



IIT Bombay's  
Centre of Excellence

in

Quantum Information  
Computing Science &  
Technology

A quick introduction  
To

QuICST

[www.quicst.org](http://www.quicst.org)

Suddhasatta Mahapatra  
Professor, Department of Physics  
Professor-in-Charge, CoE-QuICST

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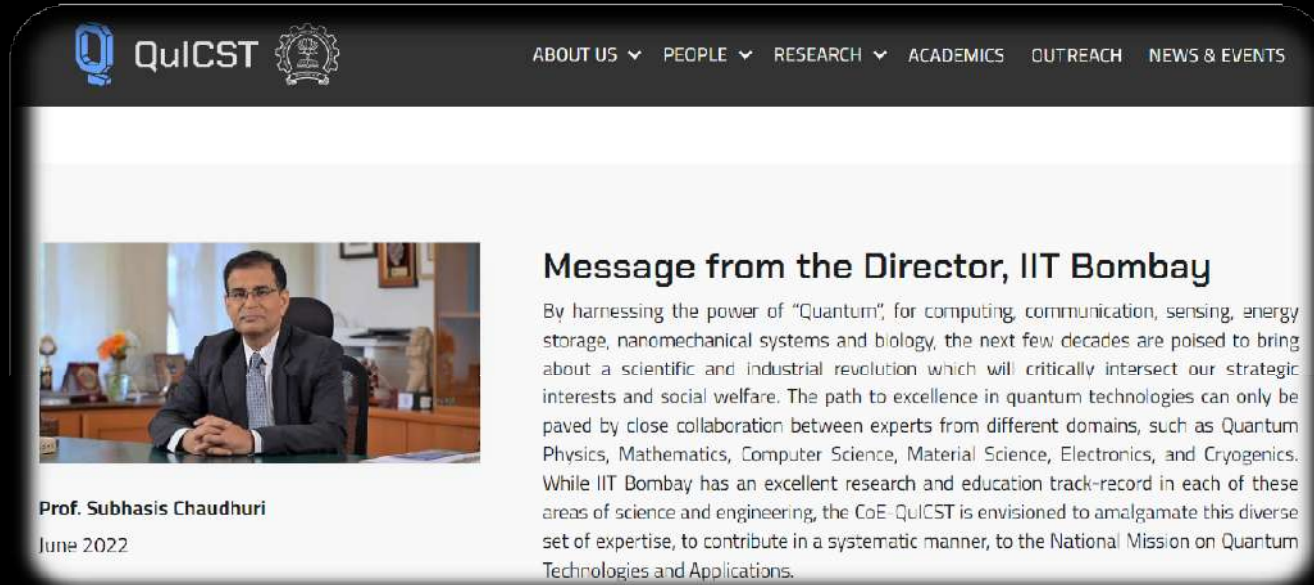
ICONS2023



Quantum Information  
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# Why QuICST?

The path to excellence in quantum technologies can only be paved by **close collaboration between experts from different domains, such as Quantum Physics, Mathematics, Computer Science, Material Science, Electronics, and Cryogenics.**



## Message from the Director, IIT Bombay

By harnessing the power of “Quantum”, for computing, communication, sensing, energy storage, nanomechanical systems and biology, the next few decades are poised to bring about a scientific and industrial revolution which will critically intersect our strategic interests and social welfare. The path to excellence in quantum technologies can only be paved by close collaboration between experts from different domains, such as Quantum Physics, Mathematics, Computer Science, Material Science, Electronics, and Cryogenics. While IIT Bombay has an excellent research and education track-record in each of these areas of science and engineering, the CoE- QuICST is envisioned to amalgamate this diverse set of expertise, to contribute in a systematic manner, to the National Mission on Quantum Technologies and Applications.

Prof. Subhasis Chaudhuri

June 2022

[www.quicst.org](http://www.quicst.org)

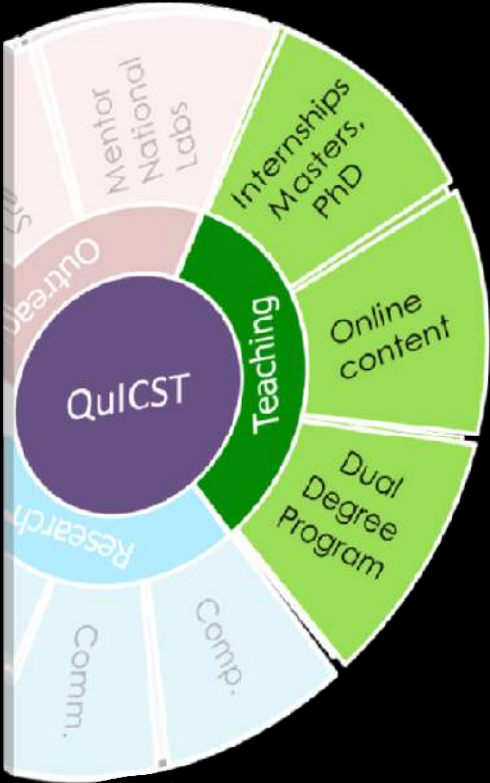
While IIT Bombay has an excellent research and education track-record in each of these areas of science and engineering, the **CoE-QuICST is envisioned to amalgamate this diverse set of expertise, to contribute in a systematic manner, to the National Mission on Quantum Technologies and Applications (NMQTA).**

