Utkarsh

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🏛 Indian Institute of Technology Bombay

Research Publications and Conference Proceedings

1 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*. (in press), Matsue, Shimane, JAPAN.

2 Singh*, A. K., **Utkarsh***, & Kumar, A. (2023). *Strain induced deterministic single photon emitters in hexagonal boron nitride[†]*.

3 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.　　　　　[†] *Manuscript in Progress*

Education

| 2019 – Present | 🔖 **Indian Institute of Technology Bombay** | 8.48/10 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 $1T - TaS_2$** *(May '23 - Present)*
Guide: Prof. Kimberly Modic 　　　　　　　　　　　　　　　　　　　　　　　　　　*TQM, IST Autria*
- Studied the **theoretical signatures of QSL** phase relevant to Pulsed Echo measurements in $1T - TaS_2$
- Implemented the **Plasma Focused Ion Beam** technique to structure $\mathbf{O(10\mu m)}$ 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 reciever 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 $1T - TaS_2$ 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**

🔖 **Topological Control of SPE emission in the strong coupling regime** *(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 flouroscence
- Optimising a **Helios Ga-FIB** system to fabricate $\mathbf{O(10^2)}$ nm BIC arrays in hBN crystals to achieve $\mathbf{O(eV)}$ tunability in the BIC resonance energies and minimum (sub 10 nm) variance in structure design
- Setting up an **automatic confocal setup** for $\mathbf{g^2(\tau)}$ and **Photoluminescence** mapping by synchronising a **ThorLabs NanoMax Stage** with a **PicoQuant MultiHarp 150** and a **Kymera 328i Spectrograph**

🔖 **Josephson Effects and Topological Superconductors: NEGF Simulations and Review** *(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 $\mathbf{2\pi}$ **and** 4π **Josephson effects** in relation to topological superconductors

Arbitrary Waveform Generation for Si-Quantum Dot based Qubit Control *(May '22 - Present)*
Guide: Prof. Suddhasatta Mahapatra   *Q-Si Lab, Department of Physics, IIT Bombay*
- Lead a team of 3, 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 *(Jul '22 - Present)*
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 *(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

Projects

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

Gamma-ray Spectroscopy | Instrumentation Subsystem | GLEE | IITBSSP *(Feb '21 - Nov '21)*
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 cm^2 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

Lens Module | Instrumentation Subsystem | STADS | IITBSSP *(Feb '20 - July '20)*
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**

Piano Man : Portable Piano on a Glove *(Sep '21 - Oct '21)*
Guide: Prof. Varun Bhalerao *Department of Physics, IIT Bombay*
- 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

Higher moments of transverse momentum in p-p collisions *(Oct '20 - Dec '20)*
Guide: Prof. Sadhana Dash *Department of Physics, IIT Bombay*
- 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** for various multiplicities by calculating higher moments of transverse momentum

Transverse Spinning of Unpolarised Light *(Jan '21 - Apr '21)*
Guide: Prof. Anshuman Kumar *Department of Physics, IIT Bombay*
- 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

Coherent State Representation of Photons *(May '22)*
Guide: Prof. Urjit Yajnik *Department of Physics, IIT Bombay*
- 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 corresponding quantum field

Scholastic Achievements

2023	Selected for **ISTernship Summer Program** funded by **OeAD** for pursuing a research internship at **IST Austria** among a total of **40 awardees worldwide**
	Selected among the **top 1100 applicants globally** who were offered funded summer research internship under the **MITACS Globalink scholarship**
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

Positions of Responsibility

May '21 - 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** for the subsystem from **50+ applicants** by evaluating their technical ability, practical approach and teamwork

Teaching Assistant | Department of Physics, IIT Bombay

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

Skills

Programming	C++, Matlab, Python - (PIPython, QCoDeS, NumPy, Matplotlib, pandas), VHDL, Arduino IDE
Software	Mathematica, COMSOL, Ansys- Lumerical FDTD, ROOT, Qiskit, LTSpice, OriginLab, Quartus
Experimental Experience	Xe and Ga Plasma Focused Ion Beam and SEM, Laue diffraction, Dillution Refrigerator 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
- Received a **special mention** for exemplary volunteering work under the department of **Sustainable Social Development, NSS, IIT Bombay** completing 80+ hours of social work
- Visited **SNJB College, Nashik** representing **Department of Sustainable Social Development, NSS** and interacted with the students and professors and demonstrated experiments to school students

Workshops
- Completed **Quantum Computing Workshop** organised by MnP Club IIT Bombay
- Completed **Astrophysics Workshop** organised by Krittika: The Astronomy Club and Techfest
- Completed 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

Miscellaneous
- Submitted a **conference proceeding** in the **International Conference on Advanced Learning Technologies** presenting a **game-based approach** to address difficulty in sentence construction for **DHH students**