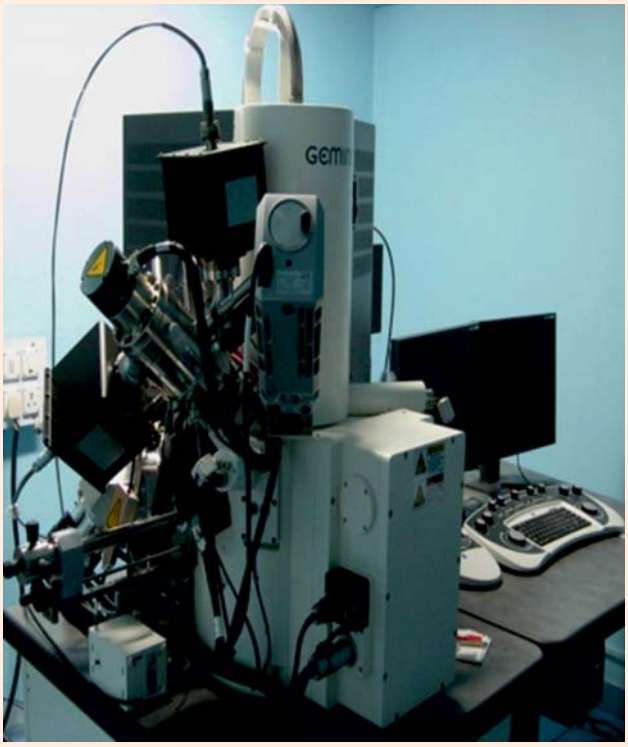
The High Resolution Transmission Electron Microscope (HRTEM) facility consists of two components: Jeol 2010 (UHR) TEM and Associated Specimen Preparation system. High-Resolution Transmission Electron Microscopy

(HRTEM) with an ultra-high resolution pole-piece (URP22) working at 200 keV electrons from LaB6 filament assures a high quality lattice imaging with a point-to-point resolution of 0.19 nm. For in-situ elemental characterization and compositional analysis, an energy dispersive system using Si(Li) detector (INCA from Oxford, UK) is regularly used. The facility carries out both planar and cross-section TEM analysis of systems. For the specimen preparation, Grinder-cum-polisher, Ultra-Sonic Disc Cutter, Dimple Grinder, Low Speed Diamond Wheel Saw, Wire Saw, Tripod Polisher, Precision Ion Polishing System (PIPS) and Millipore water purifier system facilities are used. Recently, a low-temperature cooling sample stage holder (cooling with LN2 – minimum temperature achievable is 110 K to room temperature, Model 636 from M/S Gatan Inc.) and a dry pumping system have been installed. the system is also equiped with

low and high temperature stages and fast CCD camera to carry out *in-situ* and real time studies.

FEGSEM-FIB facility:

The Cross-Beam facility consists of a field emission based scanning electron microscope (FEGSEM) and a focused ion beam (FIB) system. The facility also has other useful accessories to elemental mapping with x-ray florescence (using



energy dispersive spectrometry (EDS)), canning transmission electron microscopy (STEM), e-beam lithography (M/S Raith GmbH) and transmission electron microscopy specimen preparation using lift-out methods. The objective is to understand the combination of bottom-up and top down process in self-assembly of nanostructures. This would help us to create a new methodology that would help to grow atomic scale devices, to understand the structural aspects of nano to micro – scale structures, and to prepare site-specific TEM specimen using the SEM and FIB facilities. The electron beam energy can be varied between 100 eV to 20 keV and the Ga ion beam energy can be varied in the range of 2 – 30 keV. The images can be made with sub-nm resolution while the features can be made of dimensions ~20 nm.

Multi-Mode Scanning Probe Microscope Facility

At IOP we have a Multimode SPM (Scanning Probe Microscope) facility. SPM is being primarily utilized for the research in the fields of surface science and nanoscience for investigating surface topography, nanostructures, magnetic structures, phase imaging, electrical force imaging, STM, STS and electrochemical STM. The two primary techniques present in our SPM are:

Scanning tunneling Microscope (STM), where the tunneling current between the probe and the sample surface is imaged, and Atomic Force Microscope (AFM), where the forces are imaged. AFM can further operate in two modes viz. Contact mode and Tapping mode. In addition the AFM can be utilize to perform Lateral Force

Microscopy (LFM), Force Modulation Microscopy (FMM), Magnetic Force Microscopy (MFM), Electric Force Microscopy (EFM) and Phase Imaging. Studies in Liquid environment are also possible.

In addition, we have a large-area, high-precision AFM setup which is equiped with low Z-axis noise facility. This AFM is mostly dedicated for studying nanoscale self-organized patterned substates and thin films. Conductive AFM mode offers a gamut of physical properties to be studied. Further it has in-built nano-indentation and nano lithography facilities.

ELECTRON SPECTROSCOPY FACILITIES :

X-Ray Photoelectron Spectroscopy Setup

The present XPS system has a dual X-ray Aode (Mg/Al). The sample can be aligned by a manipulator. Photoelectrons are energy analyzed by a hemispherical mirror analyzer. The system also has the facility for sample annealing and Ar ion sputtering. Sputtering technique can be utilized for doing depth profiling studies. All the experiments are carried out under ultra high vacuum (UHV) conditions at the vacuum of 1x10-10 Torr.

X-ray photons while impinging on the sample surface produce photoelectrons which can be utilized for elemental identification. The kinetic energy distribution of electrons photo-ejected by x-rays from a sample provides a map of the discrete atomic levels, specially the core levels of the constituent atoms with in the material. Another very important aspect of XPS is the ability to distinguish different chemical environments of atoms; these appear in XPS spectra as core level binding energy shifts. The origin of chemical shifts arises from enhanced or reduced electronic screening of electrons due to charge transfer. Small mean free paths of the photo-ejected electrons make XPS very surface sensitive (~1 nm). The technique of XPS is very useful in the studies of thin film structures, heterostructures, bulk samples, and even for the studies of biological samples.

ARUPS Laboratory

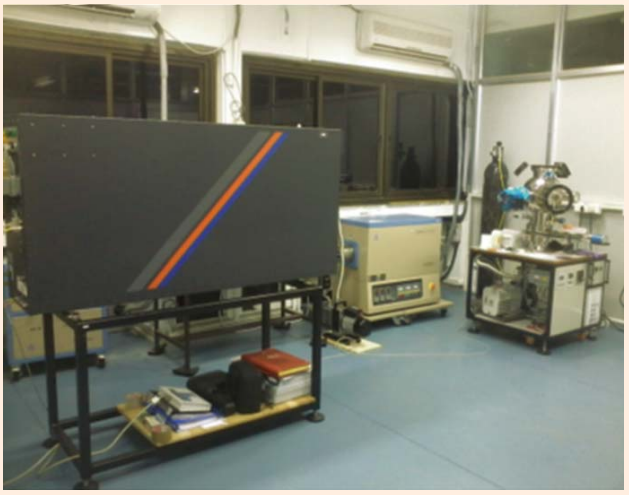
The Angle Resolved Ultraviolet Photoelectron Spectrometer (ARUPS) is equipped with facilities for doing both angle integrated valence band measurements as well as angle

resolved valence band measurements. This mu metal UHV system is supplied by M/s Omicron NanoTechnology UK. In angle integrated UPS, we probe the valence band electronic structure on polycrystalline and thin film samples. The angle resolved studies are possible on single crystals. The UPS system consists of a main analysis chamber and a sample preparation chamber, both under 10-11 mbar vacuum conditions. The main chamber is equipped with R3000, Scienta hemispherical analyzer for angle-integrated studies. A movable 65mm hemispherical analyzer, mounted on a 2-axis goniometer is also there in this chamber. These energy analyzers have a typical resolution of around 15 meV. He I (21.2 eV) and He II (40.8 eV) lines from an ultra-violet discharge lamp are used for photo excitation. The analysis chamber is also equipped with a 4-axis sample manipulator-cum cryostat, which can go down to 20K. Facility for performing Low Energy Electron Diffraction (LEED) is also available in the analysis chamber. The sample preparation chamber has facilities for scrap cleaning and evaporating metal films.

THIN FILM GROWTH FACILITIES

Pulsed Laser Deposition (PLD) System

PLD system helps growing epitaxial thin films of various materials albeit the most prefered materials are oxides. The newly installed system was developed in a piece-wise manner by procuring several modules from different sources. We are depositing epitaxial bi- and multi-layer thin films of superconducting (viz. YBCO) and colosal magneto-resistance (viz. LSMO) on suitable substrates.



DC/RF Magnetron Sputtering

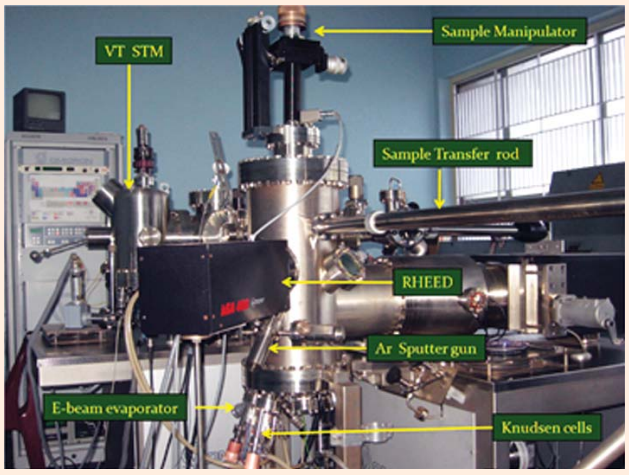
We have installed a pulsed DC/RF magnetron based sputter deposition unit. The unit has four sputter guns where two are

dedicated to operate with pulsed DC supply and the other two are connected to RF power supply. The substrate is made to rotate during film deposition towards having high-quality uniform films. One can put the substrate holder at a high temperature (up to 6000 C) for film growth at elevated temperatures. We have an additional and dedicated gun for deposition of three-dimensional nanostructures by using glancing angle deposition. Further, we have a load lock

and a plasma chamber for making nitride and/or oxide layers in vacuum. We can grow thin films of semiconductors, metals, and compounds having a wide variety of morphology and grain size. In turn, their physical properties can also be tuned. Research using this facility is aimed at developing advanced materials having novel structures and tunable properties. The system is mainly aimed to grow materials on templated substrates and compare change in their physical properties driven by anisotropy in substrate morphology. We have taken up a program to grow thin films and naostructures having applications in solar cell, spintronics, and nanophotonics.

MBE – VTSTM

The ultra clean surfaces are achieved at a vacuum condition better than 1x10-10 mbar



pressures (ultra high vacuum, UHV conditions) and appropriate cleaning of surfaces. The Molecular Beam Epitaxy (MBE) – Variable Temperature Scanning Tunneling Microscope (VTSTM) system is a custom designed unit procured from M/S Omicron GmBH, Germany. The facility consists of three Knudsen cells, one e-beam evaporation source, sample manipulator with direct and resistive heating attachments, computer controlled Reflection High Energy Electron Diffraction (RHEED) on-line analysis tool, quartz crystal thickness monitor, Residual Gas Analyzer (RGA), in-situ VTSTM through UHV transfer rods. The facility is being used to study ultra clean surfaces reconstructions on Si(100), Si(110), Si(553) and Si(557) systems, Ge, Au and Ag quantum dots deposited epitaxially on clean silicon surfaces, and epitaxially grown thin films. *In-situ* STM is used to study the atomic and electronic structure of the nanostructures and surface reconstructions. On-line RHEED is used to study the real time growth of epitaxial films

STRUCTURAL PROPERTY MEASURE-MENT FACILITIES

High Resolution X-ray Diffractometer (HRXRD)

High Resolution X-Ray defractometer (D8 Discover) can operate in grazing as well as powder XRD mode. The HRXRD system has flexibility with possible combinations of the x-ray source, optics, sample stages, and the detectors. The system consists of goniometer, short tracks, vertical, 150 mm, 3 kW X-Ray generator, grazing incidence attachment for thin film analysis with parallel beam mirror for better data quality, push plug Göbel Mirror, Cu radiation source with a set of slits for Goebel Mirror, flat LiFmonochromator and set of plug-in slits, Ni filter for Cu radiation, standard sample stage diffracted slit assembly including 2.5° Soller, dynamic scintillation detector, NaI and ICDD data base for phase identification. The diffractometer has the ability to perform a full range of applications for qualitative and

quantitative phase identification, crystal structure identification of different samples, X-ray reflectivities crystallite size determination, strain analysis and preferred orientation for established structures. In addition, we have another XRD Setup (D8, Advance), which is also in operation.

