9:00 — 9:30 Bagels and coffee

9:30 — 10:30 “Quantum Tensor Networks on a Trapped-ion Quantum Computer”, Michael Foss-Feig, Quantinuum

Abstract: The ability to selectively measure and reset qubits in real time during a quantum circuit is a crucial ingredient in most approaches to quantum error correction. I’ll review the trapped-ion quantum computing architecture being pursued at Quantinuum and our technical capabilities, and then will discuss how mid-circuit measurement may enable other more near-term algorithms. In particular, I’ll discuss (and show examples of) how some classical tensor-network techniques can be ported onto quantum computers with remarkable efficiency, potentially alleviating some bottlenecks in state of the art classical simulation techniques for many-body quantum systems.

10:45 — 11:45 "The Quantum Fourier Transform Has Small Entanglement", Chris Chen, Caltech

Abstract: The Quantum Fourier Transform (QFT) is a key component of many important quantum algorithms, most famously as being the essential ingredient in Shor's algorithm for factoring products of primes. Given its remarkable capability, one would think it can introduce large entanglement to qubit systems and would be difficult to simulate classically. While early results showed QFT indeed has maximal operator entanglement, we show that this is entirely due to the bit reversal in the QFT. The core part of the QFT has Schmidt coefficients decaying exponentially quickly, and thus it can only generate a constant amount of entanglement regardless of the number of qubits. In addition, we show the entangling power of the QFT is the same as the time evolution of a Hamiltonian with exponentially decaying interactions, and thus a variant of the area law for dynamics can be used to understand the low entanglement intuitively. Using the low entanglement property of the QFT, we show that classical simulations of the QFT on a matrix product state with low bond dimension only take time linear in the number of qubits, providing a potential speedup over the classical fast Fourier transform (FFT) on many classes of functions. We demonstrate this speedup in test calculations on some simple functions. For data vectors of length 10^6 to 10^8, the speedup can be a few orders of magnitude. The talk will be based on the paper we recently posted: https://arxiv.org/abs/2210.08468.

12:00 — 1:00 Lunch

1:15 — 2:15 “Interrogating the Tensor Network Regression Model", Ian Convy, UC Berkeley

Abstract: Tensor network regression models have emerged as a new paradigm for machine learning, inspired by the widespread use of tensor networks in quantum many-body physics and tensor analysis. These models notably encompass variational quantum circuits, which currently represent the most promising avenue for achieving the highly sought-after "quantum neural network". At its core, the tensor network regression model performs linear regression on an exponentially-large feature space, but it is unclear to what extent the model is truly utilizing that space. In this talk I will first provide an overview of tensor network regression, beginning with the variational quantum circuit and then generalizing to a broader class of model. I will then discuss two recent papers which explore whether parts of the exponential feature space are extraneous, with one paper focusing on decoherence in quantum circuit models (arXiv:2209.01195) and the other on polynomial decomposition of classical models (arXiv:2208.06029)

2:30 — 3:30 “Low-rank Tensor Network Approximation Algorithms for Quantum Simulation” Linjian Ma, University of Illinois at Urbana-Champaign

Abstract: Low-rank tensor network approximation techniques can be used to reduce the memory and computational costs associated with simulating quantum algorithms on classical computers. Two low-rank approximation techniques for simulating quantum algorithms are discussed. In the first half of the presentation, we discuss the possibility of simulating a few quantum algorithms using low-rank canonical polyadic (CP) decomposition to represent the input and all intermediate states of these algorithms. In the second half of the presentation, we discuss how randomization techniques can be used to accelerate the low-rank approximation of arbitrary tensor networks.

3:30 — 4:00 Tea

4:00 — 5:00 “Non-unitary Shortcuts to Long-range Entangled Matter” Tim Hsieh, Perimeter Institute

Abstract: The preparation of long-range entangled states using unitary circuits is limited by Lieb-Robinson bounds, but imaginary time evolution and measurements can evade such bounds. I will present two protocols (one designed for classical computers, the other for quantum simulators) taking advantage of this fact. In the first part, I will introduce a variational imaginary time ansatz for many-body quantum systems that is remarkably efficient. In particular, representing the critical point of the one-dimensional transverse field Ising model only requires a number of variational parameters scaling logarithmically with system size. In the second part, I will introduce three classes of circuits with both unitary gates and measurements that enable low-depth preparation of long-range entangled quantum matter characterized by gapped topological orders and conformal field theories (CFTs). The three classes are inspired by distinct physical insights, including tensor-network constructions, multiscale entanglement renormalization ansatz, and parton constructions. A large class of topological orders, including chiral topological order, can be prepared in constant depth or time, and one-dimensional CFT states and non-abelian topological orders can be prepared in depth scaling logarithmically with system size.