IISc's Quantum Technology Push

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http://www.iisc.ac.in/initiative-on-quantum-technologies/

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Young Researchers Meeting, IISc, Bengaluru

Background

"There is one kind of charity common enough among us... It is that patchwork philanthropy which clothes the ragged, feeds the poor, and heals the sick. I am far from decrying the noble spirit which seeks to help a poor or suffering fellow being... [However] what advances a nation or a community is not so much to prop up its weakest and most helpless members, but to lift up the best and the most gifted, so as to make them of the greatest service to the country." —J. N. Tata

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Present: IISc has set up a thematic research cluster, "Initiative on Quantum Technology", after being declared an Institute of Eminence.

The "Centre for Excellence in Quantum Technology" has been created, with support from the Ministry of Electronics and Information Technology, in collaboration with RRI and C-DAC Bengaluru.

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- The physical capabilities (e.g. number of qubits, range of communications, sensitivity of measurements) can be enhanced by an order of magnitude, with a corresponding order of magnitude increase in funding and manpower.
- We are well-prepared to (a) take advantage of any breakthrough that may occur, and (b) promote/collaborate with start-ups in the field.

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- Demonstration of 2D materials based single-photon sensors.
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- Theoretical support: Quantum algorithms, quantum simulator incorporating noisy logic gates, and post-quantum cryptography.

Expertise at IISc

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- Quantum algorithms and simulations

  Apoorva Patel (CHEP)

- Superconducting qubit devices

  Vibhor Singh (Physics), Baladitya Suri (IAP), Chetan Singh Thakur (DESE)



- Single photon detection and photon counting

  Arindam Ghosh (Physics)

- Heralded and single photon sources

  Shankar K.S. (CeNSE)

Experrtise at IISc (contd.)

- Quantum networks with integrated photonics

  Asha Bhardwaj (IAP), Varun Raghunathan (ECE)

- Post-quantum cryptography

  Sanjit Chatterjee (CSA)

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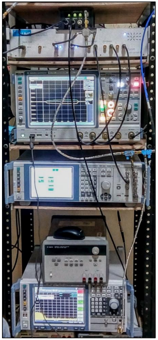
Fact: The number of physical qubits in a quantum device is approximately doubling every year (exceeds Moore's law).

Superconducting quantum devices group - Vibhor Singh

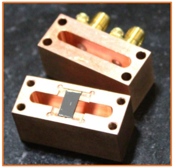
Since - 2016

1-qubit setup at IISc:

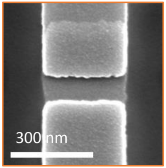
Control electronics



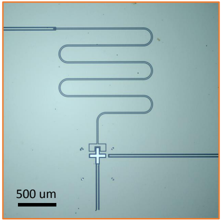
3D-transmon



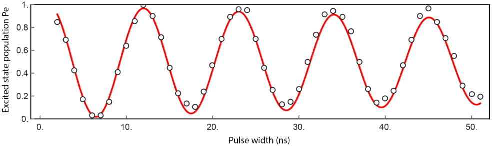
Josephson junction



Qubit in 2D architecture



- Rabi-oscillations: Coherent exchange of quanta



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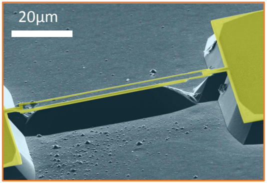
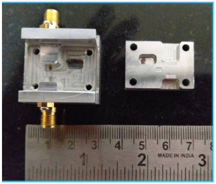
- Hybrid quantum devices (ongoing):



A high-stress suspended SiN+Al nanowire coupled to a 3D transmon qubit



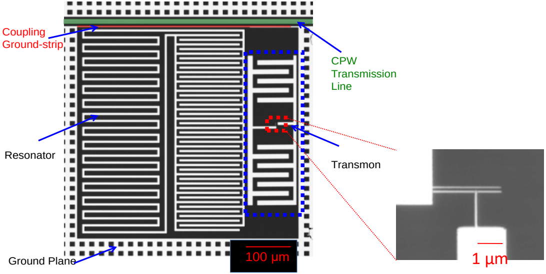
A 3D transmon qubit coupled to vibrating modes of a drumhead resonator

- Full quantum control of a massive oscillator
- Photon-phonon transducers
- A possible route for quantum entanglement between two low-frequency oscillators

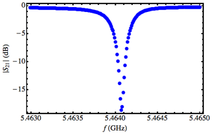
All device fabrication at Center for Nanoscience and Engineering (CeNSE) IISc Bangalore, (Funded by MeitY)

Transmons coupled to lumped element resonators

Baladitya Suri, IAP, IISc



Frequency response of LE resonator



- Lumped element (LE) resonators are single mode LC oscillators up to as high as 40 GHz
- Small footprint on chip -- 400 um x 400 um
- Coherence of these devices can be improved using design and fabrication process studies.