# An overview of QuICST



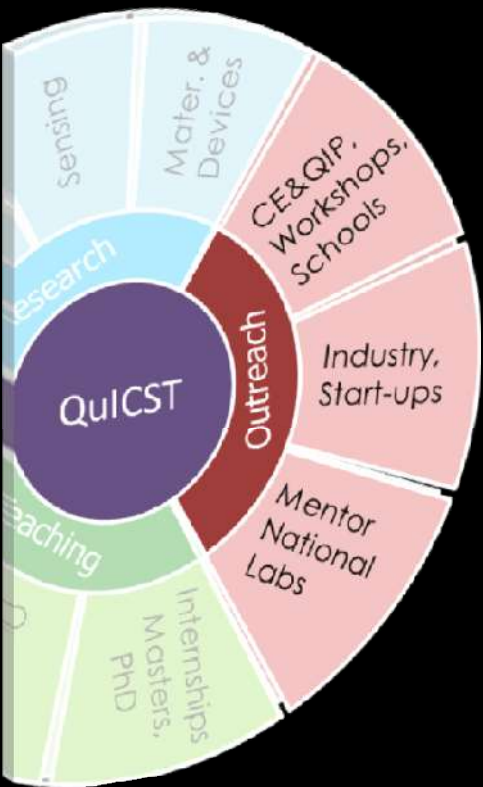
- Established: August 2022
- 15+ associated faculty members
- Projects worth INR 30 Cr under QuEST (USD 3.8 Million)
- State-of-the-art fabrication and measurement infrastructure
- Inter-disciplinary dual degree (B Tech. – M Tech.) program
- Partnering with DST, MEITY, DRDO
- Charting the roadmap of the National Quantum Mission

National Mission on Quantum Technologies and Applications (NMQTA) (~USD 800 Million)



## The Inter-disciplinary dual degree program (IDDDP)

- To be offered (tentatively) from the Autumn of 2023
- 3<sup>rd</sup>-Yr students from any engineering/science department can opt for the program (provided the prerequisites are met)
- Program will offer basket of courses focussed on both theoretical and technological aspects of QST, to choose from
- A 1-yr project work, which may be pursued in any research group associated with QuICST (theory and/or experiment)



## For the broader academia

- Customized Faculty Development Programs (FDPs)
- Short-term Training Programs (STTP)
- Online content and video lectures

## For Industry (and academia)

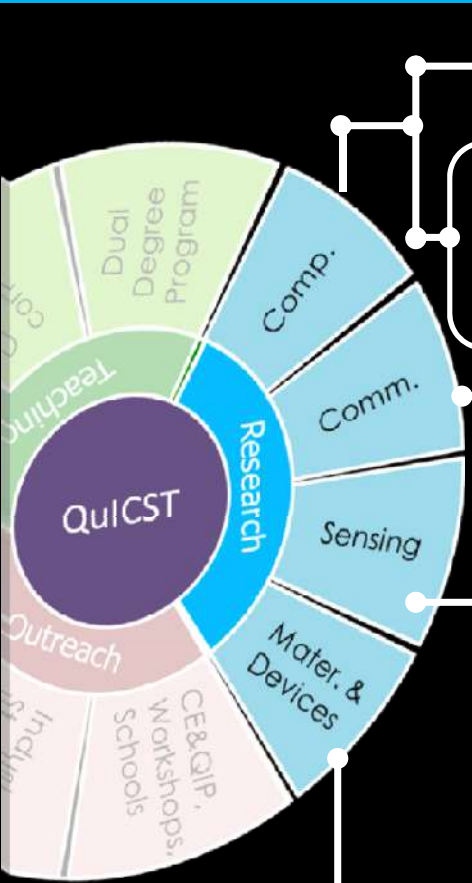
- Professional certification courses
- Eventually, online diploma and degree courses as well