XRR and XSW

The X-ray reflectivity and X-ray standing wave measurements are being carried out using indigenously built facility that consists of an 18.0 kW rotating anode (Mo) X-ray source from M/S Rikagu Co. (Japan), a silicon single crystal based monochromator, a 4-circle Huber goniometer for sample mounting and manipulation, two types of detectors (NaI and Si(Li)), a stand alone MCA and associated nuclear electronics for counting and motor controls. The data acquisition and control is done with a computer which uses few add-on cards for the purposes with control software program under Linux operating system.

X-ray reflectivity measurements are being use to study the roughness (with sub-angstrom resolution) at the surface and interfaces and depth profiling (electron densities) many systems such as multilayers, LB films, Polymers, and thin films deposited under various conditions like e-beam evaporation, MBE deposition and spin coating methods. In X-ray standing wave method, standing waves are generated in multilayers (due to long period nature in self assembled monolayers and multilayer systems) and used to determine the atomic position across the surface and interfaces, such as Pt distribution in Pt/C multilayers.

This facility is also used as high resolution XRD to study strain profile across the interfaces in thin film structures and in epitaxially grown films.

MAGNETIC PROPERTY MEASUREMENT FACILITY

SQUID - VSM

The SQUID-VSM lab consists of the Quantum Design MPMS SQUID-VSM

EVERCOOL system. The magnetic property measurement system(MPMS) is a family of analytical instruments configured to study the magnetic properties of samples over a broad range of temperatures and magnetic fields. Extremely sensitive magnetic measurements are performed with superconducting pickup coils and a Superconducting Quantum Interference Device(SQUID). To optimize speed and sensitivity, the MPMS SQUID VSM utilizes some analytic techniques employed by vibrating sample magnetometers (VSMs). Specifically, the sample is vibrated at a known frequency and phase sensitive detection is employed for rapid data collection and spurious signal rejection. The size of the signal produced by a sample is not dependent on the frequency of vibration, but only on the magnetic moment of the sample, the vibration amplitude and the design of the SQUID detection circuit. The MPMS SQUID VSM utilizes a superconducting magnet (a solenoid of superconducting wire) to subject samples to magnetic fields upto 7 Tesla (70 KOe). The squid and magnet is cooled with the help of liquid Helium. Liquid Helium is also used to cool the sample chamber, providing temperature control of samples from 400K down to 1.8K. The SQUID VSM can be used to basically perform M-T,M-H and ac susceptibility measurements at a magnetic field ranging upto 7T and temperature ranging from 4K to 400K.

OPTICAL PROPERTY MEASUREMENT FACILITY

Facility for Investigation of Photo-luminescence and Raman Spectroscopic Properties :

CMPF system was installed in May 2014 and is equipped with water cooled Argon laser. The

Micro Raman facility is operated in backscattering geometry. Confocal mapping capabilities with sub-micron spatial resolution are possible. A wide range of excitation wavelengths, using laser, is possible allowing control of the penetration depth into the material, and thus, control of the volume sampled. By combining these techniques it is possible to characterize both the vibrational and electronic properties of materials. The system will be utilized to understand the properties of many semiconductor systems including oxide semiconductors. Our group, in general, is involved in investigating the electronic structure as well as physical, optical, magnetic and chemical properties of surfaces, thin films and nanostructures, grown by a variety of techniques involving Ion sputtering, thermal deposition, vapor deposition. The interaction of DNA and polymers with surfaces and nanostructures is also being actively pursued in the group. Oxide semiconductors are energy storage materials displaying excellent UV and Visible light absorption properties when suitably patterned with nanostructures. Interaction of DNA with

oxide surfaces can demonstrate many exciting properties which have technological implications for sensors and bio- implants. Our group has shown that DNA can also act as a tiny sensor of Mercury. These systems will be investigated for their vibrational properties.

7.2 COMPUTER CENTRE

The computer facility of the Institute is dedicated towards providing its services in two categories: Scientific computation and In-House IT facilities. It holds the responsibility of managing IT infrastructure in various sections of the Institute. The centres activity ranges from Server administration, hosting various services to laptop/desktop and user support. The Centre extends its supports in a hybrid environment consisting of various operating systems such as Unix-based (Cent OS, Redhat, Fedora, Ubuntu), MS Windows and MAC OS.Our Data centre activitieshas a state-of-art mechanism to handle system administration which includes mail services, centralized storage solution with backup facility and in-House development of web and intranet and gigabit network connectivity.In order to accomplish our Data centre activities, we have installed high end servers, core, distribution, access layer network switches, Firewall (UTM) and load balancer.On computational front, 3 (three) clusters are hosted and maintained by the centre.

The centre manages over 200 Desktops, Laptops, Software and License (Mathematica, Matlab, Originetc), Closed Circuit Television (CCTV) based surveillance systems installed at several offices and laboratories.A number of heavy duty printers are installed at different locations of academic building for general printing over LAN using terminal and through Web using online printing facility. Institute has Polycom setup for meeting its video conferencing requirements.

Institute has leased line Internet connectivity from two Internet Service Providers (ISPs) of 128 Mbps each and1Gbpsnetwork connectivity by National Knowledge Network (NKN). The Institute operates over its own IP addresses from Indian Registry for Internet Names and Numbers (IRINN).Wireless network is available across all the buildings in campus. Internet facility is extended to residence area through Asynchronous Data Subscriber Line (ADSL).

The administrative work, such as accounting, personnel management, stores management has been computerized. Several software packages such as MSOffice, Wings 200 Net, Tally and multilingual software are in use.

7.3. High Performance Computing Facility: SAMKHYA (संख्या) :

SAMKHYA (संख्या) - High Performance Computing (HPC) Facility at Institute is a hybrid environment which consists Sixty (60) Compute Nodes, two (2) Master Nodes, Four (4) I/O nodes (OSS & MDS) and 50 TB of object storage, QDR Infiniband interconnect and 1 Gbps Local Area Network. The infrastructure is of two (2) precision AC (10 ton of refrigeration each) and uninterrupted supply through three (3) 40KVA & one (1) 60 KVA UPS to facilitate the system. The facility consists of 1440 CPU cores, 40 NVIDIA Tesla K80 cards and 40 Intel Xeon Phi 7120P.

Thisfacility has been rankedin the list of top supercomputers in India by CDAC, Bengaluru(July 2018 report at http://topsc.in).

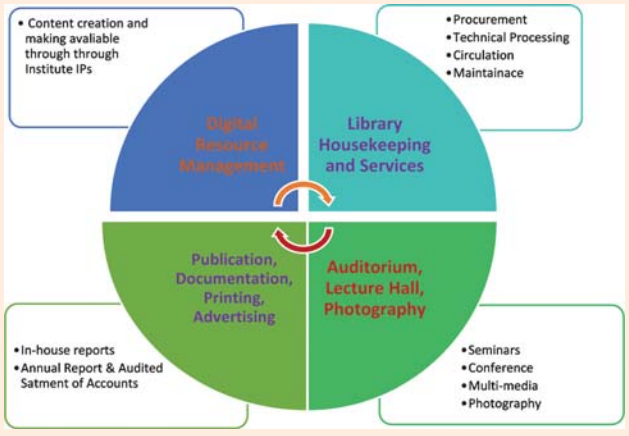
7.4. ANUNET FACILITY

Institute of Physics is a node on ANUNET with the provision to connect other units of DAE directly by VSAT link for voice and data communication. Seismic monitoring equipment has been installed in the Institute and seismic data is being continuously transmitted to Bhabha Atomic Research Centre (BARC) for analysis using ANUNET.

In addition to members of the Institute, computer facility is also being used by Researchers of several other universities and colleges in Odisha for their academic work.

7.5. LIBRARY

IOP Library broadly has two sections namely IOP Resource Centre and IOP General Library. The mandate of IOP Resource Centre is to select, acquire, process and disseminate both print and electronic/digital scientific & technical resources which meet the information needs of research community of the Institute along with stakeholders of other associated organization in a right time and right possible ways. On the other hand, IOP General Library aims to serve the requirement community and to nurture a campus-wide reading culture and habit.



Apart from the essential Library services, IOP Library also provides allied facilities like reprography, printing, publishing, advertising, photography, videography, document delivery, and auditorium with lecture hall services. Apart from these, other related activities like conducting conferences/ seminars, outreach programs are also being taken care of by IOP Library.

The Library facility is available to the members of the Institute as well as members from other academic institutions. The detailed holdings of the Library can be accessible from Library Portal @ http://www.iopb.res.in/~library/ebooks.php.

The Library facility is available to the members of the Institute as well as members from other academic institutions. The Library holdings include 16,684 books, 6000+ e-books,and 23,643 bound Journals. The Library subscribes to 135 Journals, 30 Magazines and 13 number of Newspapers. The Library has also acquired IOP (UK), John Wiley, Springer Physics and Astronomy, Scientific American, World Scientific, Annual Reviews Archives (OJA) perpetualaccess right to the back files containing all articles published since Volume 1 in electronic format. Library also subscribed two e-Books on Lecture Notes in Mathematics and Physics series from Volume1 with perpetual access right to back files,and full archives are containing all articles published up to 2017.Besides this, Library is a part of the Department of Atomic Energy (DAE) Consortium with Elsevier Science, getting access to 2000+ journals with access from 1995 onwards electronically.

Library subscribes the iThenticate (Anti-Plagiarism Web Tool) for assuring Academic Integrity of the Institute and accessible over

Institute IP ranges through library portal at:http://www.iopb.res.in/~library/plagiarism.php. Library also subscribes"Grammarly Tool" (a proprietary research writing software and citationaudit tool delivered on Cloud as a software service by Grammarly Inc., USA). Apart from the Academic [*research papers/thesis/case study/reviewetc.*], this tool can also be used for Official/Business/Technical notingand drafting for checking Grammar, Punctuation, Sentence Structure, Style and many more. The toolcanbe accessedthrough the library portal at:https://www.iopb.res.in/~library/grammerly.php.

The Library assists users in obtaining articles from other Libraries in the country under the resource sharing programme. The Library also sends out articles as Digital Inter-Library Loan (*dill@iopb.res.in*) on request for academic purposes. Currently, though the Library is automated with Libsys4 software, it is in the process to migrate to RFID based Smart Library Solution through KOHA Library Management System (LMS) which is a fully integrated multi-user package with powerful search and query facilities. It supports activities like Acquisition, Cataloguing, Circulation, Serial Control etc. Searching for books and Journals can also be performed using the WEB-OPAC in Library website (http://10.0.1.72:8080/jopacv11/html/SearchForm).

The Library is housed in a centrally air-conditioned building which is open round the clock for the convenience of the users. Library also provides reprographic services and handles the publication, printing and advertisement division of Institute.In order to spread the awareness among the Scientists and Research Community of IOP for the smooth functioning and proper utilization of all e-resources/technology-enabled services, training-cum-demo sessions are also beingorganized in the perodic interval. A one-day National Seminar on "Open Education and Scholarly Communication: Expanding National Digital Library Footprints"

along with "Librarian's Day Celebration" was also organized in 2017-18.

