Mahadevan Subramanian

(+91)7045289374
mahadevan_s@iitb.ac.in
mahadevans2432.github.io

Research interests

Quantum information processing, quantum technologies

Education

Jul 2019 – Present **Indian Institute of Technology (IIT) Bombay**, Mumbai, India
Bachelor of Technology in **Engineering Physics** (*Expected*: Summer 2023)
Pursuing **Honors** in **Physics** and a **Minor** in **Computer Science and Engineering**
GPA: 9.70/10. Ranked **3rd** in a batch of 49 students pursuing Engineering Physics.

Research Publications and Presentations

- **M. Subramanian**; S. Vinjanampathy, **Variational quantum hypothesis testing**. *Manuscript in progress.*
- **M. Subramanian**, A. Mathew, B. Muralidharan, **Resonant weak-value enhancement for solid-state quantum metrology**. *Under review at PR Applied*, arxiv:2211.17060.
- **M. Subramanian**, A. Mathew, B. Muralidharan, **Resonant tunneling enhanced weak value amplification for solid-state quantum metrology**. *APS March Meeting 2023.* N70.00015.
- **M. Subramanian**, A. Lupascu, **High-fidelity qutrit entangling gates with superconducting circuits based on parametric coupling**. *APS March Meeting 2023. APS March Meeting 2023.* D75.00011.

Research Experience & Key Projects

May 2022 – Present **Creating multi-qudit gates using superconducting transmon qudits**
Guide: Professor Adrian Lupascu, Institute for Quantum Computing, University of Waterloo
- Developed numerical simulations for creating coupling between superconducting transmons using fixed capacitive coupling and a tunable coupling scheme involving mediated coupling with a transmon.
- Demonstrated two families of qutrit entangling gates using parametric coupling with different AC drive frequencies through a tunable transmon mediating coupling between two fixed frequency transmons.
- Obtained a qutrit CZ gate using a low-depth circuit with three of the entangling parametric coupling gates and studied the expressibility of these entangling gates in low-depth circuits.

Feb 2022 – Present **Variational quantum hypothesis testing [report]**
Guide: Professor Sai Vinjanampathy, Dept. of Physics, IIT Bombay
- Studied asymptotic limits for quantum channel discrimination using the Chernoff bound, relative entropy, trace distance, and quantum Fisher information along with the relations between these limits.
- Constructed a variational quantum algorithm with a parameterized state preparation and measurement stage that encodes a Naimark extension of the two-outcome positive operator-valued measure (POVM).
- Proposed a method to evaluate error probability of discrimination using a single-qubit measurement which is used as the objective function to optimize and furthermore estimate the diamond distance.
- Simulated the algorithm for quantum illumination using parameterized continuous-variable quantum circuits and matched the performance of the theoretically optimal two-mode squeezed vacuum state.

Jan 2022 – Nov 2022 **Resonant tunneling based solid-state quantum sensor [preprint]**
Guide: Professor Bhaskaran Muralidharan, Dept. of Electrical Engineering, IIT Bombay
- Conceptualized a solid-state spintronic setup for the detection of Zeeman splitting that uses weak value amplification which is a result of using the energy channels that can do resonant tunneling.
- Performed simulations using the Keldysh (NEGF) method to benchmark the transport signal from the setup and observed noticeable signatures at the resonant tunneling energy values of the barrier setup.
- Analytically derived the quantum Fisher information (QFI) for the sensing task and compared it with the classical Fisher information (CFI) from measurements and observed that the resonant tunneling energy channels have CFI almost approach QFI demonstrating optimality of these channels for sensing.

Jul 2021 – Jan 2022 **Qudits for efficiently generating higher moments of Hermitian operators [report]**
Guide: Professor Sai Vinjanampathy, Dept. of Physics, IIT Bombay

- Proposed a method for generating higher moments of Hermitian operators using a block encoding to encode the Hermitian operator as part of a unitary in a larger dimensional Hilbert space.
- Demonstrated that given any block encoding of a Hermitian operator, higher moments can be obtained using arbitrary controlled n-qubit unitaries, which are realized using ququarts with $\mathcal{O}(n)$ overhead.
- Studied quantum error correction theory for qudits which allow for certain optimal codes not possible in qubits and analyzed concatenation success probabilities for the 5-qubit code.

Mar 2021 – Jul 2021 **State population transfers using Rabi Oscillations [report]**
Guide: Professor Barak Dayan, Weizmann Institute of Science

- Accurately calculated proportionality between intensity of EM waves required for a certain Rabi frequency for hyperfine levels of Rubidium 87 based on literature on existing experiments.
- Simulated a 25μs adiabatic state population transfer with 99.5% efficiency using Rabi pulses with peaks of 100 MHz and 10 MHz and 1 GHz single photon detuning and 2.18 MHz two photon detuning.
- Prepared a generalized framework in Python using QuTip to simulate and optimize parameter choices for a N-level chain STIRAP (stimulated Raman adiabatic passage) and cavity-STIRAP.

Scholastic Achievements

- Awarded the **Institute Academic Prize** (IIT Bombay) for exemplary academic performance in the academic years 2020-21 and 2021-22.
- Recipient of the **Mitacs-Globalink Research Internship award** (2022) to pursue a funded research internship in Canada.
- Selected for the **DAAD-WISE scholarship** (2022) for pursuing a guided research project in Germany.
- Joint Entrance Exam (JEE) 2019 for admission to Indian Institutes of Technology
  - Achieved 99.58 percentile in JEE Advanced among 200,000 participants.
  - Achieved 99.91 percentile in JEE Mains amongst 1.5 million students across India.
- Selected for a competitive national academic fellowship (KVPY) for pursuing basic sciences (2018).