## For students/public

- Online content for understanding at different levels
- Workshops and open-days



# RESEARCH@QuICST



Computing Hardware



Kasturi Saha



Suddho Mahapatra



Avradeep Pal

Algorithms, Simulations, Information theory



Sai V



S Santra



Rahul Maitra



Himadri Dhar



Manoj P



D Bhowmik

Comm. Hardware/Protocols



Kasturi Saha



Avradeep Pal



Anshuman Kumar



Apurba Laha



Siddhartha Santra

Sensing hardware



Kasturi Saha



Avradeep Pal



D Bhowmik



A Tulapurkar

Experiments Theory



Anshuman Kumar



Bhaskaran M



K Dasgupta



S Ganguly



U Ganguly



Hridis Pal



Soumya Bera



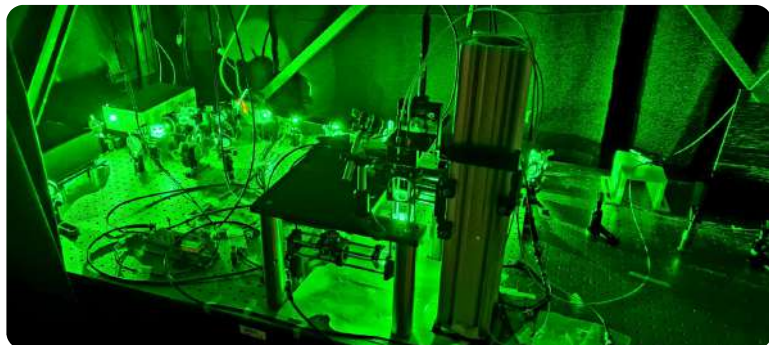
S. Pujari



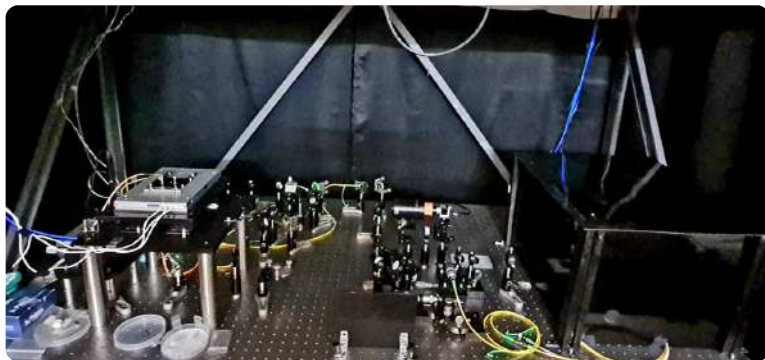
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# Research Infrastructure

## P-QUEST Lab (Kasturi Saha)



Magnetic field microscope for imaging and sensing



Single NV confocal set-up with MW & RF integrated.

## Q-Si Lab (Suddho Mahapatra)



10 mK dilution refrigerator, 300 mK system



RF & DC electronics



Wire bonder



ALD



Electron beam evaporator

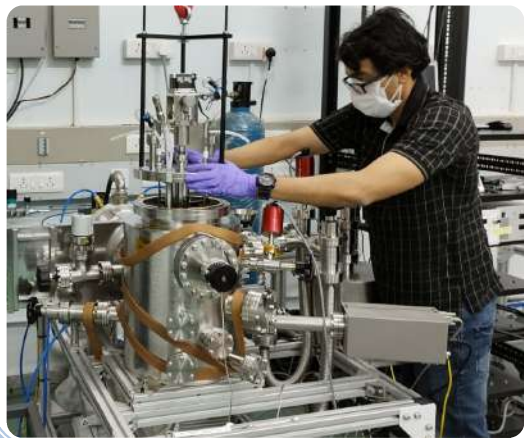




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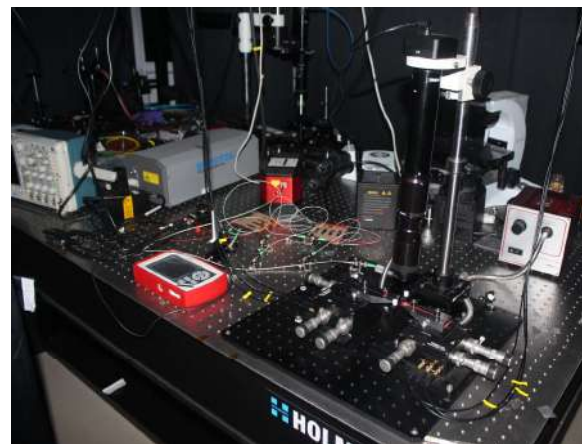
# Research Infrastructure

## QMD Lab (Avradeep Pal)

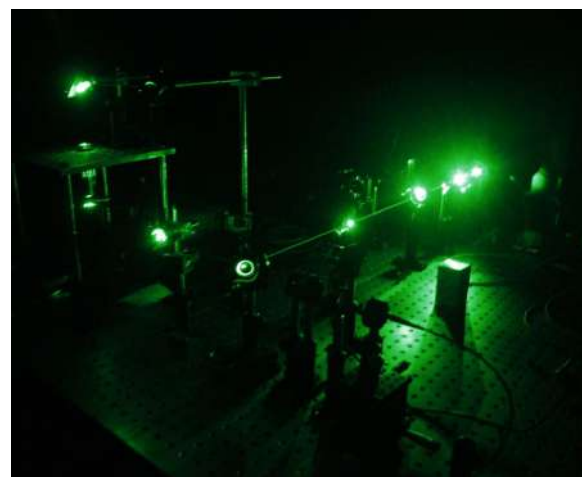


Unique UHV sputter system for extremely high quality superconducting thin films, especially NbN, NbTiN

## LOQM Lab (Anshuman Kumar)



Setup for integration and characterization of 2D quantum emitters with photonic chip platform



