National Workshop on Ion Implantation for Quantum Technologies (I²QT)

Date: 28 August 2025
Venue: Seminar Hall, Main Building, Inter-University Accelerator Centre (IUAC), Aruna Asaf Ali Marg, New Delhi -110067

Jointly Organized by: Quantum Materials and Devices Foundation (QMDF), IIT Delhi & IUAC, New Delhi

Quantum Materials and Devices Foundation in collaboration with IITD and IUAC, Delhi organised a one-day workshop on ion implantation for quantum technologies. The workshop was attended by about 100 scientist and researchers from various institutes across the country and about 50 researchers attended it in on-line mode. There were six invited talks by the eminent speakers from the country and one from the UK. The talks highlighted the role of single ion implantation and other related technologies for achieving the quantum devices.

They covered the fundamentals of implantation techniques and its application in realizing the quantum devices. The workshop ended with a panel discussion with panelist from the IITB, IISc, Sheffield University, UK and IUAC. The panel discussion highlighted the importance of ion implantation specifically single ion implantation for fabrication of quantum devices and utilizing the facilities at the IUAC for the purpose. The panel also emphasized the goals of the National Quantum Mission (NQM) in terms of developing indigenous technologies and greater collaborations. The workshop ended with a visit to the IUAC facilities of the participants.

1. Background & Motivation

Ion implantation is one of the most powerful techniques for tuning and modifying the material properties at the atomic level. In quantum technologies, it plays a central role in introducing controlled defects such as nitrogen-vacancy (NV) centers in diamond, single ion impurity in Silicon for telecom band quantum emitters and introducing controlled concentration of specific impurity centers in materials that can act as building blocks for quantum sensing, communication, and computation. The workshop brought together scientists, technologists, and facility experts to align capabilities, share case studies, and build stronger collaborations in this fast-growing field.

2. Workshop Highlights

2.1 Keynote & Technical Talks

The sessions provided a broad view of how ion implantation underpins advances in both classical and quantum technologies:

- *Dr. Devarani (IUAC New Delhi):* opened the workshop with an overview of ion implantation and low-energy ion beam facilities at IUAC, introducing participants to the strengths of India's infrastructure providing streamlined beam-time access.

- *Prof. Tanmoy Basu (TCG, CREST, Kolkata):* highlighted how ion beam technologies have moved from applications in classical materials science to critical enablers for quantum devices. He explained how precise doping and defect control help create qubits in solid-state systems.

- *Dr. Kaushalya (IIT Roorkee):* discussed progress in creating telecom band quantum emitters in silicon through ion implantation. Such emitters are important because they

operate at wavelengths compatible with optical fiber networks, enabling scalable quantum communication.

- *Dr. Ranjit Kashid (CMET Pune):* shared research on site-selective donor doping in silicon for quantum computation. This approach allows accurate placement of dopants, a key requirement for developing solid-state qubits.

- *Dr. Pritty Rao (SSPL Delhi):* emphasized applications of ion implantation in advanced semiconductor device technologies, how SSPL bridging the gap between commercial devices and next-generation quantum devices.

- *Prof. Satheesh Krishnamurthy (Surrey University, UK):* showcased the UK's National Ion Beam Centre facilities and their broad applications. He presented case studies on generating single-atom defects in materials for quantum devices.

2.2 Facilities & Capabilities

The workshop highlighted the impressive range of facilities available nationally and internationally:

- *UK Surrey Ion Beam Centre*: A flagship facility with a 1.25 MV implanter, cleanroom capabilities, and advanced analysis tools. It offers automated materials analysis and

supports applications from semiconductors to forensics.

- *IUAC, New Delhi*: Houses world-class facilities including the Negative Ion Beam Facility (NIBF), 15 UD Pelletron, Low Energy Ion Beam Facility (LEIBF), and Rutherford Backscattering (RBS). These tools are critical for ion implantation, defect analysis, and characterizing materials at multiple energy scales.

- *Other Indian Facilities*: Institutions such as IOP Bhubaneswar, ICAR Kalpakkam, NISER Bhubaneswar, and SSPL Delhi also offer important resources, strengthening India's collective capability.

2.3 Panel Discussion Insights

The highlight of the workshop was panel discussion with eminent panelist from the country, Prof Kasturi Saha, IITB, Prof Arindam Ghosh, IISc, Prof Shikha Verma, IUAC, and Prof R singh, IITD. Panelist stressed the need for indigenous technologies and nurturing the collaborations. The panel brought out important perspectives on the way forward:

- Quantum Material research is a common link across quantum sensing, communication, and computation—synergy must be actively built.

- Proposals should focus on NV center creation with thin, high-density layers, and explore lithium niobate and AlN platforms for scalable on-chip integration.

- Streamlined beam-time access will help researchers across India leverage national facilities more effectively.

- Quantum hubs must coordinate across verticals to avoid duplication and strengthen impact under the National Quantum Mission (NQM).

3. Roadmap for the Future

- Short-term (1–2 years):- Strengthen collaborations across hubs, ensure wider access to ion beam facilities, and identify flagship projects.
- Medium-term (3–5 years):- Develop integrated platforms for NV centers and telecom band emitters, and support proposals linking sensing, computing, and communication.
- Long-term (5–10 years):- Establish India as a global leader in ion implantation-enabled quantum devices, with applications extending into healthcare, environment, and secure communication.

We are grateful to all speakers, participants, and collaborators for their contributions, and especially to Prof. Rajendra Singh (IIT Delhi), Lead Principal Investigator of NQM's Quantum Materials and Devices Hub, and Prof. A.C. Pandey (Director, IUAC).

We sincerely thank Dr. Devarani (Scientist G, IUAC) for her outstanding contribution in coordinating the sessions and guiding participants through IUAC's facilities, Dr. Ashok Kapoor (QMD Consultant) for his support in shaping and conducting the workshop, and Dr. Shiv Kumar (QMD Consultant) for his valuable guidance and contributions.