Mahadevan Subramanian

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Research interests

Quantum information, NISQ algorithms, Hybrid Quantum Devices and Circuit Quantum Electrodynamics.

Education

Jul 2019 – Present — **Indian Institute of Technology, Bombay**, *CGPA: 9.72/10*, Engineering Physics
Pursuing **Honors** in **Physics** and a **Minor** in **Computer Science and Engineering**

Research Publications

- **Subramanian, Mahadevan**; Muralidharan, Bhaskaran, **Resonant-tunneling enhanced weak-values for solid-state quantum metrology**. *Manuscript in preparation.*

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.
- Studied the properties of the family of gates generated by the capacitive couplings in the circuit and explored the variations in the higher level exchanges in the tunable coupling scheme.
- Conducted a bound optimization of circuit parameters to enable complete idling of 2-qutrit operations in the tunable scheme and demonstrated that for certain capacitive coupling generators, one can construct expressible ansatzes with nearly equal performance to qutrit CZ and for obtaining arbitrary unitaries.

Feb 2022 – Present
A variational quantum algorithm for Ramsey interferometry like tasks
Guide: Professor Sai Vinjanampathy, Dept. of Physics, IIT Bombay
- Studied asymptotic limits for quantum channel discrimination in relation with Chernoff bounds, quantum Fisher information, relative entropy and trace distance in symmetric and assymetric hypothesis testing.
- Constructed an ansatz for a variational quantum algorithm with a state preparation stage followed by an unknown operation associated with a continuous parameter and finally a measurement stage.
- The cost function of the optimization is the trace distance between two values of the continuous parameter and measurement stage uses only single qubit measurements for estimation of trace distance.
- Conducting circuit optimizations taking different quantum channels between the state preparation and measurement stages.

Dec 2021 – Present
Resonant-tunneling enhanced weak-values for solid-state quantum metrology
Guide: Professor Bhaskaran Muralidharan, Dept. of Electrical Engineering, IIT Bombay
- Conceptualized a solid state spintronic setup for the detection of magnetic fields which has enhanced sensitivity as a result of using the energy channels that are capable of performing resonant tunneling.
- Performed simulations using the Keldysh (NEGF) method to benchmark the signal which the setup gives and observed noticeable signatures for the resonant tunneling energy values of the barrier setup.
- Analytically derived the quantum fisher information for the sensing task and compared with the classical fisher information from measurements and observed that classical fisher information almost approaches quantum fisher information at the resonant states.

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 which uses block encoding into larger dimension unitaries.
- Demonstrated that to get efficiently higher moments of a Hermitian operator given a block encoding of it we can use ququarts since we need arbitrary controlled n-qubit unitaries, which have been realized using ququarts with $\mathcal{O}(n)$ overhead in operations.
- 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 and an encoding for qudits.

Mar 2021 – **State population transfers using Rabi Oscillations** [report]
Jul 2021   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 $25\mu s$ 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 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.
- Secured **Department Rank 3** (of 51 students) after first 3 years of B.Tech   *May 2022*
- Recipient of the **Mitacs-Globalink Fellowship** to pursue a funded research internship in Canada. *Mar 2022*
- Selected for the **DAAD-WISE scholarship** for pursuing a guided research project in Germany. *Mar 2022*
- **Joint Entrance Exam**
  - Achieved 99.58 percentile in JEE Advanced among 200,000 participants.   *May 2019*
  - Achieved 99.91 percentile in JEE Mains amongst 1.5 million students across India.   *Apr 2019*
- Recipient of the esteemed Kishore Vaigyanik Protsahan Yojana (KVPY) Fellowship from IISc.   *May 2018*

━━━ Other Projects

Mar 2021 – **Transport across Graphene - understanding electronic optics** [report]
Apr 2021   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 – **Reading Project on Quantum Simulations** [report]
May 2021   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 theory including methods for reducing the CI space and vectorized algorithms for Full CI.

Mar 2021 – **Bell's measure of classical optical coherence** [executable paper]
Apr 2021   Prof: Anshuman Kumar, Course Project, Waves, Oscillations and Optics
- Using python, demonstrated how Bell's measure can be used as a metric to quantify coupling of degrees of freedom in a beam of light hence demonstrating a classical analogue of quantum entanglement using polarization and parity.
- Proved two qubit universality for the system of the two DOFs of polarization and parity of the light beam.

Sep 2020 – **Resynchronization of circadian oscillators, east-west asymmetry of jet-lag** [report]
Nov 2020   Prof: Amithabha Nandi, Course Project, Non-linear Dynamics
- Modelled suprachiasmatic nucleus cells using of the Forced Kuramoto model and studying the east-west asymmetry of jet-lag by simulating this model.
- Extended the model to account for continuous travel instead of instantaneous and observed slightly varying dynamics.

Apr 2020 – **Literature review of measurement theory in quantum mechanics** [report]
Aug 2020   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 which 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, University of Waterloo
- Among 30 students who were selected to attend this 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 counselling.
- 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, guiding and mentored 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:** Qiskit, QuTip, NumPy, SciPy, Matplotlib, SymPy, Pandas, TensorFlow, ROOT
- **Others:** HTML, CSS, AutoCAD, Solidworks, Arduino IDE

▬▬ Relevant Courses

- **Physics :** Quantum Information & Computing, Quantum Transport in Nanoelectronic Devices, Methods in Analytical Techniques*, Introduction to Condensed Matter Physics, Introduction to Atomic & Molecular Physics*, Introduction to Nuclear & Particle Physics*, Electromagnetic Theory, Statistical Physics, Photonics, Quantum Mechanics I & II, Group Theory Methods, Waves & Oscillations & Optics
- **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

*Courses marked with a * will be completed in Autumn 2022*

▬▬ Extracurricular Activities

- Composed a background score for the Radio-play "Madhud" which won third place in Saarang (IIT Madras's cultural festival)   *Feb 2021*
- Composed an original score for IIT Bombay's first Radio-play - "Atithi", released on Spotify.   *Jan 2021*
- **Institute Cultural Summer Project**   *Aug 2020*
  - Composed two original songs using a digital audio workstation which have been released on various streaming platforms under **Symphony**, music club of IIT Bombay.
- **Goonj GC, Music Arcade GC** (inter-hostel music competitions)   *Feb, Mar 2020*
  - Performed keyboard in Goonj GC and arranged an original piece that was performed by our band.
  - Secured 2nd position in Music Arcade GC and was awarded best keyboardist.
- Performed keyboard in Surbahaar, an annual musical event in IIT Bombay with an audience of 2,000 people