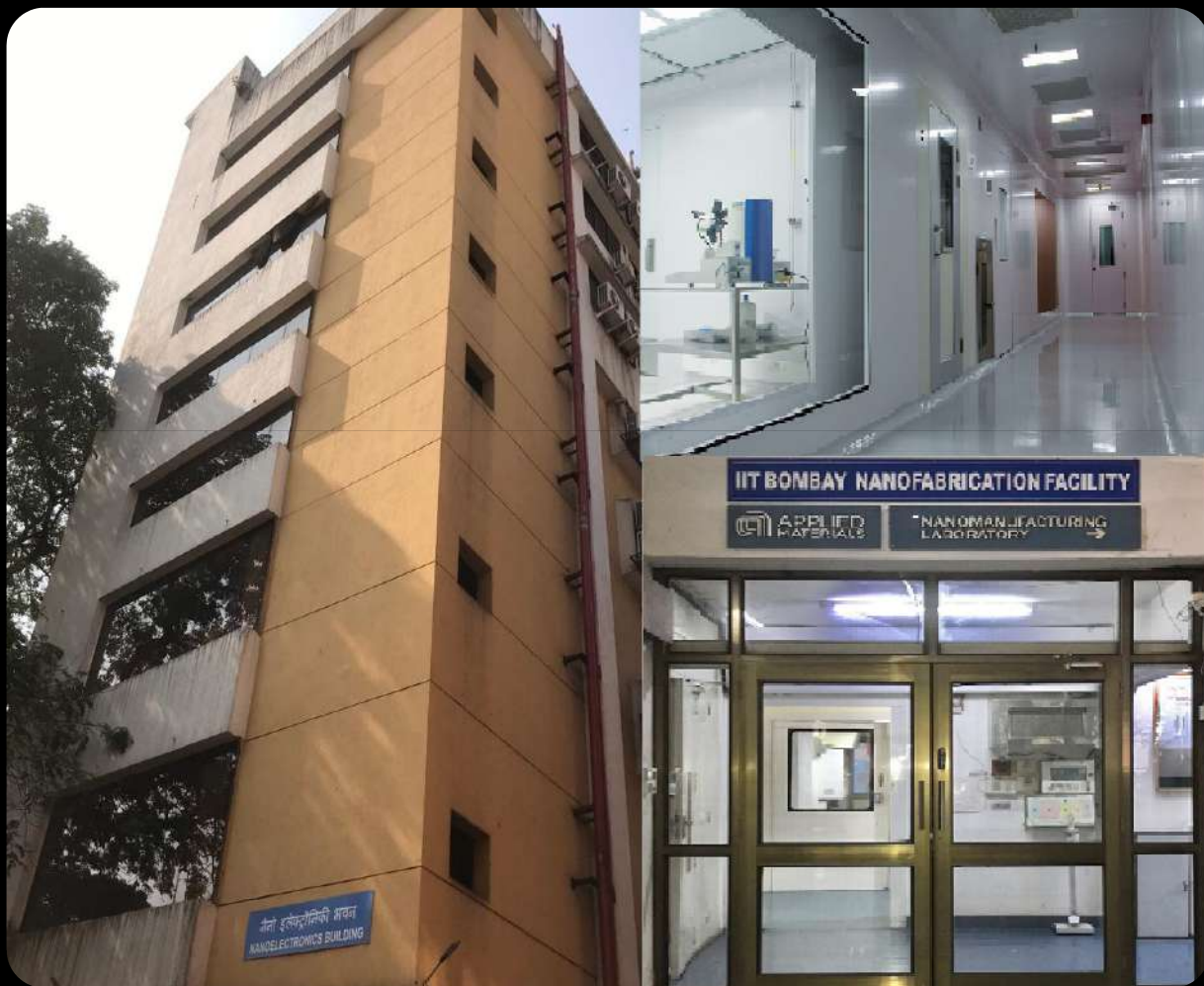
Setup for  $g^{(2)}$  correlation measurements for single photon emitters in 2D semiconductors





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# Nanofab@IIT Bombay



| Tool Type                                      | Number     |
|--|------------|
| Deposition, Growth and Annealing systems       | 50         |
| Dry Etch tools                                 | 7          |
| Electrical characterization tools              | 14         |
| Lithography tools                              | 6          |
| Material and structural characterization tools | 22         |
| Miscellaneous                                  | 23         |
| <b>Total</b>                                   | <b>122</b> |

## Key fabrication tools:

- Raith 150Two 30 kV and Raith Voyager 50 kV EBL systems
- Mask aligners for photolithography x 4
- Electron beam evaporators x 3
- DC and RF sputtering x 2
- Reactive ion etching system x 2
- MBE systems for group-IV, III-As, III-N epitaxy



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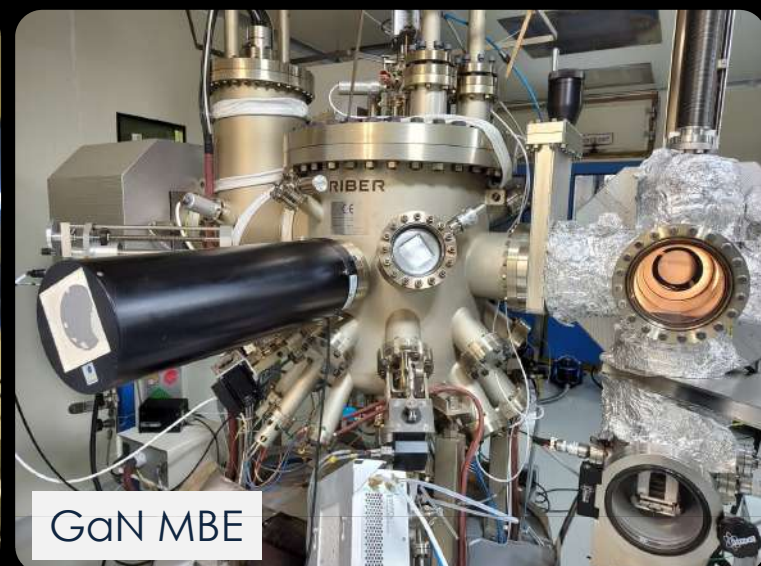
# Research Infrastructure



RAITH 150TWO



DSA (MJB6)



