Cornell Quantum Day
Book of Abstracts
(July 31, 2025)

Oral Presentations

Speaker: Kevin Chou
Institution and Position: Quantum Circuits, Inc.
Title: Demonstrating high-fidelity operations using dual-rail cavity erasure qubits
Abstract: Erasure qubits have re-emerged as a strategy to significantly reduce hardware requirements for quantum error correction through both higher thresholds and more favorable logical error suppression with increasing code distance. Such erasure qubits are designed to 'self-report' most of their errors without the need for additional ancilla qubits. We will show how to realize erasure qubits using a simple superconducting cavity-based dual-rail encoding. In this dual-rail cavity qubit we encode a qubit in the single-photon manifold of two cavity modes. The dominant error channel is single photon loss to the vacuum state which can be efficiently detected, converting this photon loss error into an erasure-like error. The residual dephasing and bit-flip Pauli errors in our system are much rarer, with error rates at least an order of magnitude smaller than our photon loss rates. This strong hierarchy of errors is necessary for our dual-rail cavity qubits to perform well in a quantum error correction setting such as in a surface code. We also describe a new controlled-Z gate, which uses an auxiliary transmon-based coupler as a source of dispersive coupling between two dual-rail qubits. We benchmark this gate and experimentally show that it has high-fidelity and low-erasure rates, while also exhibiting a rather novel error 'asymmetry', whereby the control qubit suffers from more decoherence than the target qubit, leaving the target qubit mostly error-free. We show how to leverage this error asymmetry for error correction. Finally, we combine all these operations into a multi-qubit system and show some early results experiments on a system comprising of five dual-rail cavity qubits. We perform logical state preparation and measurement operations in a distance-2 surface code, showing how the code can correct for a single erasure and detect a single Pauli error.

Speaker: Mark M. Wilde
Advisor(s): Associate Professor, Electrical and Computer Engineering
Title: Quantum thermodynamics and semi-definite optimization

Abstract: In quantum thermodynamics, a system is described by a Hamiltonian and a list of non-commuting charges representing conserved quantities like particle number or electric charge, and an important goal is to determine the system's minimum energy in the presence of these conserved charges. In optimization theory, a semi-definite program involves a linear objective function optimized over the cone of positive semi-definite operators intersected with an affine space. These problems arise from differing motivations in the physics and optimization communities and are phrased using very different terminology, yet they are essentially identical mathematically. By adopting Jaynes' mindset motivated by quantum thermodynamics, I'll discuss how minimizing free energy in the aforementioned thermodynamics problem, instead of energy, leads to an elegant solution in terms of a dual chemical potential maximization problem that is concave in the chemical potential parameters. As such, one can employ standard (stochastic) gradient ascent methods to find the optimal values of these parameters, and these methods are guaranteed to converge quickly. At low temperature, the minimum free energy provides an excellent approximation for the minimum energy. I'll then show how this Jaynes-inspired gradient-ascent approach can be used in both classical and quantum algorithms for minimizing energy, and equivalently, how it can be used for solving semi-definite programs, with guarantees on the runtimes of the algorithms. The approach discussed here is well grounded in quantum thermodynamics and, as such, provides physical motivation underpinning why algorithms published fifty years after Jaynes' seminal work, including the matrix multiplicative weights update method, the matrix exponentiated gradient update method, and their quantum algorithmic generalizations, perform well at semi-definite optimization tasks. Joint work with Nana Liu, Michele Minervini, and Dhrumil Patel.

Speaker: Asad Bhuiyan
Advisor(s): Chao-ming Jian
Title: Free Fermion Dynamics with Measurements: Topological Classification and Adaptive Preparation of Topological States
Abstract: We develop a general framework for classifying fermionic dynamical systems with measurements using symmetry and topology. We discuss two complementary classification schemes based on the Altland-Zirnbauer tenfold way: (1) the many-body evolution operator (mEO) symmetry class, which classifies fermionic dynamics at the many-body level and generalizes to interacting dynamics, and (2) the single-particle transfer matrix (sTM) symmetry class, which classifies free-fermion dynamics at the single-particle level and connects to Anderson localization physics. In the free-fermion limit, these two frameworks are in one-to-one correspondence and yield equivalent topological classifications of area-law entangled dynamical phases. This leads to a novel dynamical bulk-boundary correspondence: the topology of the dynamical system's spacetime

\textit{bulk} determines the topology of the area-law entangled steady-state ensemble living on its temporal \textit{boundary}. Building on this correspondence, we provide a general realization of topological dynamical phases using Gaussian adaptive circuits. They are designed to prepare and stabilize free-fermion topological states as their steady states in \textit{any} spatial dimension. While circuits with exponentially local operations can stabilize a single topological steady state, those with finite-range operations can reach a topological steady-state ensemble. As a demonstration, we explicitly construct and simulate 2+1d adaptive circuits that realize mEO-class-A topological dynamics. We show that the finite-range versions converge to an ensemble of Chern insulators in □(1) circuit depth. We numerically study the topological phase transitions and dynamical domain-wall modes between different topological dynamical phases in this symmetry class. We also analyze the robustness of our adaptive circuit protocol to coherent noise.