7.6 AUDITORIUM :

We have an auditorium in our campus where we organize Colloquiums, Seminars, Workshops, Conferences, Cultural activities, Social programs regularly. This auditorium can easily accomodate 330 people. It has all the high-quality amenities to organize above mentioned events.

PERSONNEL

8.1	Faculty Members	:	159
8.2	National Post-Doctoral Fellows (NPDF)	:	160
8.3	Post-Doctoral Fellows	:	160
8.4	Research Associate	:	160
8.5	Doctoral Scholars	:	160
8.6	Administration Personnel	:	161
8.7	Retired Members	:	162

PERSONNEL

8.1. Faculty Members

1. **Prof. Sudhakar Panda**
   Director and Sr. Professor
   Theoretical High Energy Physics
2. **Prof. Arun M. Jayannavar**
   Sr. Professor
   Condensed Matter Physics (Theory)
3. **Prof. S. M. Bhattacharjee**
   Sr. Professor
   Condensed Matter Physics (Theory)
4. **Prof. Ajit M. Srivastava**
   Professor
   High Energy Physics (Theory)
5. **Prof. Shikha Varma**
   Professor
   Condensed Matter Physics (Experiment)
6. **Prof. Pankaj Agrawal**
   Professor
   High Energy Physics (Theory)
7. **Prof. Biju Raja Sekhar**
   Professor
   Condensed Matter Physics (Experiment)
8. **Prof. P. V. Satyam**
   Professor
   Condensed Matter Physics (Experiment)
9. **Prof. Snehadri B. Ota** *(up to 03.08.2017)*
   Reader - F
   Condensed Matter Physics (Experiment)
10. **Prof. Sudipta Mukherji**
    Professor
    High Energy Physics (Theory)
11. **Prof. Suresh K. Patra**
    Professor
    Nuclear Physics (Theory)
12. **Prof. Tapobrata Som**
    Professor
    Condensed Matter Physics (Experiment)
13. **Prof. Goutam Tripathy**
    Reader-F
    Condensed Matter Physics (Theory)
14. **Prof. Pradip Kumar Sahu**
    Associate Professor
    Nuclear Physics (Theory)
15. **Prof. Dinesh Topwal**
    Reader - F
    Condensed Matter Physics (Experiment)
16. **Prof. Amitabh Virmani**
    Reader - F
    High Energy Physics (Theory)
17. **Prof. Sanjib Kumar Agarwalla**
    Reader - F
    High Energy Physics (Theory)
18. **Prof. Arijit Saha**
    Reader - F
    Condensed Matter Physics (Theory)
19. **Prof. Saptarshi Mandal**
    Reader - F
    Condensed Matter Physics (Theory)
20. **Prof. Satyaprakash Sahoo**
    Reader - F
    Condensed Matter Physics (Experiment)

21. **Prof. Aruna Kumar Nayak**
    Reader-F
    High Energy Physics (Experiment)
22. **Prof. Debashis Chaudhuri**
    Reader - F
    Condensed Matter Physics (Theory)
23. **Prof. Shamik Banerjee**
    Reader - F
    High Energy Physics (Theory)
24. **Prof. Debakanta Samal**
    Reader - F
    Condensed Matter Physics (Experiment)
25. **Prof. Debottam Das**
    Reader - F
    High Energy Physics (Theory)
26. **Prof. M. M. Mitra**
    Reader - F
    High Energy Physics (Theory)
27. **Prof. Kirtiman Ghosh**
    Reader - F
    High Energy Physics (Theory)

8.2. Post-Doctoral Fellows

1. Paramita Dutta*(Joined on 1st August, 2016 under Prof. A. M. Jayannavar)*
2. Shidharth S. Ram *(Joined on 4th April, 2017 under Prof. P. V. Satyam)*
3. Ravi K. Bomali*(Joined on 1st July, 2017 under Dr. D. Topwal)*

8.3. Post-Doctoral Fellows

1. Dr. Subhajit Sarkar
2. Dr. Sk. Firoz Islam
3. Dr. Sangram Keshari Das
4. Dr. Shakti Shankar Acharya
5. Dr. Chaitra S. Hegde
6. Dr. Bhaskara Chandra Behera
7. Dr. Mruganka Mouli Mandal
8. Dr. Soumya C
9. Dr. Tapoja Jha
10. Dr. Minati Biswal
11. Arnab Dasgupta
12. T. Arun
13. Maguni Mahakhud
14. Ravi Kumar Bomali
15. Md. Younus
16. Shidharth Shankar Ram
17. M. Muneeswaran
18. S. Bhattacharjee
19. Haripriya Rath

8.4. Research Associate

1. Subhashis Rana
2. Tanmoy Pal
3. Anjan Bhukta
4. Arnab Ghosh
5. Himanshu Lohani
6. Mohit Kumar
7. Priyo Shankar Pal
8. Sabya Sachi Chatterjee
9. Shreyansh Shankar Dave

8.5. Doctoral Scholars

1. Shailik Ram Joshi
3. Subhadip Ghosh
5. Arpan Das
6. Soumyabrata Chatterjee
8. Subrata Kumar Biswal
9. Bidisha Chakrabarty
10. Puspendu Guha
12. Shreyansh Shankar Dave
14. Sudipta Mahana

15. Arpan Das *(Junior)*
26. Ashis Kumar Manna
17. Bharat Kumar
18. Chandan Datta
19. Debashis Saha
20. Mahesh Saini
21. Paramita Maiti
22. Pronoy Nandi
23. Ranveer Singh
24. Amit Kumar
25. Biswajit Das
26. Ganesh Chandra Paul
27. Partha Paul
28. Pratik Roy
29. Sujay Shil
30. Vijigiri Vikas
31. Alapan Dutta
32. Atanu Maity
33. Amir Shee
34. Dibyendu Rana
35. Dilruba Hasina
36. Mukaddar Sk.
37. Amina Katun (INO Proj. Student)

8.6. ADMINISTRATIVE PERSONNEL

Shri R. K. Rath, Registrar

(i) Director's Office:

1. Sk Kefaytulla*(up to 31st March, 2018)*
2. Rajesh Mohapatra
3. Lipika Sahoo
3. Rajan Biswal
5. Sudhakar Pradhan

(ii) Registrar's Office

1. Bira Kishore Mishra
2. Abhimanyu Behera

(iii) Establishment

1. M.V. Vanjeeswaran
2. Bhagaban Behera
3. Baula Tudu
4. Samarendra Das
5. Abhisek Maharik
6. Ghanashyam Pradhan
7. Gokuli Charan Dash

(iv) Stores & Transport

1. Pramod Kumar Senapati
2. Sadananda Pradhan
3. Sanatan Jena
4. Sarat Chandra Pradhan
5. Jahangir Khan
6. Keshaba Chandra Dakua

(v) EPABX

1. Arakhita Sahoo
2. Ghanashyam Naik

(vi) Despatch

1. Krushna Chandra Sahoo

(viii) Accounts

1. Ranjan Kumar Nayak
2. Pravat Kumar Bal *(up to 21st May, 2017)*
3. Jitendra Kumar Mishra
4. Bhaskara Mishra
5. Prativa Choudhury
6. Sahadev Jena
7. Soubhagya Laxmi Das
8. Aviram Sahoo
9. Priyabrata Patra
10. Raj Kumar Sahoo
11. Jyoti Ranjan Behera
12. Chandramani Naik
13. Bansidhar Panigrahi

(ix) Maintenance

1. Arun Kanta Dash
2. Debaraj Bhuyan
3. Bansidhar Behera
4. Brundaban Mohanty
5. Deba Prasad Nanda
6. Rama C. Murmu*(up to 31th March., 2018)*
7. Naba Kishore Jhankar
8. Purna Ch. Maharana
9. Sajendra Muduli
10. Pabani Bastia
11. Rabi Narayan Mishra
12. Umesh Ch. Pradhan
13. Gandharba Behera
14. Biswa Ranjan Behera
15. Kapila Pradhan
16. Martin Pradhan
17. Chandra Mohan Hansdah

(x) Estate Management

1. Saroj Kumar Jena.
2. Gangadhar Hembram
3. Tikan Kumar Parida
4. Banamali Pradhan
5. Biswanath Swain
6. Bijoy Kumar Swain
7. Bijoya Kumar Das
8. Babuli Naik
9. Meena Dei *(up to 31st May, 2017)*
11. Sanatan Pradhan
12. Bhaskara Mallick
13. Kulamani Ojha
14. Pitabas Barik
15. Dhoba Naik
16. Charan Bhoi
17. Jatindra Nath Bastia
18. Basanta Kumar Naik
19. Daitari Das
20. Ramesh Kumar Patnaik

(xi) Library

1. Basudev Mohanty *(From 1st Dec, 2016)*
2. Dillip Kumar Chakraborty
3. Ajita Kumari Kujur
4. Rama Chandra Hansdah
5. Rabaneswar Naik
6. Kisan Kumar Sahoo
7. Kailash Chandra Jena
8. Pradip Kumar Naik

(xii) Computer Centre

1. Makrond Siddhabhatti
2. Nageswari Majhi

(xiii) Laboratory

1. Sanjib Kumar Sahu
2. Anup Kumar Behera
3. Sachindra Nath Sarangi
4. Khirod Chandra Patra
5. Madhusudan Majhi
6. Ramarani Dash
7. Santosh Kumar Choudhury
8. Biswajit Mallick
9. Pratap Kumar Biswal
10. Bala Krushna Dash
11. Soumya Ranjan Mohanty
12. Purna Chandra Marandi
13. Srikanta Mishra
14. Ranjan Kumar Sahoo

(xiv) Workshop

1. Subhabrata Tripathy
2. Ramakanta Nayak
3. Rabi Narayan Naik

8.7 List of Retired Members

Name: Shri Pravat Kumar Bal
Designation: Accounts Officer
DoJ: 04.06.1982
DoR: 31.05.2017

Name: Smt. Meena Dei
Designation: MTS/B
DoJ: 25.11.1992
DoR: 31.05.2017

Name: Dr. Snehadri Bihari Ota
Designation: Reader – F
DoJ: 31.07.1992
DoR: 03.08.2017

Name: Shri Atul Mishra
Designation: Health Physist (RSO)
DoJ: 19.08.2016
Do Relieve: 09.05.2017

Name: Sk. Kefaytulla
Designation: Admn. Officer (Academic)
DoJ: 05.06.1981
DoR: 31.03.2018

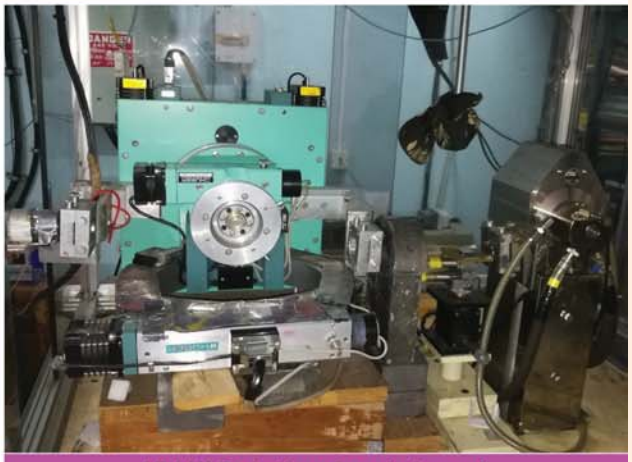
Name: Shri Rama Chandra Murmu
Designation: Tradesman-E
DoJ: 11.01.1996
DoR: 31.03.2018

MAJOR INSTRUMENTS DISPLAYED DURING 44TH FOUNDATION DAY

44th FOUNDATION DAY — 4th September 2018

3.0 MV Tandem Pelletron Accelerator 1991 - 1992

The Ion Beam laboratory of IOP consists of a NEC model 9SDH-2 tandem pelletron accelerator that can deliver positive ion beams in the energy range of 1-12MeV.