GaN MBE



DC/RF SPUTTER



E-BEAM EVAPORATOR



PLASMA DOPING





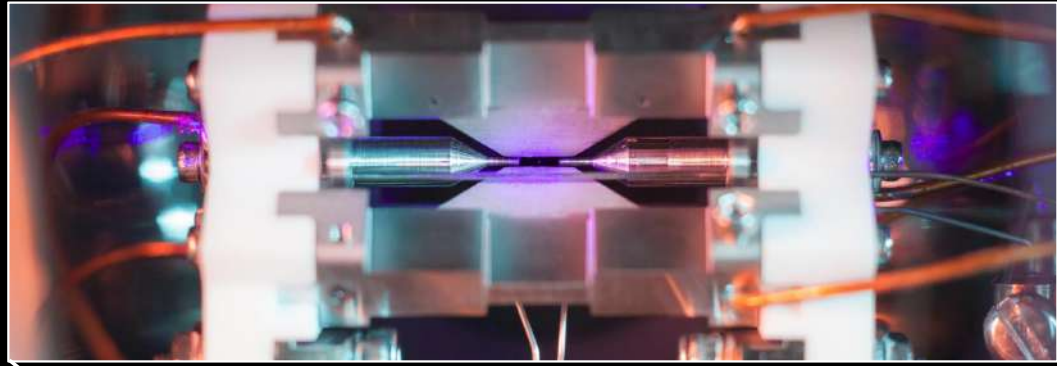
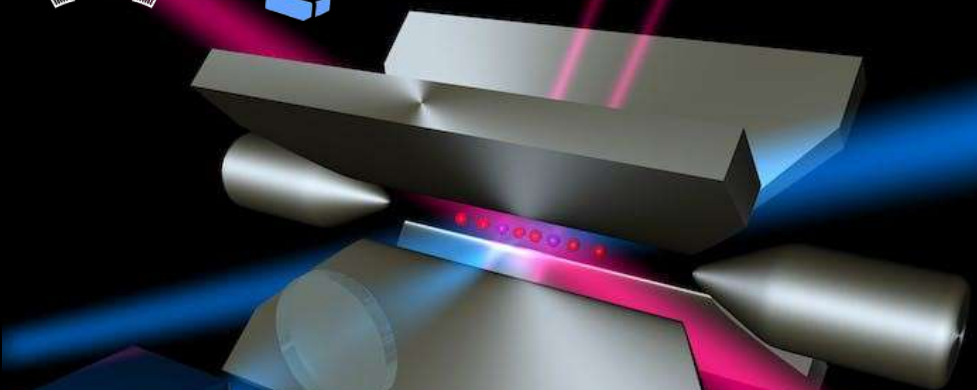
# “Quantum-enabling” the nation

The ‘working principles’ may be quantum, but the ‘infrastructure’ is classical

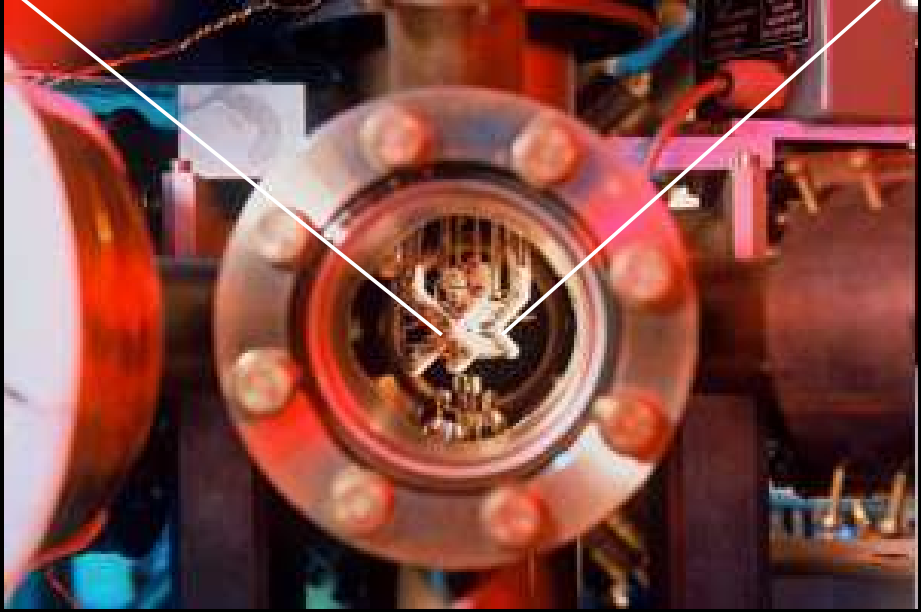
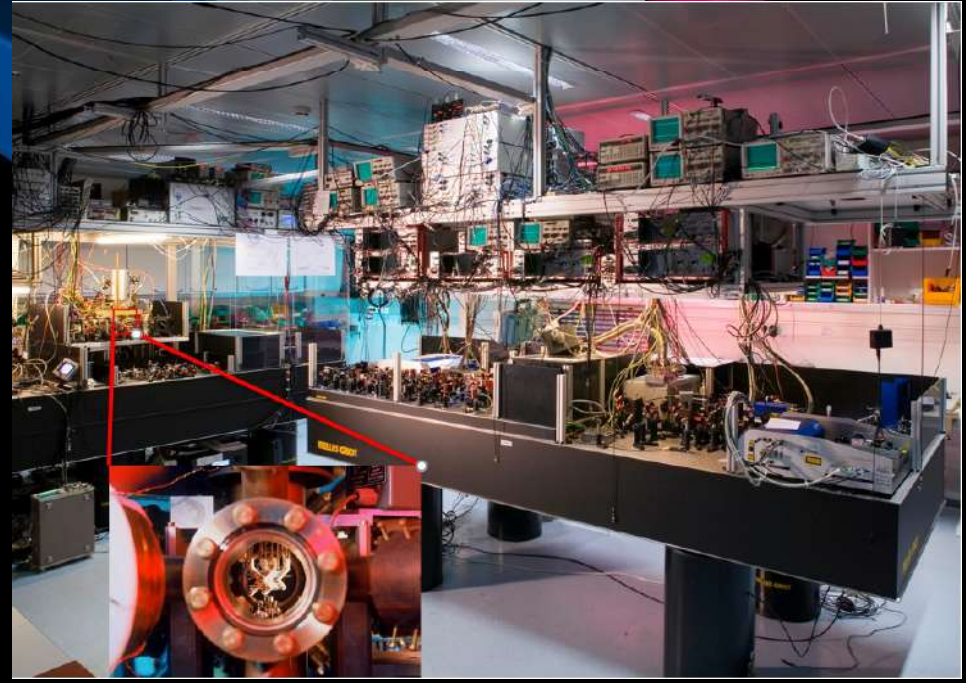