Speaker: Anthony D’Addario
Advisor(s): Gregory Fuchs
Title: Imaging Harmonic Generation in Permalloy using a Scanning Nitrogen Vacancy Center Microscope
Abstract: Spin waves are a promising medium for frequency multiplication, a mechanism where a nonlinear system generates harmonics of the input frequency. Previous work has measured up to 60 harmonics in a soft ferromagnet, NiFe (permalloy), at very small magnetic fields, with nitrogen vacancy (NV) center magnetometry. When driven by an oscillating magnetic field, the permalloy generates coherent magnons at harmonics of the drive frequency, measured via changing photoluminescence signals from NV centers when the magnons' dipolar stray fields match the ground state NV center spin transitions. In this work, we scan a quantum sensor - a single NV center spin - above the sample to measure the strong spatial dependence of the harmonic generation in permalloy. Also, the two NV spin transitions exhibit distinct spatial patterns, suggesting a possible underlying complexity in the mechanisms driving harmonic generation. In addition, we have a method to reconstruct the magnetization structure in the permalloy from two-dimensional stray field measurements taken at a fixed height above it. Using both magnetization reconstruction and micromagnetic simulations, we are investigating whether the spatial variation in harmonic generation correlates with features of the sample’s magnetic configuration, such as domains, domain walls, or demagnetization fields.

Speaker: Matthew LaHaye
Institution and Position: Air Force Research Laboratory, Information Directorate - Principal Research Physicist

Title: Quantum Transduction for Heterogenous Integration of Quantum Information Systems

Abstract: The Quantum Information Sciences (QIS) branch at the Air Force Research Laboratory's Information Directorate (Rome Lab) performs cutting-edge experimental and theoretical research in a multitude of topics at the frontiers of quantum computing and quantum networking. Conducted in support of Air Force strategic objectives in quantum information processing and entanglement distribution, the QIS branch has numerous active research efforts in quantum algorithms and quantum technologies such as trapped-ion systems, integrated quantum photonics, and superconducting quantum circuitry. In this talk, I will give an overview of the research efforts at Rome Lab to develop quantum interconnects between the different quantum technologies (a.k.a. heterogeneous quantum interfaces) and highlight plans to establish a quantum networking testbed for fundamental investigations of entanglement distribution and heterogeneous network design at the recently opened Innovare Advancement Center.

Speaker: Darren Pereira

Advisor(s): Erich Mueller

Title: Kinetic-ferromagnetism-to-antiferromagnetism crossover in Fermi-Hubbard quantum simulators

Abstract: The Fermi-Hubbard model displays a rich variety of quantum phases, despite its simplicity. This model is now accessible to quantum simulators, such as cold atoms trapped in optical lattices. Motivated by experimental capabilities, we numerically study the phenomenon of "kinetic magnetism." We calculate the magnetic correlations that result from the motion of a single particle or hole dopant in the hard-core limit, as the geometry evolves from a square to a triangular lattice. In particular, we perform a high-temperature expansion, which expresses the partition function as a sum over closed paths taken by the dopant. We evaluate this using a sophisticated quantum Monte Carlo approach which is free of finite-size effects and allows us to simulate low temperatures, even in cases where there is a sign problem. For the case of a hole dopant, we find a crossover from kinetic ferromagnetism to kinetic antiferromagnetism as the geometry is tuned from square to triangular, which can be observed in current quantum gas microscopes.

Speaker: Yichen Xu

Advisor(s): Eun-ah Kim

Title: Fault-tolerant protocols through spacetime concatenation

Abstract: We introduce a framework called spacetime concatenation for fault-tolerant compilation of syndrome extraction circuits of stabilizer codes. Spacetime concatenation enables efficient compilation of syndrome extraction circuits into dynamical codes through structured gadget layouts and encoding matrices, facilitating low-weight measurements while preserving logical information. Our framework uses conditions that are sufficient for fault-tolerance of the dynamical code, including not measuring logical operators and preserving the spacetime distance. We construct explicit examples of dynamical codes using this framework, including the dynamical bivariate bicycle code and a dynamical Haah code, while illustrating their fault-tolerant properties. Furthermore, we analyze the classification and resource trade-offs of dynamical codes, demonstrating their adaptability to hardware constraints, including fabrication defects and qubit dropout scenarios.

Poster Presentations

Madison Chin (Wilde Group)
"Constrained free energy minimization for the design of thermal states and stabilizer thermodynamic systems"

Anand Ithepalli (Jena Group)
"Improvements in superconducting microwave resonators and JJs on epitaxial nitride platform"

Hyejin Kim (Kim Group)
"Learning measurement-induced phase transitions using attention"

Haoran Lu (Fatemi Group)
"Kramers-protected hardware-efficient error correction with Andreev spin qubits"

Ziao Wang (Kim Group)
"Spin dynamics of quantum E8 integrable model"

Qin Xu (Fuchs group)
"Cooling and squeezing a microwave cavity state with magnons using an optomechanical-type coupling"