



Research Publications and Conference Proceedings

- 1 Singh, A. K., **Utkarsh** et al. (2024). Interplay of plasmonics and strain for hexagonal boron nitride emission engineering. arXiv: 2401.11428 [physics.optics]
- 2 **Utkarsh**, Singh, A. K., & Kumar, A. (2024). Plasmonic enhancement of strain-activated room-temperature SPEs in few-layer hBN. In *SPIE Photonics West 2024 oral presentation*. (in press), San Francisco, California, U.S.
- 3 **Utkarsh**, Singh, A. K., & Kumar, A. (2023). Plasmonic enhancement of strain-activated room-temperature SPEs in hBN monolayer. In *XXII International Workshop on Physics of Semiconductor Devices 2023*, IIT Madras, India.
- 4 Katla, V., **Utkarsh** et al. (2020). An Approach to Star Tracker Design for Nano-Satellite Applications. In *National Conference on Small Satellite Technology and Applications*, Trivandrum, India.
- 5 Prasad, A., Prajapati, S., **Utkarsh**, & Badhe, V. (2023). Design and development of a sentence construction game for deaf and hard of hearing (dhh) users: A qualitative usability study.

Education

2019 – Present

🏛 Indian Institute of Technology Bombay

8.63/10 GPA

B. Tech. – M. Tech. Dual Degree, Engineering Physics with a specialization in Nanoscience

Research Experience

- 🏷 **Pulsed Echo Measurements for the Quantum Spin Liquid phase in 1T – TaS₂** (May '23 - Aug '23)
Guide: Prof. Kimberly Modic TQM, IST Austria

 - Studied the **theoretical signatures of QSL** phase relevant to Pulsed Echo measurements in 1T-TaS₂
 - Implemented the **Plasma Focused Ion Beam** technique to structure **O(10 μm)** size lamellae in Si
 - Successfully simulated and verified the propagation of RF sound waves in a cubic Si crystal implementing a single ZnO transducer as the transmitter and receiver and producing associated electrical signals
 - Worked towards realising **shear wave ZnO transducers** deploying **RF magnetron sputtering**
 - Deployed and optimised **polishing** and **tape-exfoliation** techniques on 1T-TaS₂ to obtain smooth crystal surfaces for high quality sputtering of **ZnO transducers**
 - Learnt and performed **Laue diffraction** to devise the crystallographic planes for polishing, and also learnt about high frequency **RF probes** for **low temperature - high field measurements**
- 🏷 **A Monolithic Platform for Strong Coupling of SPEs to a BIC Cavity** [Abstract] (Jul '23 - Present)
Guide: Prof. Anshuman Kumar LOQM Lab, Department of Physics, IIT Bombay

 - Reviewed the existing literature on the **strong coupling** of SPEs to BIC cavities, their topological nature, and the induced fluorescence enhancement to optimise BIC cavity structure for the visible spectrum
 - Optimising parameters for **ion implantation** to induce **visible** and **IR quantum emitters** in pristine hBN multilayers, also implementing chemical activation by **polar solvents** developing on previous works
 - Performing numerical simulations in **COMSOL** to study a variety of BIC structures and their corresponding resonances, further developing the coupling of SPEs to study the variations in fluorescence
 - Optimising a **Ga⁺-FIB** system to fabricate **O(10²) nm** BIC arrays in hBN crystals to achieve **O(eV)** tunability in the BIC resonance energies and minimum (~ 10 nm) variance in structure design
 - Setting up an **automated confocal setup** for **g²(τ)** and **Photoluminescence** mapping
- 🏷 **Josephson Effects and Topological Superconductors: Simulations & Review** [Report] (Jan '23 - May '23)
Guide: Prof. Bhaskaran Muralidharan CNQT, IIT Bombay

 - Studied the **BCS formalism** of superconductivity to understand the **AC and DC Josephson effects**
 - Reviewed the literature on **Majorana Zero Modes** and the **Kitaev model**, ultimately studying the implementation of MZMs on a **Rashba Nanowire** in proximity to an s-wave superconductor with a B-field
 - Studied **quantum transport** and applied the formalism of **NEGF** to simulate S-N-S and S-I-S Josephson Junctions and thus understanding the **2π and 4π Josephson effects** in relation to topological superconductors

- **Arbitrary Waveform Generation for Si-Quantum Dot Qubit Control** [Presentation] (May '22 - Jan '23)
 Guide: Prof. Suddhasatta Mahapatra Q-Si Lab, Department of Physics, IIT Bombay
 - Lead a team of three, developed **QCoDeS** drivers to control an **Arbitrary Waveform Generator**, a **Vector Signal Generator**, and associated equipment to engineer **RF pulses** for quantum control of spin qubits
 - Performed I-V measurements on **Si-MOSFET Hall probes** for quality check of dopant implantation, oxide integrity, ohmic contacts, etc. in the fabricated heterostructures
 - Studied the working of a **dry dilution refrigerator**, to be used for low-temperature experiments
 - Studied sensing and measurement techniques used for **quantum control** of quantum dots based spin qubits in silicon heterostructures