# THE Ion-trap PLATFORM



Ion Trap Quantum Computing Research, Dept. of Phys., Univ. Oxford

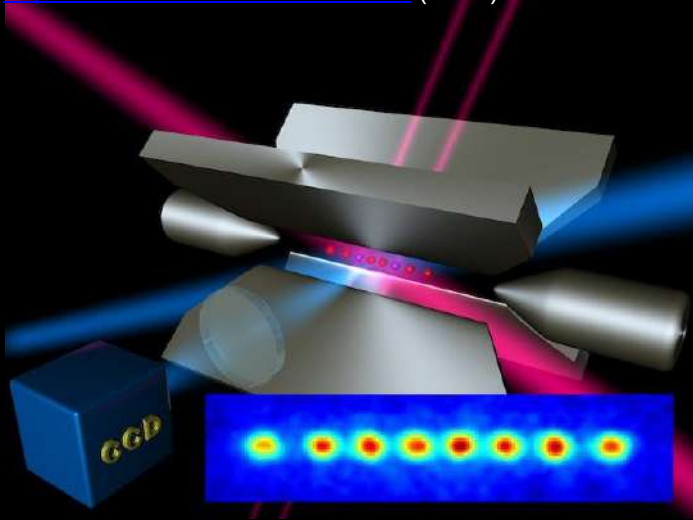


BLATT LAB



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<https://www.laserfocusworld.com> (2014)



## COMPONENTS/EXPERTISE

High-power, narrow line-width lasers at specific UV and visible wavelengths:

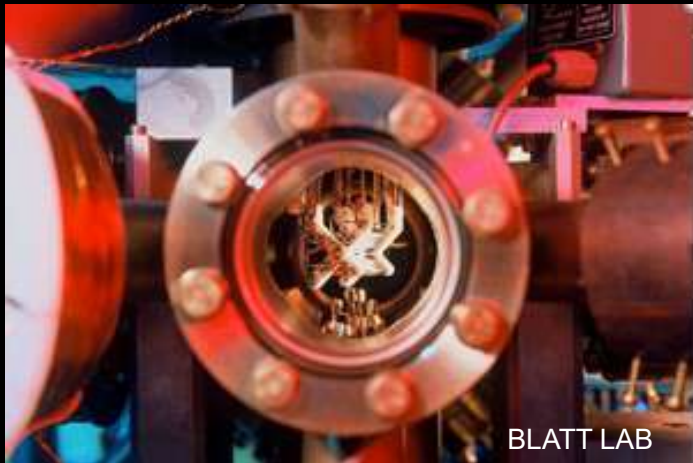
*GaN Technology*

Ultra-high vacuum chambers/components

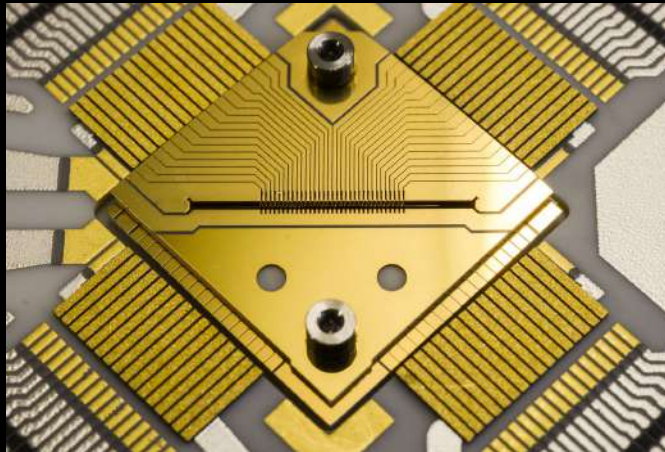
*UHV technology*

MW generators, network analysers etc.

*Microwave electronics*



BLATT LAB



AG SCHMIDT-KALER, JGU, MAINZ

# Ion trap PLATFORM

## CHIP ION TRAP

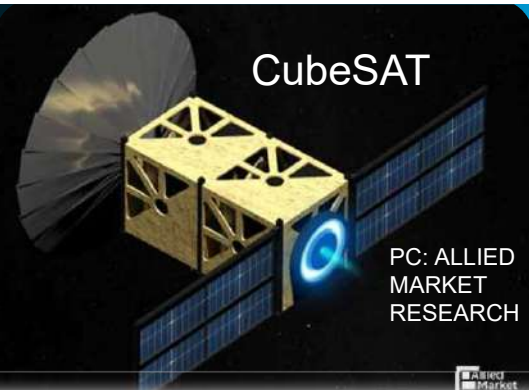
Fabrication depends on MEMS/NEMS and CMOS technologies