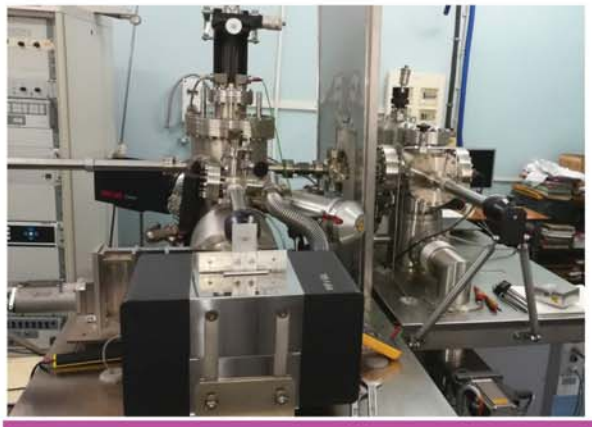


18 kW Rotating Anode based X-ray Reflectometry and X-ray Standing wave facility 1993

The powerful, high-frequency 18 kW X-ray generator designed for flexibility, high stability and low maintenance operation.

Transmission Electron Microscope 2000

TEM, is a microscopy technique in which a beam of electrons is transmitted through a specimen to form an image.



Molecular Beam Epitaxy (MBE) 2001

Molecular-beam epitaxy (MBE) is an epitaxy method for thin-film deposition of single crystals.

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Mr. Makrand Siddhabhatti, Systems Manager, Computer Centre

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X-Ray photoelectron Spectroscopy
2001

XPS is a surface-sensitive quantitative spectroscopic technique that measures the elemental composition at the parts per thousand range, empirical formula, chemical state and electronic state of the elements that exist within a material.

UV-VIS-NIR Spectrophotometer
2002

UV-Vis-NIR spectrometer is a powerful tool for optical characterization of thin film solar cells mainly.

Angle – Resolved UPS
2005

Angle-Resolved UPS facility maps the dispersion of electronic bands near the Fermi level and, in particular, the Fermi surface itself by exciting the bound electrons in a metal with a given photon energy hv.

Grazing Angle X-ray Diffractometer (GAXRD), Powder Diffractometer
2007

GIXD uses small incident angles from a crystalline structure for the incoming X-ray or neutron beam to make diffraction surface sensitive.

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Low Energy Broad Beam Ion Source
2008

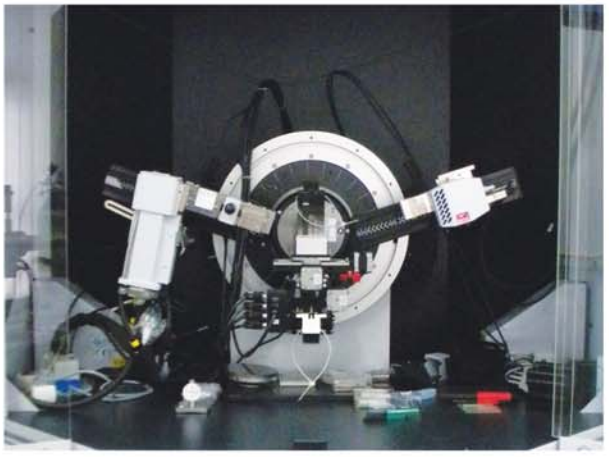
IBS is a very promising and cost-effective bottom-up technique for fabricating self-organized nanoscale periodic patterns over a large-area (up to 2- to 3-inch diameter) in a single step.

SQUID–VSM based MPMS System
2009

SQUID magnetometer is one of the most effective and sensitive ways of measuring magnetic properties which allows to directly determine the overall magnetic moment of a sample in absolute units.

Atomic Force Microscope
2009

AFM is a type of scanning probe microscopy (SPM), with demonstrated resolution on the order of fractions of a nanometer, more than 1000 times better than the optical diffraction limit.



High-resolution XRD system with reciprocal space mapping
2010

This is a versatile high resolution X-ray diffractometer that use a Cu anode as the X-ray source and is equipped with Gobel mirror in the x-ray optical path for production of monochromatic high intensity Cu K_{α} x-ray beam with less than 0.05° divergence.

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Focused Ion Beam (FIB)
2010

FIB is a microscopy technique in which a beam of gallium ions can be used to destructively remove material through a process known as sputtering.

Pulsed Laser Deposition unit
2010

PLD is a physical vapor deposition (PVD) technique where a high-power pulsed laser beam is focused inside a vacuum chamber to strike a target of the material that is to be deposited.

Surface Profilometer
2010

Surface profilometer measures roughness, waviness, and step height in a variety of applications. It works on deflection height measurement mechanism and magneto static force control system.

Electron Cyclotron Resonance (ECR) ion source
2011

ECR ion source is widely used for the production of high quality multiply charged ion beams for accelerator based materials research, atomic physics research and industrial applications.

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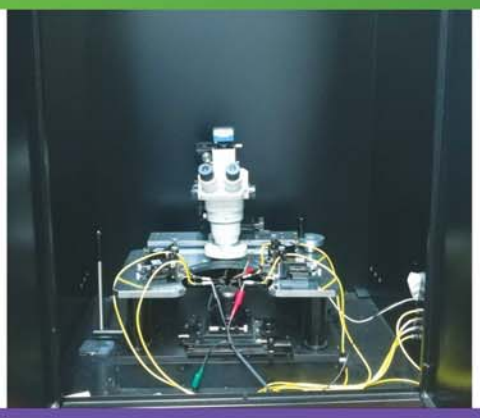
Physical Property Measurement System (PPMS)
2012

The PPMS is an automated low-temperature and magnet system for the measurement of material properties like specific heat, magnetic AC and DC susceptibility and both electrical and thermal transport properties.



Probe Station for Electrical transport Measurement
2012

A platform for measurement of electrical characteristics with help of Semiconductor Parameter Analyzer.

Field Emission Set up
2012

Field emission (FE) is emission of electrons induced by an electrostatic field.

Micro-Raman System
2015

Raman spectroscopy is a spectroscopic technique used to observe vibrational, rotational, and other low-frequency modes in a system.

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Environmental SEM 2015

ESEM allows collecting electron micrographs of specimens that are "wet," uncoated, or both by allowing for a gaseous environment in the specimen chamber.

Liquid Nitrogen Plant

The main purpose of a liquid nitrogen plant is to provide us with high purity gaseous nitrogen.

CNC Setup

CNC setup is the automated control of machining tools (drills, boring tools, lathes) by means of a computer, in which the machine operates on a piece of material to transform it to precise specifications.

EDS

EDS is an analytical technique used for the elemental analysis or chemical characterization of a sample.

COMPILED AND DESIGNED BY:

Mr. Makrand Siddhabhatti, Systems Manager, Computer Centre

परीक्षित लेखा विवरण

AUDITED STATEMENT OF ACCOUNTS
2017-18

भौतिकी संस्थान
INSTITUTE OF PHYSICS
भुवनेश्वर, ओडिशा
BHUBANESWAR, ODISHA

पार्थ एस. मिश्र एंड कंपनी/PARTHA S MISHRA & CO.
सनदी लेखाकारों / CHARTERED ACCOUNTANTS
जीए-140, निलाद्री विहार / GA-140, NILADRI VIHAR
भुवनेश्वर / BHUBANESWAR – 751 021
मोबाइल / MOBILE: 8637260078

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PARTHA S MISHRA & CO
Chartered Accountant

INDEPENDENT AUDITORS' REPORT

To,

The Director
The Institute of Physics
Bhubaneswar

We have audited the accompanying financial statements of **INSTITUTE OF PHYSICS** which comprises the Balance Sheet as at 31st march 2018 and the Statement of Income and Expenditure and Statement of receipt and Payments for the year ended as on that date.

Management's Responsibility for the Financial Statements

Management is responsible for the preparation of these financial Statements that give a true and fair view of the financial position, financial performance of the Institute in accordance with the applicable

Accounting Standards and Societies Registration Act 1860. This responsibility includes the design, implementation and maintenance of the internal control relevant to the preparation of the financial statements that are free from material misstatement, whether due to fraud or error.

Auditor's Responsibility

Our responsibility is to express an opinion on these financial statements based on our audit. We conducted our audit in accordance with the standards on Auditing issued by the Institute of Chartered Accountants of India. Those Standards require that we comply with ethical requirements and plan and perform the audit to obtain reasonable assurance about whether the financial statements are free from material misstatement.

Contd.....P/2

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

Plot No. GA-140, Ground Floor, Niladri Vihar, Bhubaneswar-751021, Ph. : 0674-2720247, Mob. :+91-9437044824 / 9776044824, 9439880419
E-mail : parthamishra1@yahoo.com / psmefiling@gmail.com / psm_caoff@rediffmail.com

An audit involves performing producing procedures to obtain audit evidence about the amounts and disclosures in the financial statements. The procedure selected depend on the auditor's judgment, including the assessment of the risk of material misstatement of the financial statements, whether due to fraud or error. In making those risk assessments , the auditors considers internal controls relevant to the Entity's preparation and fair representation of the financial statements in order to design audit procedures that are appropriate in the circumstances. An audit also includes evaluating the appropriateness of accounting polices used and the reasonableness of the accounting estimates made by the management, as well as evaluating the overall presentation of the financial statements.

We believe that the audit evidence we have obtained is sufficient and appropriate to provide a basis for our audit opinion

Qualified Opinion

Basis of qualification:

1. IAS 10 regarding to fixed assets and As6 for depreciation have not been followed. There was no fixed asset register to verify the Individual asset residual value. Depreciation has been charged on gross block at the end of the year on SLM method irrespective of the fact that individual old assets may have been depreciated in full. E- Journals have been capitalized as tangible assets and depreciated for the whole year. E- Journals are paid in calendar yearly basis but the whole years E-journals have been capitalized thus contravening the provisions of the AS10 and AS-6. The depreciation on assets purchased during the year was also charges for the whole year instead of proportionate basis from date to use.

Contd.....P/3

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

The interest from STDR given against Letter of credit should not be deducted from the cost of fixed Assets but should be shown as "Income from Other Sources".

2. IAS 12 on Accounting of Government grants has not been followed. The grants have been recognized on realization basis. Capital grants are recognized as capital fund and shown as Liability.

Matter of emphasis:

Attention of the management is also drawn on the following matters:

1. The lease deed for 50 acres of land at Mouza Nayapalli is not available. However, the copy of the land allotment letter and possession letter ware available in the file. Lease records in respect of 6.130 acres was available. The ROR shows that the 47.32 Acre land belongs to Education Department, Govt. of Odisha. So Institute of physics must take necessary steps to mutate the schedule land in its favor.
2. Balances of advances and liabilities recognized from third Parties are subjects to confirmation.

We are not qualifying our report on the above points.

Based on the above, in our opinion and to the best of our information and according to the explanations given to us, the financial statements read with the Accounting policies and notes on accounts and the separate report as annexed herewith the report, give the information required by the Act in the manner so required and give a true and Fairview in conformity with the accounting principles generally accepted in India.

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

Contd.....P/4

a. In the case of Balance sheet of the state of affairs of the Institute AS AT March 31, 2018
b. In the case of the statement of income and expenditure, of the deficit of the Institute for the year ended on that date.
c. In case of statement of Receipt and Payments, the receipts and payments for the year ended on that date.

Report on legal and Regulatory Requirements

a. We have obtained all the information and explanations which to the best of our knowledge and belief, were necessary for the purpose of our audit and have found them to be satisfactory.
b. In our opinion proper books of account as required by law have been kept by the Institute, So far as appears from our examination of those books.
c. The Balance sheet, Statement of Income and Expenditure & Receipts & Payment Statement dealt with by this report are in agreement with the books of accounts.

