

---

## Academic Report (2020-21)

---



Harish - Chandra Research Institute  
Chhatnag Road, Jhunsi  
Prayagraj - 211019, India

# Ujjwal Sen

## Research Summary:

In the last academic year, I have been working on different aspects of quantum devices, and at the interface of quantum information with other sciences.

In one of these works, I have collaborated with Ahana Ghoshal on heat current and entropy production rate in local non-Markovian quantum dynamics of a global Markovian evolution. We examined the elements of the balance equation of entropy in open quantum evolutions, and their response as we go over from a Markovian to a non-Markovian situation. In particular, we looked at the heat current and entropy production rate in the non-Markovian reduced evolution, and a Markovian limit of the same, experienced by one of two interacting systems immersed in a Markovian bath. The analysis naturally led us to define a heat current deficit and an entropy production rate deficit, being differences between the global and local versions of the corresponding quantities. The investigation brought us, in certain cases, to a complementarity of the time-integrated heat current deficit with the relative entropy of entanglement between the two systems.

In another work, I have collaborated with Kornikar Sen and Chirag Srivastava to provide measurement-device-independent nonlinear entanglement witnesses. Entanglement witnesses are one of the most effective methods to detect entanglement. It is known that nonlinear entanglement witnesses provide better entanglement detection than their linear counterparts, in that the former detect a strictly larger subset of entangled states than the latter. Whether linear or nonlinear, the method is measurement-device dependent, so that imperfect measurements may cause false certification of entanglement in a shared state. Measurement-device-independent entanglement witnesses provide an escape from such measurement dependence of the entanglement detection for linear entanglement witnesses. We presented measurement-device-independent nonlinear entanglement witnesses for non-positive partial transpose entangled states as well as for bound entangled states with positive partial transpose. The constructed measurement-device-independent nonlinear entanglement witnesses certified the entanglement of the same sets of entangled states as their device-dependent parents do, and therefore are better than the linear entanglement witnesses, device-independent or otherwise.

## Publications:

1. Riddhi Ghosh, Ahana Ghoshal, and Ujjwal Sen, *Quantum thermal transistors: Operation characteristics in steady state versus transient regimes*, *Phys. Rev. A* **103**, 052613, (2021).
2. Chirag Srivastava, Sreetama Das, and Ujjwal Sen, *Resource theory of quantum coherence with probabilistically non-distinguishable pointers and corresponding wave-particle duality*, *Phys. Rev. A* **103**, 022417 (2021).
3. Kornikar Sen, Chirag Srivastava, Shiladitya Mal, Aditi Sen De, and Ujjwal Sen, *Detection loophole in measurement-device-independent entanglement witness*, *Phys. Rev. A* **103**, 032415 (2021).

## Invited Lectures/Seminars:

1. *Quantum talks*, IIT Hyderabad, India, June-July 2020. Online. Presented a talk on “Quantum devices using systems with impurities”.
2. *International E-Conference on Recent Advances in Physics*, GPGC, Bazpur, India, 24-25 Jun, 2020. Online. Presented a talk on “Quantum devices using systems with impurities”.
3. *Physics Colloquium*, IIT Gandhinagar, India, 03 July 2020. Online. Presented a talk on “Quantum devices using systems with impurities”.
4. *QMAT-2020*, SN Bose National Center for Basic Sciences, Kolkata, India, 07-11 Sep, 2020. Online. Presented a talk on “Quantum devices in disordered systems”.
5. *India-Russia Quantum Technologies Meet*, Embassy of India in Russia and the DST, GoI, 10 Sep, 2020. Online. Presented a talk on “Quantum information meets few- and many-body physics”.
6. *Technical Education Quality Improvement Programme (TEQIP) - III sponsored Faculty development program (FDP) on Quantum Information and Computation*, NIT Sikkim, India, 03-17 Oct, 2020. Online. Presented two talks on “Interface of quantum information with few- and many-body physics”.

## Other Activities:

1. Current PhD students: Chirag Srivastava, Ahana Ghoshal, Kornikar Sen, Tanaya Ray. [Sreetama Das, another student, was awarded a PhD degree recently.]
2. Courses taken/ongoing: Research methodology and Numerical Methods, January-May 2020 (shared with Prof. Santosh K. Rai); Quantum information and computation 2, January-May 2020 (shared with Prof. Aditi Sen De); Quantum Information and Computation 1, August-December 2020 (shared with Profs. Arun Kumar Pati and Aditi Sen De); Quantum Information and Computation 2, January-May 2021 (shared with Prof. Aditi Sen De); Quantum mechanics 2, May-August 2021.
3. Committees: Convener of HRI computer committee, members of HRI cluster computing, HRI outreach program, HRI faculty appointment committees.
4. Mentored/mentoring projects of Aparajita Bhattacharyya, Priya Ghosh, Sayan Mondal, Tanay Konar, Anish Majumdar.
5. Mentored/mentoring the masters theses of Ingita Banerjee, IIT Dhanbad; Sheikh Parvez Mandal, IISER Pune; Soubhadra Maiti, IISER Pune. Online.
6. Visiting students (online): Sheikh Parvez Mandal, Ayushi Dubal, Riddhi Ghosh, Sayanwita Biswas, Ingita Banerjee, Kartikeya Arora, Soham Sau, Shilpa Mahato, Soubhadra Maiti, Adithi Ajith, Swati Choudhary, Arunava Majumdar, Sudheer Kumar.