- **Plasmonic Nanoantennas for Strain Engineering of SPEs in 2D hBN** [Report] (Jul '22 - Dec '23)
 Guide: Prof. Anshuman Kumar LOQM Lab, Department of Physics, IIT Bombay
 - Performed literature review of the properties and theoretical understanding of SPEs in hBN.
 - Prepared **monolayer samples** of hBN with **tape exfoliation** and integrated them with **EBL fabricated plasmonic nanostructures** via a PDMS assisted **dry transfer method**
 - Analysed hBN samples via **Raman Spectroscopy** confirming the presence of monolayers. Analysed the **PL map** of monolayer hBN over the nanostructures and studied the surface topography with **AFM**
 - Contributed to setup **in-house PL mapping**, imaging, and $g^{(2)}$ and **lifetime measurements**
 - Performed **FDTD** simulations for plasmonic nanoantennas on Si substrate with and without hBN

- **Entanglement Entropy in Coupled Harmonic Oscillator Systems** [Report] (Aug '21 - Apr '22)
 Guide: Prof. Shankaranarayanan S Department of Physics, IIT Bombay
 - Studied the **zero-mode divergence** in entanglement entropy in a coupled harmonic oscillator and worked on understanding the contribution of high energy eigenstates to the divergence of entanglement entropy
 - Studied the relation between zero-mode divergence and **space-time curvature** and the **EUP**

- **Quantum Many-Body simulations with Machine Learning** (May '21 - Feb '22)
 Guide: Prof. Nilmani Mathur Department of Theoretical Physics, TIFR
 - Conducted literature survey on the applications of **Tensor Networks** and implementation of **MPS** and **PEPS** as numerical ansatz for approximating interesting quantum many-body wave-functions
 - Implemented **importance sampling** in Monte Carlo for the **2-D Ising model** and **classical XY model** with the **Metropolis** and **Wolff cluster** algorithms and analysed the thermodynamic properties
 - Implemented a **restricted Boltzmann machine** to generate Monte Carlo samples for the 2-D Ising model
 - Learnt about the **inaccuracies in generative machine learning methods** for simulating the phase transitions of the Ising and the XY models

Scholastic Achievements

- | | |
|------|--|
| 2024 | ■ Awarded the Chanakya Postgraduate Fellowship for pursuing Master's research by I-HUB QTF |
| 2023 | ■ Sanctioned a grant of INR 220,000 (~ 2,600 \$) for presenting at SPIE Photonics West 2024
■ Selected for the ISTernship Summer Program at IST Austria among 40 awardees worldwide
■ Selected for the MITACS Globalink Research Internship among 1100 awardees worldwide |
| 2019 | ■ Secured All India Rank 22 in National Entrance Screening Test among 60,000 candidates
■ Achieved 99.10 percentile in JEE Advanced among 2,45,000 eligible candidates
■ Achieved 99.74 percentile in JEE Main out of 1.2 million candidates |

Projects

- **Optical Investigation of Shape and Size-controlled Silver Nanoparticles** [Report] (Jan '23 - Present)
 Guide: Prof. Mohd. Aslam Department of Physics, IIT Bombay
 - Prepared **Ag nanoparticles** using the **Polyol method** for better control on the particle size
 - Characterised the **surface plasmon absorption** in Ag NPs using **UV-Vis spectroscopy**
 - Learnt **PVD**, **AFM** and **SEM** for further extension of the project and characterization of the sample

- Gamma-ray Spectroscopy | Instrumentation Subsystem | GLEE | IITBSSP**
A global mission that aims to conduct science and test technology on the surface of the moon using chipsats

 - Conducted extensive literature survey on the **Lunar radiation environment** and related missions
 - Analysed possibilities for onboard detection of **alpha particles, neutrons** and **X/ γ -rays** using **PIN diodes, SDDs, SiPMs, CMOS** and **CCD** detectors given the stringent power and space requirements of LunaSats
 - Designed a **small, low-powered gamma-ray spectroscopy system** for the **5 × 5 cm²** chip with PIN diodes and devised the testing, simulation, and calibration plan, incorporating the various possible effects of radiation on the circuit and **guided two students** in the design and simulation phase

(Feb '21 - Nov '21)
- Lens Module | Instrumentation Subsystem | STADS | IITBSSP**
A CubeSat-compatible Star Tracker-based Attitude Determination System to be tested onboard the PS4-OP

 - Devised **requirements** for compatible lens systems based on **bench-marked performance criteria**
 - Designed, simulated and analysed various **multiple and single-lens systems** in **Zemax OpticStudio**

(Feb '20 - July '20)
- Higher moments of transverse momentum in p-p collisions [Report]**
Guide: Prof. Sadhana Dash