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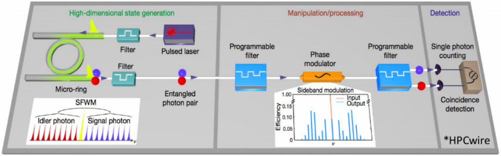
- **Heralded photon pair and single photon sources are essential to realise Quantum Photonics signal processing.**
- **The sources would enable**
  - **Random number generation for secure communication.**
  - **High-speed photonic quantum computing**

Schematic of a photonic integrated chip with process elements



- **Current optical quantum technology are demonstrated in visible and short-wave IR wavelength. The demonstrations use bulk optical components.**

- **In this project, we propose to develop sources and signal process in the communication wavelength band (1550 nm).**

- **The technology will be developed and demonstrated in a photonic integrated circuit.**

IISc has developed photonic IC for communication and sensing application using fabrication facility at CeNSE

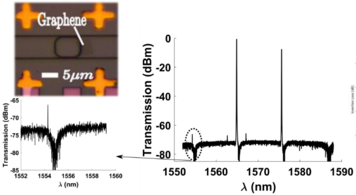
—Shankar Kumar Selvaraja

Project deliverables

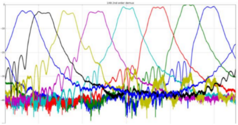
- Develop and demonstrate a photonic circuit platform for heralded and single photon source generation, manipulation and detection.
- Develop and demonstrate a compact photon source and detector in telecommunication wavelength.
- Develop and demonstrate quantum integrated photonic elements to realize quantum optical signal processing for key distribution and random number generator.

Current developments

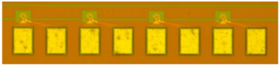
On-chip nonlinear process for correlated photon generation

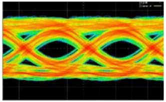


On-chip multi-wavelength filter



High-speed broadband light modulator (45GHz)





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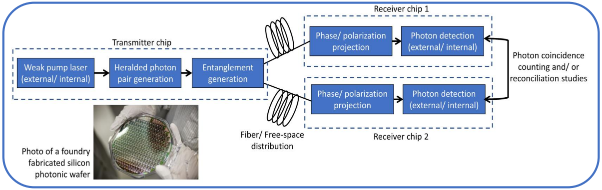
Quantum Network with Integrated photonics



Objectives of the proposed work:

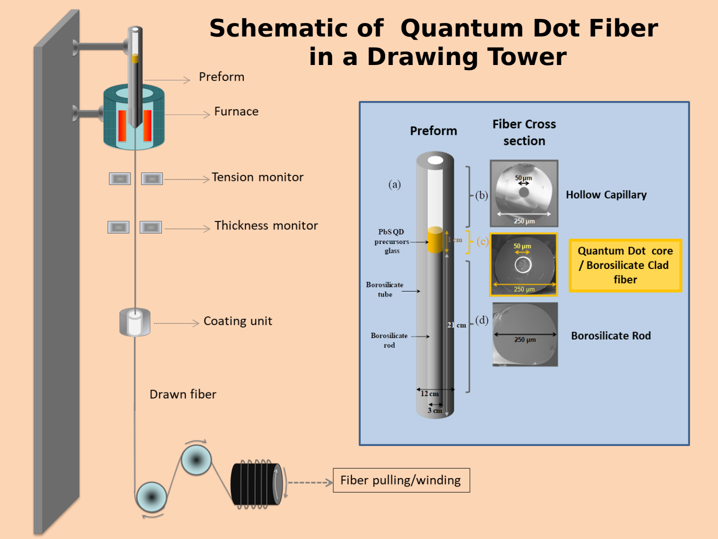
- Demonstrate a small footprint, high efficiency integrated optical solution for chip-to-chip quantum key distribution with fibre and/or free-space as the communication medium.
- Compare performance and benchmark with current state-of-the-art optical table based QKD implementations.
- Train students and project staff to become proficient in quantum optical technologies relevant to communications, integrated optics and experimental optical techniques.

Salient points of the proposed work:

- Integrated quantum transceivers offer the benefits of improved stability, efficiency, small footprint and ability to integrate complex functionalities on a semiconductor chip. Compatible with fibre or free-space links.
- Integration of optical components essential to build quantum communication nodes to realize future quantum networks and interconnect quantum computing systems

—Varun Raghunathan

Fibre Optics Laboratory (Asha Bhardwaj)



Quantum fibres have to be designed to minimise dispersion and dissipation.

Quantum dots embedded in an optical fibre can be part of quantum sensors and repeaters.

Quantum Technologies

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Unforeseen and disruptive applications are possible.

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We cannot afford to be left behind!