For PARTHA S. MISHRA & CO.
Chartered Accountants
Sanjaya kumar Patra
CA S.K. Patra (FCA, DISA)
Partner, M. No-301929

DATE:- 11/09/2018

BHUBANESWAR

INSTITUTE OF PHYSICS
BHUBANESWAR

ANNEXURE TO THE AUDIT REPORT (REFERED TO IN OUR REPORT ON EVEN DATE)

AUDIT OBSERVATIONS ON THE ACCOUNTS OF INSTITUTE OF PHYSICS FOR THE FIANCIAL YEAR 2017-18

1) Maintenance of books of accounts:

The following manual books of accounts are maintained in the year 2017-18

a) Cash cum bank book

b) Cheque issue register

c) Staff advance register

d) Security deposit register

e) TDS register

2) Cash and bank:

a) In some cases the institute has paid cash above Rs. 10000 to visiting scientists/ Employees. Instances are given at Annexure-1

b) The institute has operated 27 nos. of bank accounts. All banks have been reconciled. Our observation on BRS is given in Annexure -2.

3) Others:

a) Advances to staff unadjusted for more than 3 months were found in the following cases. The same should be adjusted /recovered at an earliest.

Date	Name	Purpose	Amount(Rs.)
09/05/2016	Tabobrata Som	Purchase Advance	5,000.00
02/03/2017	Dinesh Topwal	Lab. Maintenance	5,000.00
14/11/2017	Dinesh Topwal	Spin Structure	23,347.00
31/01/2018	Alumni Asso.	Science outreach	14,790.00
13/02/2018	Suresh Ku. Patra	JEST	1,10,000.00

b) Also there are some LTC advances pending as on 31.03.2018 for more than one (1) month as stipulated by IOP guideline. Some of such instances are given below.

Sl.	Name	Date of Advance	Amount	Period of journey	Date of Adjustment
1	P K Biswal	15.02.2018	15,400.00	01/05/18 to 07/05/18	13/08/2018
2	G S Nayak	19.03.2018	24,300.00	12/03/18 to 23/03/18	21/05/2018
3	B N Swain	19.03.2018	24,300.00	12/03/18 to 23/03/18	23/05/2018
4	R N Mishra	19.03.2018	19,000.00	12/03/18 to 23/03/18	22/05/2018
5	T Parida	19.03.2018	6,300.00	12/03/18 to 23/03/18	11/06/2018

c) Some amounts are recovered from various parties on various dates towards GST. However, IOP is not liable to deduct any such amount from any person. Hence the same should be refunded as soon as possible.

For PARTHA S. MISHRA & CO.
Chartered Accountants
Sanjaya kumar Patra
CA S.K. Patra (FCA, DISA)
Partner, M. No-301929

DATE:-07/09/2018

BHUBANESWAR

Annexure 1

Cash Payments Exceeding Rs 10,000

Sl.No.	V. No./ date	Description	Amount
1	472/03.07.17	Honorarium paid to Prof. Ashok Das	70,000.00
2	657/29.07.17	Honorarium paid to Prof. Ashok Das	70,000.00
3	408/23.06.17	Honorarium paid to Prof. Ashok Das	15,000.00
4	2053,2054/ 22.03.2018	Honorarium & TA paid to Sarira Sahoo	22,385.00

Annexure-2

Observation on Bank Reconciliation Statement.

Sl.	Details of Bank	Chequ no/ Date	Amount	Remarks
1	IOB NON PLAN	873917/28.12.2017	3,200.00	Ch. Issued For More Than 3 Months
2	IOB NON PLAN	Neft/13.04.2017	3,225.00	Credit in Bank But Not Shown in Cash Book
3	IOB NON PLAN	NEFT/12.05.2017	10,000.00	
4	IOB NON PLAN	NEFT/07.10.2017	1,000.00	
5	IOB NON PLAN	NEFT/04.11.2017	36,888.00	
6	IOB NON PLAN	NEFT/08.02.2018	20,000.00	
7	IOB NON PLAN	NEFT/12.02.2018	13,500.00	

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

INSTITUTE OF PHYSICS, BHUBANESWAR

BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

CORPUS/ CAPITAL FUND AND LIABILITIES	Schedule	Current Year	Previous Year
CORPUS/ CAPITAL FUND	1	69,71,21,502	67,45,86,852
RESERVES AND SURPLUS	2	-	-
EARMARKED/ ENDOWMENT FUNDS	3	1,14,84,655	61,79,629
SECURED LOANS AND BORROWINGS	4	-	-
UNSECURED LOANS AND BORROWINGS	5	-	-
DEFFERED CREDIT LIABILITIES	6	-	-
CURRENT LIABILITIES AND PROVISIONS	7	17,23,08,774	17,97,42,611
TOTAL		**88,09,14,931**	**86,05,09,092**
ASSETS			
FIXED ASSETS	8	76,98,16,547	74,35,59,573
INVESTMENTS FROM EARMARKED/ ENDOWMENT FUNDS	9	-	-
INVESTMENTS OTHERS	10	-	-
CURRENT ASSETS, LOANS, ADVANCES ETC.	11	11,10,98,384	11,69,49,519
TOTAL		**88,09,14,931**	**86,05,09,092**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

In terms of our report of even date annexed

For PARTHA S. MISHRA & CO.
Chartered Accountants
Sanjaya kumar Patra
CA S.K. Patra (FCA, DISA)
Partner, M. No-301929

Place : Bhubaneswar
Date : 11-09-2018

REGISTRAR
INSTITUTE OF PHYSICS

11/09/18
DIRECTOR
INSTITUTE OF PHYSICS

INSTITUTE OF PHYSICS, BHUBANESWAR

STATEMENT OF INCOME AND EXPENDITURE FOR THE PERIOD/YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

INCOME	Schedule	Current Year	Previous Year
Income from sale or services	12	-	-
Grants/ Subsidies	13	38,96,00,000	37,10,59,000
Fees/ Subscriptions	14	-	-
Income from investments	15	-	-
Income from royalty, Publication etc	16	-	-
Interest Earned	17	3,76,413	32,56,571
Other Income	18	37,37,940	20,64,842
Increase decrease in stock of finised goods/ WIP	19	-	-
TOTAL (A)		**39,37,14,353**	**37,63,80,413**
EXPENDITURE			
Establishment Expenses	20	21,37,68,299	21,37,38,555
Other Administrative Expenses etc.	21	8,16,47,284	8,90,66,559
Expenditure on grants Subsidies etc (Plan grant Surrendered)	22	-	-
Interest Paid	23	-	-
Depreciation (Corresponding to Schedule 8)		11,66,42,121	10,58,20,621
TOTAL (B)		**41,20,57,704**	**40,86,25,735**
Balance being excess of Expenditure over Income (B-A)		(1,83,43,351)	(3,22,45,322)
BALANCE BEING SURPLUS/(DEFICIT) CARRIED TO CORPUS/ CAPITAL FUND		**(1,83,43,351)**	**(3,22,45,322)**
SIGNIFICANT ACCOUNTING POLICIES	24		
CONTINGENT LIABILITIES AND NOTES ON ACCOUNTS	25		

In terms of our report of even date annexed

Place : Bhubaneswar
Date : 11-09-2018

For PARTHA S. MISHRA & CO.
Chartered Accountants
Sangaya Kumar Patra
CA S.K. Patra (FCA, DISA)
Partner, M. No-381929

रजिस्ट्रार/REGISTRAR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

11/09/18
निदेशक/DIRECTOR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 1 - CORPUS/CAPITAL FUND				
Balances as at the beginning of the year		67,45,86,853		70,68,32,174
Add : Contributions towards Corpus/Capital Fund	4,08,78,000		-	
Add/(Deduct) : Balance of Income/(Expenditure) transferred from Income & expenditure Account	(1,83,43,351)	2,25,34,649	(3,22,45,322)	(3,22,45,322)
Balances as at the year end		**69,71,21,502**		**67,45,86,852**

PARTHA S. MISHRA & CO. * Chartered Accountants * FRN 324467E

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भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

	Current Year				
SCHEDULE 3 - EARMARKED/ENDOWMENT FUNDS	OB	Receipt	Payment	CB	Previous Year
1. L. K. Panda Memorial Fellowship	2,05,149	10,243	5,000	2,10,392	2,05,149
2. TPSC Account	6,047	1,02,376	85,586	22,837	6,047
3. Inspire Grant of Dr. S.K.Agarwalla	34,579	6,19,040	2,61,154	3,92,465	34,579
4. Inspire Grant of Dr. Manimala Mitra	8,50,414	26,092	1,39,727	7,36,779	8,50,414
5. NPDF of Dr. S. S. Ram	-	10,44,299	8,65,275	1,79,024	-
6. NPDF of Dr. R. K. Bommali	-	9,64,446	5,46,799	4,17,647	-
7. NPDF of Dr. P. Dutta	5,14,545	5,27,596	9,43,414	98,727	5,14,545
8. JC Bose Grant of Prof. S. Panda	-	19,15,491	3,67,628	15,47,863	-
9. JC Bose Grant of Prof. A. M. Jayannavar	5,93,450	18,470	5,19,670	92,250	5,93,450
10. JC Bose Grant of Prof. S. M. Bhattacharjee	2,83,101	13,10,453	7,22,121	8,71,433	2,83,101
11. Ramanujan Fellowship Grant of Dr. A. K. Nayak	5,27,630	3,19,327	4,31,858	4,15,099	5,27,630
12. INSA Grant of Prof. J. Maharana	4,55,456	1,17,021	4,57,497	1,14,980	4,55,456
13. BI IFCC Grant of Dr. P. K. Sahu	24,60,480	97,114	3,88,611	21,68,983	24,60,480
14. UGC-CSR Grant	2,03,959	7,927	-	2,11,886	2,03,959
15. Woman Scientist Grant of Dr. S. Bandopadhyay	-	12,23,715	10,64,876	1,58,839	-
16. DST Grant of Prof. S. Varma	-	5,02,648	1,10,939	3,91,709	-
17. SERB Grant of Dr. D. Chaudhuri	-	12,37,104	33,041	12,04,063	-
18. Max-Plank Grant of Dr. D. Samal	-	26,97,147	4,94,757	22,02,390	-
19. DRDO Project	24,479	951	-	25,430	24,479
20. Fly Ash Utilisation Programme	4,525	176	-	4,701	4,525
21. CSIR Pool Scientist Programme	6,257	1,031	-	7,288	6,257
22. Indo-Japan S&T Co-operation	9,558	371	59	9,870	9,558
TOTAL:	**61,79,629**	**1,27,43,038**	**74,38,012**	**1,14,84,655**	**61,79,629**

PARTHA S. MISHRA & CO. * FRN 324467E * Chartered Accountants

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भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 7 - CURRENT LIABILITIES AND PROVISIONS:				
A. CURRENT LIABILITIES				
1. Statutory Liabilities:				
NPS Recovery Payable	1,44,449		50,535	
Professional Tax Payable	400		53,225	
TDS Salary Payable	24,80,604		-	
TDS Non-Salary Payable	41,430		1,77,506	
Plan TDS Payable	45,093		-	
GST Recovery Payable	1,11,317		-	
WCT Recovery Payable	89,013		3,44,266	
		29,12,306		6,25,532
2. Other Liabilities:				
Earnest money Deposit	21,61,070		10,82,792	
Caution money from Scholars	10,200		8,600	
GSLI Claim Payable	-		36,746	
Pension Payable	37,30,438		1,31,798	
Project Grant Payable	-		12,46,000	
Provision for Expenses	2,60,92,515		4,01,36,630	
Provident Fund Payable	11,262		-	
SSB Fellowship Payable	15,000		-	
Security Deposit - contractors	14,59,294		22,47,208	
		3,34,79,779		4,48,89,774
TOTAL (A)		**3,63,92,085**		**4,55,15,306**
B. PROVISIONS				
1. Gratuity		6,92,58,198		7,03,06,690
2. Superannuation / Pension		-		-
3. Accumulated Leave Encashment		6,66,58,491		6,39,20,615
4. Others (Specify)		-		-
TOTAL (B)		**13,59,16,689**		**13,42,27,305**
TOTAL (A + B)		**17,23,08,774**		**17,97,42,611**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