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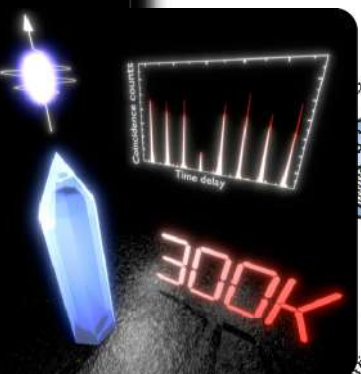
# Quantum Network



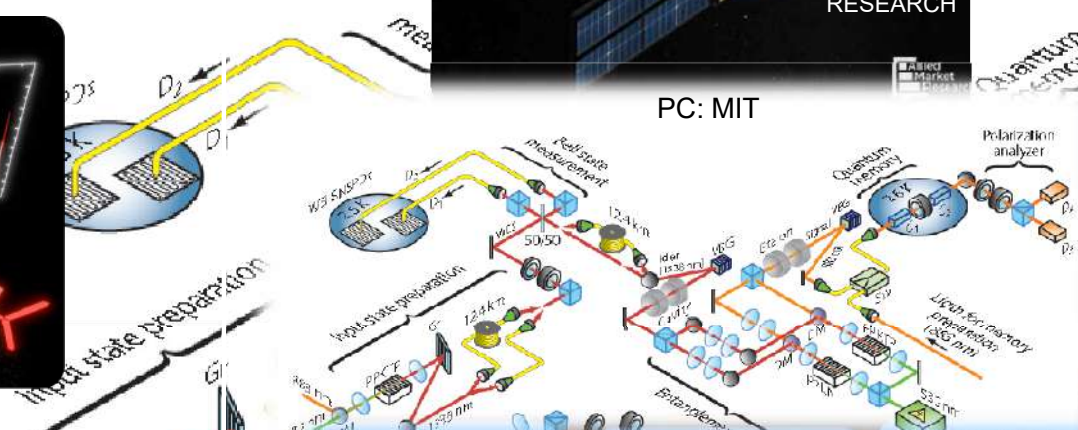
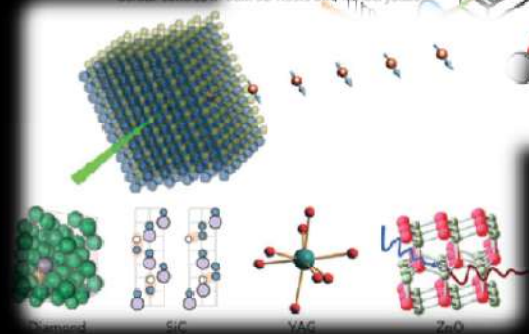
CubeSAT

PC: ALLIED MARKET RESEARCH

SINGLE PHOTON SOURCE



GaN QD-LED ARAKAWA



**Silicon 10G Modulators**  
 driven with on-chip circuitry  
 highest quality signal  
 low loss, low power consumption

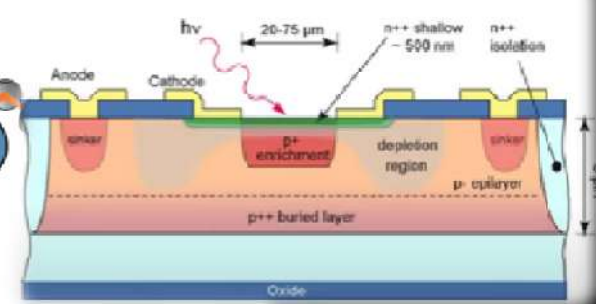
**Flip-chip bonded lasers**  
 wavelength 1550nm  
 passive alignment  
 non-modulated = low cost/reliable

**Silicon Optical Filters - DWDM**  
 electrically tunable  
 integrated w/ control circuitry  
 enables >100Gb in single mode fiber

**Complete 10G Receive Path**  
 Ge photodetectors  
 trans-impedance amplifiers  
 output driver circuitry

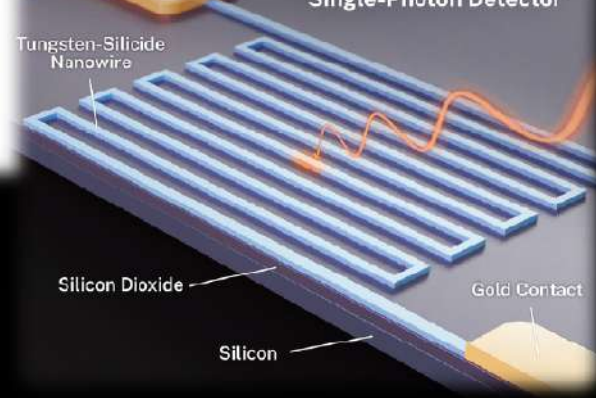
**Integrated Silicon Photonics,**  
 PC: Luxtera

## SINGLE PHOTON DETECTOR



Light for memory preparation (883 nm)