 - Applied the data analysis framework **ROOT** developed by **CERN** to analyse over **two million events** generated using **PYTHIA 8** for p-p collisions at 13 TeV center of mass energy
 - Confirmed **positive skewness** via higher moments of transverse momentum for various multiplicities

(Oct '20 - Dec '20)
Department of Physics, IIT Bombay
- Transverse Spinning of Unpolarised Light**
Guide: Prof. Anshuman Kumar

 - Studied the formulation of **evanescent waves** and **Gaussian beams** generated by unpolarised sources
 - Confirmed the existence of the transverse spin angular momentum from respective **coherency matrices**
 - Reproduced the **spin angular momentum density plots** for a Gaussian beam

(Jan '21 - Apr '21)
Department of Physics, IIT Bombay
- Coherent State Representation of Photons [Report]**
Guide: Prof. Urjit Yajnik

 - Derived the coherent states for a harmonic oscillator and the **vacuum distribution** for a scalar field with the corresponding creation and annihilation operators
 - Related the **plane-wave photon state** with the coherent state representation of the quantum field

(May '22)
Department of Physics, IIT Bombay
- Piano Man : Portable Piano on a Glove [Presentation]**
Guide: Prof. Varun Bhalerao

 - Implemented a **position based note selection algorithm** on an **Arduino Uno** using an **U/S sensor**
 - Integrated an **LCD** display, along with an **ROM** to **read-write** the sequence of notes being played

(Sep '21 - Oct '21)
Department of Physics, IIT Bombay

Positions of Responsibility

Teaching Assistant, Department of Physics, IIT Bombay

- Spring '24

General Physics Lab

 - Responsible for assisting students with the **Fresnel's biprism experiment**, clearing conceptual doubts, testing their understanding and grading lab reports
- Autumn '23

Analog Electronics Lab

 - Responsible for assisting students with weekly assignments, clearing conceptual doubts, debugging circuits and grading lab assignments
- Autumn '20

Quantum Physics and Applications

 - Conducted tutorial and doubt clearing sessions, weekly tests, and graded answer books of 40+ undergraduate freshmen

Student Satellite Team, IIT Bombay

- May - Nov '21

Subsystem Head | Instrumentation Subsystem

 - Guided a **14-member inter-system team** towards best instrument integration practices
 - Executed **three-step recruitment process** to short-list and mentor **8 students** from **50+ applicants** by evaluating their technical ability, practical approach and teamwork

Skills

Programming	C++, Matlab, Python - (PILPython, QCoDeS, NumPy, Matplotlib, pandas), VHDL, Arduino IDE
Software	Mathematica, COMSOL, Ansys- Lumerical FDTD, ROOT, Qiskit, LTSpice, OriginLab, Quartus
Experimental	Xe and Ga Plasma Focused Ion Beam and SEM, Laue diffraction, Dillution Refrigerator
Experience	Photoluminescence spectroscopy, Photon Correlation Study, Laser alignment, Raman Spectroscopy, Atomic Force Microscopy, Scanning Electron Microscopy, Physical Vapor Deposition, UV-Vis Spectroscopy

Courses

Physics	Quantum Mechanics I and II, Quantum Transport, Semiconductor Physics, Quantum Information and Computing, Quantum Optics, Methods in Material Characterisation, Nanoscience: Introduction to Fabrication, Atomic and Molecular Physics, Statistical Physics, Electromagnetic Theory, Photonics, Introduction to Condensed Matter Physics
Mathematics	Calculus, Linear Algebra, Real Analysis, Introduction to Numerical Analysis, Complex Analysis, Differential Equations
Labs	Nanoscience Characterisation Techniques, Solid State and Nuclear Physics, Optics and Spectroscopy, Analog Circuits, Op-amp Circuits, Digital Electronics, Microprocessors

Extracurricular

Social service	<ul style="list-style-type: none">Received a special mention for exemplary volunteering work under the department of Sustainable Social Development, NSS, IIT Bombay completing 80+ hours of social workVisited SNJB College, Nashik representing Department of Sustainable Social Development, NSS and interacted with the students and professors and demonstrated experiments to school students
Workshops	<ul style="list-style-type: none">Completed Quantum Computing Workshop organised by MnP Club IIT BombayCompleted Astrophysics Workshop organised by Krittika: The Astronomy Club and TechfestCompleted Learner's Space's Scientific Computation and Mathematical Modelling bootcamp organised by Maths and Physics club IIT Bombay as a part of the Technical Summer School

References

- Prof. Anshuman Kumar
Laboratory of Optics of Quantum Materials (LOQM)
Indian Institute of Technology Bombay
- Prof. Kimberly Modic
Thermodynamics of Quantum Materials (TQM)
Institute of Science and Technology Austria
- Prof. Suddhasatta Mahapatra
Silicon Quantum Computing Lab (Q-Si Lab)
Indian Institute of Technology Bombay