रजिस्ट्रार/REGISTRAR
INSTITUTE OF PHYSICS

11/09/18
निदेशक/DIRECTOR
INSTITUTE OF PHYSICS
BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

SCHEDULE 8 - FIXED ASSETS

DESCRIPTION	GROSS BLOCK				DEPRECIATION					NET BLOCK	
	Cost/valuation As at beginning of the year	Additions during the year	Deductions during the year	Cost/valuation at the year-end	As at the beginning of the year	Rate %	For the year	Deductions / Adjustments during the year	Total up to the Year-end	As at the Current year-end	As at the Previous year-end
A. FIXED ASSETS (PLAN):											
1. LAND:											
a) Leasehold	50,00,000	-	-	50,00,000	-		-	-	-	50,00,000	50,00,000
2. BUILDINGS:											
a) On Leasehold Land	20,43,90,885	65,95,494	-	21,09,86,379	4,33,63,379	1.63	34,39,078	-	4,68,02,457	16,41,83,922	16,10,27,506
3. ROADS	65,48,158	-	-	65,48,158	31,97,773	19.00	12,44,150	-	44,41,923	21,06,235	33,50,385
4. PLANT MACHINERY & EQUIPMENT	76,58,21,916	3,85,86,033	-	80,44,07,949	31,95,15,109	5.28	4,24,72,740	-	36,19,87,849	44,24,20,100	44,63,06,807
5. COMPUTER/PERIPHERALS	13,17,49,210	1,25,36,975	-	14,42,86,185	8,89,46,869	16.21	2,33,88,791	-	11,23,35,660	3,19,50,525	4,28,02,341
6. Capital Work in Progress	-	-	-	-	-	-	-	-	-	-	-
TOTAL (A)	**1,11,35,10,169**	**5,77,18,502**	**-**	**1,17,12,28,671**	**45,50,23,130**		**7,05,44,759**	**-**	**52,55,67,889**	**64,56,60,782**	**65,84,87,039**
B. FIXED ASSETS (NON-PLAN)											
1. VEHICLES	26,45,742	5,72,181	3,47,106	28,70,817	20,06,515	9.50	2,72,728	3,47,106	19,32,137	9,38,680	6,39,227
2. FURNITURE, FIXTURES	2,19,04,530	12,06,265	-	2,31,10,795	2,10,94,318	9.50	1,14,595	-	2,12,08,913	19,01,882	8,10,212
3. OFFICE EQUIPMENT	12,61,36,673	25,68,477	-	12,87,05,150	12,23,63,617	9.50	2,44,005	-	12,26,07,622	60,97,528	37,73,056
4. ELECTRIC INSTALLATIONS	79,05,702	4,09,68,800	-	4,88,74,502	54,22,505	6.33	30,93,756	-	85,16,261	4,03,58,241	24,83,197
5. LIBRARY BOOKS	40,61,59,107	3,98,64,870	-	44,60,23,977	32,87,92,265	9.50	4,23,72,278	-	37,11,64,543	7,48,59,434	7,73,66,842
TOTAL (B)	**56,47,51,754**	**8,51,80,593**	**3,47,106**	**64,95,85,241**	**47,96,79,220**		**4,60,97,362**	**3,47,106**	**52,54,29,476**	**12,41,55,765**	**8,50,72,534**
TOTAL OF CURRENT YEAR (A+B)	**1,67,82,61,923**	**14,28,99,095**	**3,47,106**	**1,82,08,13,912**	**93,47,02,350**		**11,66,42,121**	**3,47,106**	**1,05,09,97,365**	**76,98,16,547**	**74,35,59,573**
PREVIOUS YEAR	1,55,61,63,471	12,20,98,452	-	1,67,82,61,923	82,88,81,729		10,58,20,621	-	93,47,02,350	72,72,81,742	72,72,81,742

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

रजिस्ट्रार/REGISTRAR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

11/09/18

निदेशक/DIRECTOR
भौतिकी संस्थान/INSTITUTE OF PHYSICS
भुवनेश्वर/BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 11 - CURRENT ASSETS, LOANS, ADVANCES ETC.				
A. CURRENT ASSETS:				
1. Inventories:				
a) Electrical Fittings Stock	10,82,983		9,43,219	
b) Office Stationery	3,45,949		1,07,514	
c) Computer Stationery	3,65,242		6,92,282	
d) Cleaning Material Stock	23,183		56,306	
e) Diesel Stock	81,349		93,306	
f) Carpentry Material Stock	1,35,774		1,81,279	
g) Workshop Spares	6,34,564		-	
h) PH Material Stock	59,354		1,98,291	
		27,28,398		22,72,197
2. Cash balances in hand (including cheques/ drafts and imprest)		29,588		31,622
3. Bank Balances:				
a) With Scheduled Banks:				
i) In current accounts SBI		59,58,472	2,14,81,712	
b) Savings accounts				2,14,81,712
i) IOB CS Pur (Non-Plan)	1,21,60,145		4,54,03,617	
ii) IOB CS Pur (Plan)	6,52,29,103		1,40,98,177	
iii) UBI CS Pur (Non-Plan)	17,40,808		1,19,274	
iv) UBI CS Pur (Plan)	21,468		47,93,592	
v) Project Bank Account	1,14,84,655		61,79,629	
		9,06,36,179		7,05,94,289
TOTAL (A)		**9,93,52,637**		**9,43,79,820**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF BALANCE SHEET AS AT 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 11 - CURRENT ASSETS, LOANS, ADVANCES ETC. (Contd.)				
B. LOANS, ADVANCES AND OTHER ASSETS				
1. Loans (Interest bearing):				
a) Computer Advance	1,39,200		44,400	
b) Motor Cycle Advance	-		27,250	
c) Motor Car Advance	14,000		26,000	
d) House Buildings Advance	4,000		16,000	
		1,57,200		1,13,650
2. Interest Accrued but not due on Loans				
a) Motor Cycle Advance	4,097		-	
b) House Buildings Advance	67,839		83,798	
c) Computer Advance	8,444		10,919	
		80,380		94,717
3. Loans (Non-Interest bearing):				
a) Staff Advance	1,67,137		16,801	
b) Medical Advance	-		1,68,150	
c) Festival Advance	-		1,13,400	
d) Travel Advance	9,31,700		4,08,230	
		10,98,837		7,06,581
4. Advances and other amounts recoverable in cash or in kind or for value to be received:				
a) On Capital Account	45,44,913		5,57,428	
b) Prepayments	96,584		92,101	
c) Security deposit With CESCO	26,21,944		26,21,944	
d) Franking machine deposit	45,846		24,416	
e) Security Deposit with BSNL	2,000		2,000	
f) Security Deposit for GAS	20,950		20,950	
g) STDR against L/C	30,77,093		1,83,35,912	
		1,04,09,330		2,16,54,751
TOTAL (B)		**1,17,45,747**		**2,25,69,699**
TOTAL (A + B)		**11,10,98,384**		**11,69,49,519**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

REGISTRAR, INSTITUTE OF PHYSICS, BHUBANESWAR

11/09/18

DIRECTOR, INSTITUTE OF PHYSICS, BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 13 - GRANTS/ SUBSIDIES				
1. DAE - Government of India				
a) Non-Plan (Salary)	21,85,00,000		17,35,68,000	
b) Non-Plan (General)	8,11,00,000		9,45,00,000	
c) Plan	9,00,00,000		10,29,91,000	
		38,96,00,000		37,10,59,000
2. Government Of Orissa (Non-Plan Revenue)		-		-
TOTAL		**38,96,00,000**		**37,10,59,000**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 17 - INTEREST EARNED				
1. On Term Deposits:				
a) With Scheduled Banks	-		-	
b) Others (L/C & Security Deposit)	3,57,238		4,10,162	
		3,57,238		4,10,162
2. On Savings Accounts:				
a) With Scheduled Banks		-		28,38,731
3. On Loans:				
a) Computer Advance	9,800		5,425	
b) Motor Cycle Advance	5,894		-	
c) Pending Advance	3,481		2,253	
		19,175		7,678
TOTAL		**3,76,413**		**32,56,571**

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 18 - OTHER INCOME				
1. Miscellaneous Income		15,18,631		8,03,096
2. Sale of Tender paper		3,500		42,750
3. House/Guest House Rent		21,59,708		12,12,296
4. Sale of Assets		-		6,700
5. Profit on Sale of Asset		56,101		-
TOTAL		**37,37,940**		**20,64,842**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 20 - ESTABLISHMENT EXPENSES				
1. Salaries and Wages				
a) Staff Salary	12,17,08,057		10,27,78,108	
b) NPS Contribution	23,00,632		20,53,787	
c) Honorarium	16,37,884		10,86,793	
d) Fellowship	1,67,48,381		1,21,89,075	
e) Temporary Status Employee Salary	1,23,055		1,96,360	
f) Remuneration to Medical Officer	4,20,000		3,80,000	
		14,29,38,009		11,86,84,123
2. Allowances and Bonus				
a) PRIS	96,07,444		1,92,42,160	
b) Update Allowance	22,90,928		12,76,298	
c) Overtime Allowance	31,220		69,151	
d) Night Duty Allowance	31,849		1,22,366	
		1,19,61,441		2,07,09,975
3. Staff Welfare Expenses				
a) Reimbursement of Medical Expenses	44,67,112		34,21,182	
b) Canteen Expense	10,806		78,374	
c) Recreation & Welfare Expenses	8,91,010		15,84,743	
d) Children Education Allowance	13,62,759		9,42,285	
e) Medical Aid Centre Expenses	3,356		-	
		67,35,043		60,26,584
4. Retirement and Terminal Benefits				
a) Leave salary	70,08,732		1,70,38,727	
b) Pension	3,92,74,748		3,28,17,621	
c) Gratuity	43,04,682		1,73,17,589	
		5,05,88,162		6,71,73,937
5. Others				
a) Contigency Grant to Scholars		15,45,644		11,43,936
TOTAL		**21,37,68,299**		**21,37,38,555**

PARTHA S. MISHRA & CO. * FRN 324467E * Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 21 - OTHER ADMINISTRATIVE EXPENSES ETC.				
1. MAINTENANCE - a) Civil	50,24,152		73,41,076	
b) Vehicle	5,98,435		7,06,880	
c) Library	1,03,043		1,38,837	
d) Workshop	5,61,270		1,76,608	
e) Furniture	1,70,272		2,05,407	
f) Electrical	17,15,873		13,55,439	
g) AC Plant	36,24,523		33,59,673	
h) Computer	42,32,043		45,35,296	
i) Laboratory	81,65,867		24,61,556	
j) Garden	1,94,831		1,63,982	
k) Telephone	3,26,765		2,78,077	
l) Office Equipment	2,07,571		2,72,435	
		2,49,24,645		2,09,95,266
2. Electricity and power		2,23,83,066		2,26,56,449
3. Water charges		2,90,993		2,77,789
4. Conference & Symposia		6,00,282		2,86,839
5. Science Outreach Activities		6,49,423		2,97,139
6. Postage & Telegram		1,50,136		1,48,320
7. Telephone & Telex		19,56,622		4,52,317
8. Printing and Stationery		8,57,928		5,54,614
9. Travelling Expenses - a) Conference TA	8,77,515		5,65,242	
b) Foreign Travel	5,52,216		6,03,560	
c) Visiting scientist TA	5,79,259		3,66,263	
d) Domestic Travel	16,74,066		11,45,591	
e) Leave Travel concession	7,80,993		6,05,668	
f) Hire Charge	24,064		6,638	
		44,88,113		32,92,962
SUB-TOTAL (A)		**5,63,01,208**		**4,89,61,695**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF INCOME & EXPENDITURE FOR THE YEAR ENDED 31ST MARCH 2018

(Amount - Rs.)