Other Projects

Mar 2021 – Apr 2021 **Transport across Graphene - understanding electronic optics [report]**
Guide: Professor Bhaskaran Muralidharan, Course: Quantum Transport in Nanoscale devices

- Studied quantum transport in Graphene and obtained conductance quantization from simulations using the Keldysh non equilibrium Greens functions method.
- Simulated and studied Klein tunneling, an optical like behavior of electrons due to dirac-cone like band structure of Graphene and also studied theoretical explanations involving chirality for the same.

Oct 2020 – May 2021 **Reading Project on Quantum Simulations [report]**
Guide: Professor Alok Shukla, IIT Bombay

- Explored physical implementations of Bose Hubbard hamiltonian using atoms and ions to observe phase transitions, and NMR spectroscopy for ground state energy calculation of the hydrogen molecule.
- Reviewed Variational Quantum Eigensolvers and their applications in simulations of molecules and a modified version of VQE called ctrl-VQE which optimizes pulse shapes instead of circuit parameters.
- Studied Hartree-Fock theory and Configuration Interaction (CI) theory including methods for reducing the CI space and vectorized algorithms for Full CI.

Apr 2020 – Aug 2020 **Literature review of measurement theory in quantum mechanics [report]**
Guide: Professor Amber Jain, IIT Bombay

- Reviewed different interpretations of quantum mechanics including Bohmian mechanics, many worlds interpretation, Ghirardi–Rimini–Weber theory and experiments aimed at distinguishing between them.
- Examined certain experiments that aimed to find the quantum to classical transition point according to the Ghirardi–Rimini–Weber and Continuous Spontaneous Localization models.

Summer schools attended

June 2022 **Undergraduate school of experimental quantum information processing**
Institute for Quantum Computing (IQC), University of Waterloo
- Attended a summer school with theoretical lectures given by IQC faculty on broad subgroups of quantum information including quantum algorithms, trapped ions, superconducting quantum circuits and photonic quantum computers.
- The experimental part of the school included working in the low temperature lab, fabrication in a cleanroom, verifying quantum entanglement and conducting experiments on a 2 qubit NMR machine.

Positions of Responsibility

Jun 2021 – Apr 2022 **Department Academic Mentor**
Department Academic Mentorship Program, IIT Bombay
- Mentored 8 sophomores in the department, providing academic guidance and general counseling.
- Involved in bridging the student-faculty gap and taking up activities promoting student interaction.

May 2021 – Apr 2022 **Maths and Physics Club, IIT Bombay**
Institute Technical Council, IIT Bombay
Manager
- Led a team of 5 conveners towards fostering the enthusiasm of 500+ students in physics and math and having an outreach of 10,000+ enthusiasts online.
- Organized several institute-wide competitions, group discussions and lectures to promote interest in and maintain an enthusiastic community for mathematics and sciences.

Moderator, Quantum Computing workshop [workshop repo] (Aug 2020)
- Developed course content for an 8-day workshop on Qiskit and teaching the basics of quantum computing which attracted 500+ students from multiple universities across India. Held hands on sessions explaining basic quantum algorithms such as the quantum fourier transform.

Dec 2020 – Mar 2021 **Teaching Assistant, PH 107 (Quantum Physics and Application)**
Instructor: Prof. CV Tomy, Department of Physics, IIT Bombay
- Conducted tutorials for a class of 40 students and guided them with their coursework.
- Conducted and evaluated quizzes for the course and held doubt sessions when necessary.

Technical Skills

- **Languages:** Python, Mathematica, C++
- **Packages & Softwares:** QuTip, NumPy, SciPy, Matplotlib, SymPy, Qiskit
- **Others:** HTML, CSS, AutoCAD, Solidworks, Arduino IDE

Relevant Courses

- **Physics :** Quantum Information & Computing, Introduction to Atomic & Molecular Physics, Quantum Transport in Nanoelectronic Devices, Introduction to Condensed Matter Physics, Electromagnetic Theory, Statistical Physics, Photonics, Quantum Mechanics I & II, Group Theory Methods in Physics
- **Computer Science :** Introduction to Machine Learning, Design and Analysis of Algorithms, Data Structures & Algorithms, Logic for Computer Science, Computer Programming and Utilization
- **Math :** Numerical Analysis, Complex Analysis, Partial Differential Equations, Linear Algebra, Calculus
- **Other :** Optics & Spectroscopy lab, Solid State & Nuclear Physics lab, Electronic labs - Digital, Microprocessors & Analog, Data Analysis and Interpretation, Digital Systems, Economics, Physical Chemistry

Extracurricular Activities

- Composed the background score for the Radio-play "Madhud", which won third place in Saarang (cultural festival of IIT Madras)
- Composed an original score for IIT Bombay's first Radio-play - "Atithi", released on Spotify.
- Composed two original songs as part of an Institute Cultural Summer Project during the summer of 2020, that have been released on various streaming platforms under Symphony, music club of IIT Bombay.
- Performed keyboard in Surbahaar, an annual musical event in IIT Bombay with an audience of 2,000, as well as various inter-hostel music competitions.

References

- **Dr. Sai Vinjanampathy**
  Associate Professor, Department of Physics
  Indian Institute of Technology Bombay
  email: sai@phy.iitb.ac.in

- **Dr. Bhaskaran Muralidharan**
  Professor, Department of Electrical Engineering
  Indian Institute of Technology Bombay
  email: bm@ee.iitb.ac.in

- **Dr. Adrian Lupascu**
  Associate Professor, Department of Physics & Astronomy
  University of Waterloo
  email: alupascu@uwaterloo.ca