Superconducting Nanowire Single-Photon Detector



PC: NIST

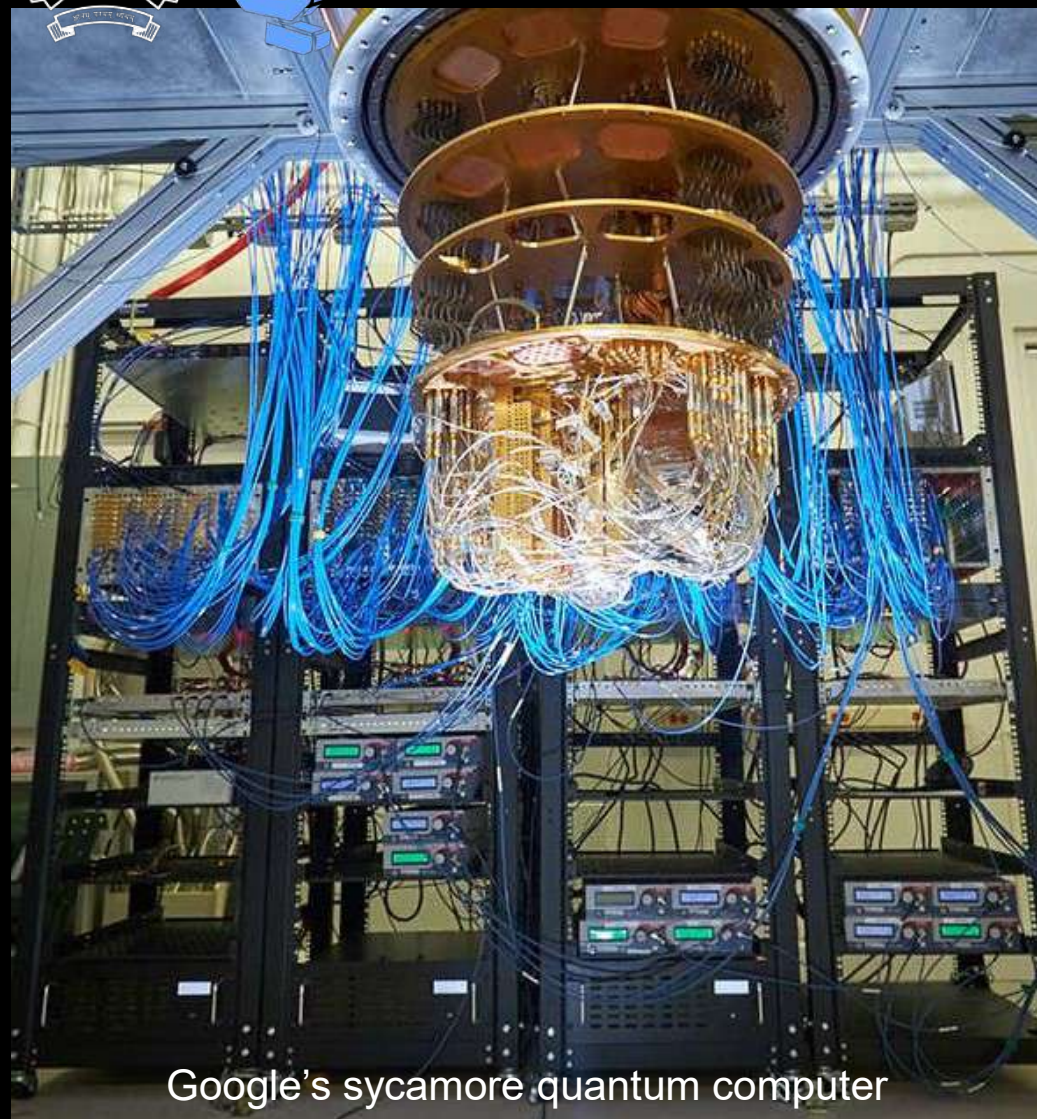




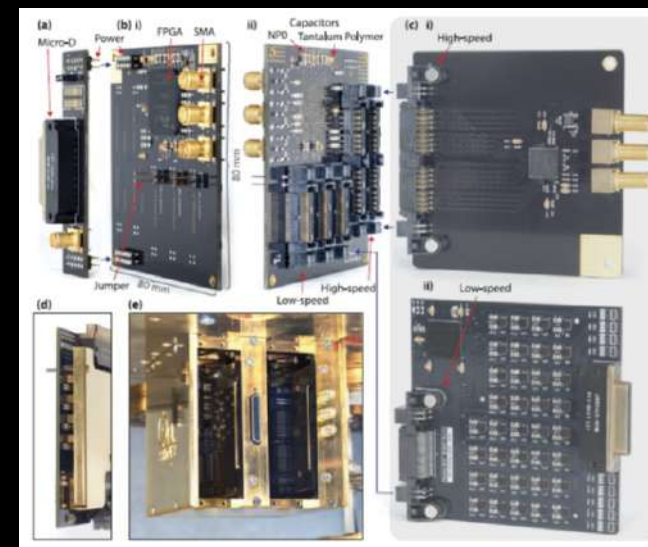
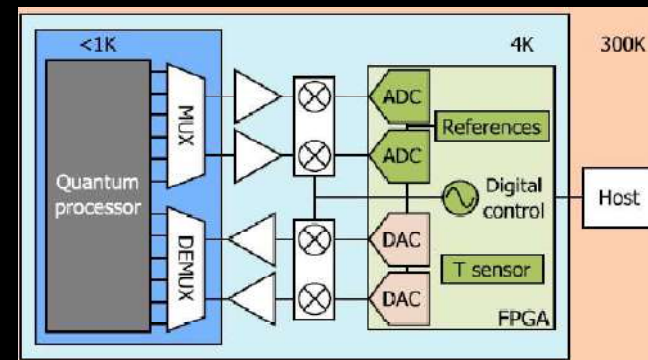
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# CONTROL ELECTRONICS

FPGA-based DSP platform for cryogenic temperatures



Google's sycamore quantum computer



D J REILLY ET AL., 2016, PRATI et al., 2017



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IBMQ DILUTION  
REFRIGERATOR

**Thank you**