	Current Year		Previous Year	
SCHEDULE 21 - OTHER ADMINISTRATIVE EXPENSES Contd....				
10. Auditors Remuneration		59,000		59,000
11. Entertainment Expenses		3,49,392		4,25,684
12. Security Charges		83,90,886		85,74,915
13. Professional Charges		6,93,875		2,19,690
14. Project Revenue Expenses				
a) ALICE Utilisation and CBM Participation	27,44,509		26,76,431	
b) Development of Computing and Network Facilities	22,28,718		61,71,803	
c) Development of Research in HEP	-		31,93,975	
d) Development of Research in NP	-		18,36,010	
e) Strengthening Low Energy Accelerator	3,78,256		14,14,450	
f) Study of Growth and Characterisation	2,941		42,49,544	
g) Theoretical CM and QI	-		31,84,368	
h) Investigating Spin Structure	1,63,525		-	
i) Infrastructure and Housing	67,07,735		74,44,049	
		1,22,25,684		3,01,70,630
15. Advertisement and Publicity		5,35,773		4,23,985
16. Others				
a) Miscellaneous Expenses	3,06,017		2,30,960	
b) JEST Expenses	39,319		-	
c) Interest refund to DAE	27,46,130		-	
		30,91,466		2,30,960
SUB-TOTAL (B)		**2,53,46,076**		**4,01,04,864**
GRAND TOTAL (A + B)		**8,16,47,284**		**8,90,66,559**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR
STATEMENT OF RECEIPTS & PAYMENTS FOR THE FINANCIAL YEAR 2017-18

(Figure in Rs.)

	RECEIPTS	SCH	Current Year	Previous Year		PAYMENTS	SCH	Current Year	Previous Year
I.	**Opening Balances**				I.	**Expenses**			
	a) Cash in hand		31,622	4,138		a) Establishment Expenses (Corresponding to Sch 20)	C	22,98,45,591	16,31,41,059
	b) Bank balances					b) Administrative Expenses (Corresponding to Sch 21)	D	6,82,76,939	5,80,98,473
	i) In current accounts SBI		2,14,81,712	99,74,635	II.	**Payments made against funds for various projects**		74,37,953	1,11,147
	ii) In Savings accounts				III.	**Investments and deposits made**			
	Indian Overseas Bank (NP)		4,54,03,617	2,32,32,003		a) Out of Earmarked/Endowment funds		-	-
	Indian Overseas Bank (Plan)		1,40,98,177	4,43,07,151		b) Out of Own Funds (Investments-Others)		-	-
	Union Bank (NP)		1,19,274	24,68,336	IV.	**Expenditure on Fixed Assets & Capital W.I.P**			
	Union Bank (Plan)		47,93,592	84,74,715		a) Purchase of Fixed Assets	E	8,77,40,165	12,47,50,262
	Project Bank Account		2,11,196	2,72,697		b) Expenditure on Work-in-Progress		-	-
II.	**Grants Received**				V.	**Refund of surplus money/Loans**			
	a) From Govt. of India - Plan		9,00,00,000	10,29,91,000		a) To the Government of India		-	-
	Non-Plan		29,96,00,000	26,80,68,000		b) To the State Government		-	-
	b) From State Government		-	-		c) To other providers of funds		-	-
III.	**Receipt from Sponsored Project**		1,86,64,123	49,646	VI.	**Finance Charges (Interest)**		-	-
IV.	**Interest Received**				VII.	**Other Payments**			
	a) On Bank deposits		-	28,38,731		Project Revenue Expenses	F	1,36,30,149	3,53,65,487
	b) Loans, Advances etc.	A	3,90,750	4,92,487		Staff Loan	G	1,46,500	3,45,150
V.	**Other Income**				VIII.	**Closing Balance**			
	Misc Receipts		13,11,260	7,31,532		a) Cash in hand		29,588	31,622
	Sale of Tender paper		3,500	42,750		b) Bank balances			
	House/Guest House Rent		21,59,708	12,12,296		i) In current accounts SBI		59,58,472	2,14,81,712
	Sale of Asset		56,101	6,700		ii) Savings accounts			
VI.	**Amount Borrowed**		-	-		Indian Overseas Bank (NP)		1,21,60,145	4,54,03,617
VII.	**Any Other Receipts**					Indian Overseas Bank (Plan)		6,52,29,103	1,40,98,177
	Earnest Money Deposit		12,25,700	(5,94,645)		Union Bank (NP)		17,40,808	1,19,274
	Security Deposit		(7,28,165)	9,78,395		Union Bank (Plan)		21,468	47,93,592
	Caution Money		1,800	2,600		Project Bank Account		1,14,37,366	2,11,196
	Recoveries / Current Dues	B	48,30,280	23,97,601					
	TOTAL		**50,36,54,247**	**46,79,50,768**		**TOTAL**		**50,36,54,247**	**46,79,50,768**

For PARTHA S. MISHRA & CO.
Chartered Accountants
Sanjaya kumar Patra
CA S.K. Patra (FCA, DISA)
Partner, M. No-301929

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE A - INTEREST ON LOANS & ADVANCES		
Interest on House Building Advance	15,959	65,518
Interest on Motor Cycle Advance	1,797	-
Interest on Computer Advance	12,275	14,554
Interest on Pending Advance	3,481	2,253
Interest on Security Deposit	3,57,238	4,10,162
Total	**3,90,750**	**4,92,487**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE B - RECOVERIES & CURRENT DUES		
Advance For Motor Cycle	27,250	29,000
Advance For Motor Car	12,000	12,000
Advance For House Building	12,000	12,000
Advance For Computer	51,700	37,650
Advance For Festival	1,13,400	2,65,500
Advance For Cycle	-	1,375
GSLI Claim Payable	(36,746)	36,746
NPS Recovery Payable	93,914	50,535
Pension Payable	35,98,640	1,31,798
Professional Tax Payable	(52,825)	53,225
Project Grant Payable	(12,46,000)	12,46,000
GST Recovery Payable	1,11,317	-
Plan TDS Payable	45,093	-
Provident Fund Payable	11,262	-
TDS Non-Salary Payable	(1,36,076)	1,77,506
TDS Salary Payable	24,80,604	-
WCT Recovery Payable	(2,55,253)	3,44,266
Total	**48,30,280**	**23,97,601**

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

REGISTRAR INSTITUTE OF PHYSICS

DIRECTOR INSTITUTE OF PHYSICS BHUBANESWAR

INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE C - Establishment Expenses		
Salary	12,90,27,085	9,18,99,996
NPS	20,53,224	20,53,787
PRIS	2,46,17,558	62,64,925
Update Allowance	16,07,226	14,20,959
Leave Salary	29,33,678	30,37,157
Temporary Status Salary	1,39,230	1,95,759
Book Grant & Contigency	15,45,644	11,43,936
Canteen Expenses	10,806	78,374
Entertainment	3,47,592	4,27,484
Honorarium	16,52,723	10,99,051
Overtime Allowance	34,904	70,018
Children Education Allowance	1,19,249	9,82,414
Pension	3,87,36,210	3,25,89,863
Pre Doctoral Fellowship	28,19,237	27,69,839
Doctoral Fellowship	94,62,939	93,11,688
Post Doctoral Fellowship	40,89,405	-
SSB Award Fellowship	-	(1,80,000)
Recreation Club Expenses	8,91,010	15,84,743
Reimbursement of Medicine	42,98,962	34,21,182
Remuneration Medical Officer	4,20,000	3,70,000
Medical Aid Centre Expenses	3,356	-
Visiting Scientist TA	5,79,259	3,66,263
Leave Travel Concession	9,10,463	6,26,898
Gtatuity	35,45,831	36,06,723
Total	**22,98,45,591**	**16,31,41,059**

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE D - Administrative Expenses		
Administrative		
Advertisement	5,35,773	4,23,985
Audit Fees	59,000	57,500
Conferene & Symposia	6,00,282	2,86,839
Science Outreach activities	7,49,443	2,11,909
Interest Refund to DAE	27,46,130	-
Electricity Charges	2,24,16,935	2,31,02,331
Night Duty Allowance	65,960	99,488
Miscellaneous Expenses	3,06,017	2,30,136
Postage & Telegraph	1,83,545	1,45,258
Printing Stationey	10,96,363	5,61,392
Security Services	85,57,289	86,15,188
Foreign Travel Expenses	6,18,216	7,41,560
Domestic Travel Expenses	16,74,066	11,45,591
Confernce TA	8,77,515	5,17,342
Telephone & Telex	19,81,775	4,08,809
Water Charges	2,89,785	2,76,640
Hire Charge	24,064	6,638
JEST Expenses	1,49,319	-
Professional Charges	6,93,875	2,19,690

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SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE D - Administrative Expenses (Contd....)		
Maintenance		
Computer Maintenance	39,08,358	47,33,256
Laboratory Maintenance	85,54,507	24,56,556
Civil Maintenance	47,38,568	74,58,813
Office Equipment Maintenance	2,02,598	2,77,054
Furniture Maintenance	1,70,272	2,05,407
Library Maintenance	1,03,043	85,871
AC Plant Maintenance	35,58,723	31,09,023
Garden Maintenance	1,95,544	1,63,269
Electrical Maintenance	10,88,924	14,25,586
Telephone Maintenance	3,26,765	2,78,077
Workshop Maintenance	11,95,834	1,76,608
Vehicle Maintenance	6,08,451	6,78,657
Total	**6,82,76,939**	**5,80,98,473**

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SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE E - PURCHASE OF FIXED ASSETS		
NON-PLAN		
Books	14,06,613	7,17,865
Library & Journals	3,84,12,617	3,19,43,672
Office Equipment	25,68,477	6,40,069
Furnitue & Fixtures	12,06,265	5,72,267
Telephone Equipment	-	9,400
Computer Equipment	-	9,369
Workshop Equipment	2,43,582	7,02,134
Electrical Installation	90,800	-
Vehicle	5,72,181	-
Laboratory Equipment	23,78,171	-
PLAN		
ALICE Utilization and CBM participation	36,97,913	9,65,666
Development of Computing & Network Facilities	69,30,019	6,63,95,737
Development of Research in HEP	-	3,72,526
Strengthening Low Energy Accelerator	1,27,56,479	94,63,599
Study of Growth & Characterization of Advanced Materials	82,63,885	85,36,287
Theoretical Condensed Matter and Quantum Information	15,10,529	17,23,887
Infrastructure & Housing	65,95,493	26,97,784
Investigating Spin Structure	11,07,141	-
Total	**8,77,40,165**	**12,47,50,262**

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SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE F - PROJECT REVENUE EXPENSES		
PLAN		
ALICE Utilization and CBM participation Expenses	30,72,509	23,08,731
Development of Computing & Network Facilities Expenses	22,28,718	61,71,803
Development of Research in HEP Expenses	-	31,93,975
Development of Research in NP Expenses	-	18,36,010
Strengthening Low Energy Accelerator Expenses	3,78,256	14,14,450
Study of Growth & Characterization of Advanced Materials Expenses	11,33,799	42,44,544
Theoretical Condensed Matter and Quantum Information Expenses	(5,000)	31,89,368
Infrastructure Expenses	66,34,995	1,30,06,606
Investigating Spin Structure Expenses	1,86,872	-
Total	**1,36,30,149**	**3,53,65,487**

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INSTITUTE OF PHYSICS, BHUBANESWAR

SCHEDULES FORMING PART OF STATEMENT OF RECEIPTS & PAYMENTS FOR THE YEAR ENDED 31ST MARCH 2018

(Amount Rs)

	Current Year	Previous Year
SCHEDULE G - STAFF LOAN		
Advance For Festival	-	1,89,000
Advance For Motor Cycle	-	30,000
Advance For Computer	1,46,500	29,000
Advance For Medical	-	97,150
Total	**1,46,500**	**3,45,150**

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SCHEDULES FORMING PART OF THE ACCOUNTS FOR THE PERIOD ENDED 31.03.2018

SCHEDULE 24 - SIGNIFICANT ACCOUNTING POLICIES

1. **ACCOUNTING CONVENTION**

   The financial statements are prepared and presented on the basis of historical cost convention and on the accrual method of accounting.

2. **INVENTORY VALUATION**

   Stock of Office Stationery, Computer Stationery, Cleaning Material Stock, Hardware and Electrical items etc. are valued at cost.

3. **INVESTMENT**

   The Institute has no long-term Investment of any nature. However, there are short-term investment in shape of STDR with bank against Letter of Credit.

4. **FIXED ASSETS**

   Fixed Assets are stated at cost of acquisition inclusive of Carriage Inward, duties & taxes and other incidental direct expenses incurred in relation to such particular fixed assets. Physical Stock verification has been made for the year 2017-18. One Laptop is found missing during Physical Stock verification.

5. **DEPRECIATION**

   5.1. Depreciation is provided on straight-line method at the rates specified in the Company Act, 1956, the amendment of 2013 has not been taken into account. Depreciation has been charged on those assets whose WDV are not zero as per the fixed assets schedule for opening balances and current year additions have been charged for the full year.

   5.2. Assets costing Rs.5000/- or less are fully provided.

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6. **GOVERNMENT GRANTS / SUBSIDIES**

The grants are accounted for on realisation basis.

6.1. Plan & Non-Plan grants utilised for capital expenditure is treated as General Fund.

6.2. Plan & Non-Plan grants utilised for revenue expenditure has been taken into Income & Expenditure A/c. as expenditure.

7. **FOREIGN CURRENCY TRANSACTIONS**

Transactions involving foreign currency are accounted at the exchange rate prevailing on the date of the transaction

8. **LEASE**

Out of the total land in possession of the Institute, 6.130 Acres are leasehold and lease rent has been paid upto 31.03.2017. Rest of the land are alienated in favour of the Institute and for this part no, rent is due to the State Government.

9. **RETIREMENT BENEFITS**

9.1. Liability in respect of Gratuity on retirement payable as on 31.03.2018 has been provided in accounts on actuarial valuation.

9.2. Provision for liability towards accumulated leave encashment benefit to the employees as on 31.03.2018 has been provided for in accounts on actuarial valuation.

9.3. Provision for liability payable towards Pension to employees has not been provided in the Accounts and is accounted on Cash basis.

9.4. No Pension fund has yet been created by the Institute.

9.5. Contribution to newly defined pension scheme have been made by the Institute for those employees who have joined the Institute after 01-01-2004.

9.6. The Institute has its own Provident Fund Trust who manages the Provident Fund of the employees who have joined the Institute on or before 31.12.2003.

PARTHA S. MISHRA & CO. FRN 324467E Chartered Accountants

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SCHEDULES FORMING PART OF THE ACCOUNTS FOR THE PERIOD ENDED 31.03.2018

SCHEDULE 25 – CONTIGENT LIABILITIES AND NOTES ON ACCOUNTS

1. CONTIGENT LIABILITIES

1.1.	Claims against the Institute not acknowledged as debt	NIL
1.2.	Bank Guarantee given by / on behalf of the Institute	NIL
1.3.	Bills discounted with Bank	NIL
1.4.	Letter of Credit opened by bank on behalf of the Institute outstanding as on 31.03.2018 against 100% margin money	30,77,093/-
1.5.	Disputed demand in respect of	
	Income Tax (TDS) as on 31.03.2018	NIL
	Sales Tax (IDS)	NIL
	Municipal Taxes	NIL
1.6.	In respect of claims from parties for non-execution of orders	NIL

2. NOTES ON ACCOUNTS

2.1. CURRENT ASSETS. LOANS AND ADVANCES

In the opinion of the Management, the current assets, loans and advances have a value on realization in the ordinary course of business, equal at least to the aggregate amount shown in the Balance Sheet.

2.2. CURRENT LIABILITIES & PROVISIONS

All known liabilities except Pension to retired employees have been provided in the accounts of the Institute.

All Unclaimed liabilities for more than 3 years have been taken into Miscellaneous Income.

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2.3. **TAXATION**

Since Institute is a research oriented organization founded by Government of India, Department of Atomic Energy & partly by Government of Odisha and in view there being no taxable income under Income-tax Act 1961, no provision for Income tax has been made during the year.

2.4. External Grants from DST & other funding agencies for specific projects/fellowship have not been included in the accounts earlier have now been taken into account in the year under Earmarked Fund.

2.5. Figures in the Balance Sheet and Income & Expenditure Account have been rounded off to nearest rupee.

2.6. Previous year's comparative figures have been regrouped/ rearranged, wherever necessary. Figures in the brackets indicate deductions.

2.7. Institute has conducted physical verification of Library Books during 2017-18. The shortage of books/ journals in the report has been accounted for in the books of accounts to the extent the Governing Council has accorded its approval.

2.8. STDR Against LC of Rs.30,77,093/- includes the following:

Date of Payment	Head of A/c	Party Name	Item Name	Amount
18/03/2016	Study of Growth & characterisation	Oxford Instrument	Energy dispersive system	7,74,540
29/08/2017	Theoretical CMQI	Quantum Design	Evercool PPMS Coolhead	15,19,568
05/01/2018	Strengthening Low Energy	Trillium US Inc	Cryo Pumping System	2,67,985
17/01/2018	Computing & Networking	Locuz Entp. Solution	Server System	5,15,000

2.9. Miscellaneous Income includes Unclaimed Liability of Rs.2,07,371/- towards Caution Money from Scholars (Rs.200/-), Security Deposit from Contractors (Rs.59,749/-) & Earnest Money Deposit (Rs.1,47,422/-).

2.10. Income recognition on interest on staff Loan is accounted after the repayment of principal as per practice adopted. Interest on saving bank is accounted on receipt basis.

2.11. Schedule 1 to 25 are annexed to and form an integral part of the Balance Sheet as at 31.03.2018 and Income & Expenditure Account for the year ended on that date.

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2.12. FOREIGN CURRENCY TRANSACTIONS

Value of Imports calculated on C.I.F/Ex-works & FOB basis	Current Year (Rs.)	Previous Year
a) Purchase of Lab. Equipments	1,45,60,994	6,49,23,308
b) Stores, Spares and Consumables	38,27,339	1,07,84,183
c) Journal subscription	3,79,99,042	3,15,46,495
Expenditure in foreign currency		
a) Travel	Nil	Nil
b) Other expenditure	Nil	Nil
Earnings		
Value of Exports on FOB basis	Nil	Nil
Remuneration to Auditors		
As Auditors	50,000	50,000

PARTHA S.MISHRA & CO. FRN-324167E Chartered Accountants

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ACTION TAKEN REPORT ON THE COMMENTS OF STATUTORY AUDITOR ON THE ANNUAL ACCOUNTS OF INSTITUTE OF PHYSICS, BHUBANESWAR FOR THE FINANCIAL YEAR 2017-18

Sl. No.	AUDITOR'S OBSERVATION	INSTITUTE'S REPLY
Qualified opinion		
Basis of qualification		
1	IAS 10 regarding to fixed assets and As6 for depreciation have not been followed. There was no fixed asset register to verify the Individual asset residual value. Depreciation has been charged on gross block at the end of the year on SLM method irrespective of the fact that individual old assets may have been depreciated in full. E- Journals have been capitalized as intangible assets and depreciated for the whole year. E- Journals are paid in calendar yearly basis but the whole years E-journals have been capitalized thus contravening the provisions of the AS10 and AS-6. The depreciation on assets purchased during the year was also charges for the whole year instead of proportionate basis from date to use. The interest from STDR given against Letter of credit should not be deducted from the cost of fixed Assets but should be shown as "Income from Other Sources"	Noted for corrective measures. The Institute has engaged M/s.Laldash & Co., CAs vide W.O. No. 793 dt.25.06.2018 for preparation of Asset Register from 2011-12 onwards and guide us in this matter. Noted for future guidance.
2	IAS 12 on Accounting of Government grants has not been followed. The grants have been recognized on realization basis. Capital grants are recognized as capital fund and shown as Liability.	The Institute has been receiving full grant from DAE (Govt. of India) under Plan and Non-Plan which is treated as Capital Fund as per the provision of Accounting Standard 12.

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Matter of emphasis		
1	The lease deed for 50 acres of land at Mouza Nayapalli is not available. However, the copy of the land allotment letter and possession letter ware available in the file. Lease records in respect of 6.130 acres was available. The ROR shows that the 47.32 Acre land belongs to Education Department, Govt. of Odisha. So Institute of physics must take necessary steps to mutate the schedule land in its favor.	Govt. of Odisha has been requested on the matter and the action is on.
2	Balances of advances and liabilities recognized from third Parties are subject to confirmation.	Noted
Audit Observation on Accounts		
1	**Maintenance of books of accounts:** The following manual books of accounts are maintained in the year 2017-18: a) Cash cum bank Book b) Cheque issue register c) Staff advance register d) Security deposit register e) TDS register	No comment.
2	**Cash and Bank:** a) In some cases the institute has paid cash above Rs. 10000 to visiting scientists/Employees. Instances given at Annexure-1. b) The Institute has operated 27 Nos. of Bank accounts. All banks have been reconciled. Our observation on BRS is given at Annexure-2.	a) The Institute is making almost all payments by NEFT/RTGS. In some remote cases, Cash has been paid to Visiting Scientists who does not have bank account in India. b) The bank has been requested to provide details of remitter in respect of credit given by bank. On identification of nature of receipts, necessary entries will be given in the Accounts for the current year i.e.2018-19.

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3	**Others:** a) Advances to staff unadjusted for more than 3 months were found in the following cases. The same should be adjusted /recovered at an earliest.	a) The outstanding advances have been recovered/ adjusted as mentioned against each

Date	Name	Purpose	Amount(Rs.)	
09/05/2016	Tabobrata Som	Purchase Advance	5,000.00	Recovered from his Salary in April' 2018
02/03/2017	Dinesh Topwal	Lab. Maintenance	5,000.00	-do-
14/11/2017	Dinesh Topwal	Spin Structure	23,347.00	Adjusted/Recovered from Salary in June' 2018
31/01/2018	Alumni Asso.	Science outreach	14,790.00	Being adjusted
13/02/2018	Suresh Ku. Patra	JEST	1,10,000.00	Reimbursement received on 05.06.2018 & 07.06.2018

	b) Also there are some LTC advances pending as on 31.03.2018 for more than one (1) month as stipulated by IOP guideline. Some of such instances are given below.	b) In all the cases journey has been conducted within the allowable period. The employee concerned have submitted their bill in time. Processing of bills took time in office. However, the observation of Audit is noted for future guidance.

Sl.	Name	Date of Advance	Amount	Period of journey		Date of Adjustment
1	P K Biswal	15.02.2018	15,400.00	01/05/18 07/05/18	to	13/08/2018
2	G S Nayak	19.03.2018	24,300.00	12/03/18 23/03/18	to	21/05/2018
3	B N Swain	19.03.2018	24,300.00	12/03/18 23/03/18	to	23/05/2018
4	R N Mishra	19.03.2018	19,000.00	12/03/18 23/03/18	to	22/05/2018
5	T Parida	19.03.2018	6,300.00	12/03/18 23/03/18	to	11/06/2018

	c) Some amounts are recovered from various parties on various dates towards GST. However, IOP is not liable to deduct any such amount from any person. Hence the same should be refunded as soon as possible.	c) During the transition period of rollover from VAT to GST, TDS has been made in some cases. Steps are being taken for refund of the amount to the parties from whose bill such deduction have been made.

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