QI 33: Quantum Materials and Many-Body Systems

Time: Friday 9:30–12:00 Location: HFT-TA 441

QI 33.1 Fri 9:30 HFT-TA 441

Classification of Phases of Matrix Product States with Symmetric Quantum Circuits, and Symmetric Measurements with Feedforward — •David Gunn[1], Tristan Kraft[1], Georgios Styliaris[2], and Barbara Kraus[1,3] — [1]University of Innsbruck — [2]Max-Planck-Institut für Quantenoptik — [3]Technical University of Munich

We consider how symmetry-preserving measurements with feedforward alter the phase classification of matrix product states (MPS) in the presence of global on-site symmetries. We demonstrate that, for all finite abelian symmetries, by including symmetry-preserving measurements, any two symmetric MPS belong to the same phase. We give an explicit protocol to achieve a transformation between any two phases that uses only a depth-two circuit, two rounds of symmetric measurements, and a constant number of auxiliary systems per site. In the case of non-abelian symmetries, symmetry protection prevents one from deterministically transforming states to product states directly via measurements. Nonetheless, we provide an asymptotically deterministic, symmetry-preserving protocol, using a log-depth circuit and measurements, that demonstrates certain non-abelian, symmetry-protected topological (SPT) phases also trivialize.

QI 33.2 Fri 9:45 HFT-TA 441

Deterministic generation of qudit photonic graph states from quantum emitters — •Zahra Raissi[1,2], Edwin Barnes[2], and Sophia E. Economou[2] — [1]Paderborn University, Paderborn, Germany — [2]Virginia Tech, Virginia, USA

We propose and analyze deterministic protocols to generate qudit photonic graph states from quantum emitters. We show that our approach can be applied to generate any qudit graph state, and we exemplify it by constructing protocols to generate one- and two-dimensional qudit cluster states, absolutely maximally entangled states, and logical states of quantum error correcting codes. Some of these protocols make use of time-delayed feedback, while others do not. The only additional resource requirement compared to the qubit case is the ability to control multi-level emitters. These results significantly broaden the range of multi-photon entangled states that can be produced deterministically from quantum emitters and open up new possibilities for quantum information processing.

QI 33.3 Fri 10:00 HFT-TA 441

Closed-form expressions for graph states — •Hrachya Zakaryan, Konstantinos Rafail Revis, and Zahra Raissi — Department of Computer Science, Paderborn University, Germany

Two-colorable graphs states are multipartite entangled states, which can be represented by two-coloarble graphs. These are graphs where the vertices can be divided into two disjoint sets, such that no vertices in each set are connected by an edge. These graphs give rise to important graph states such as the cluster and GHZ states, which are vital quantum resources. We consider qudit systems, and therefore examine unweighted and weighted graphs, in two cases: Controlled-Z (CZ) edges and Controlled-Phase (CP) edges. Closed forms for their corresponding Local-Unitary (LU) equivalent states are obtained. Additionally, setups with specific phases and experimental interest, are examined. An extension of the stabilizer formalism to CP based graphs as well as multi-colorable graphs is considered.

QI 33.4 Fri 10:15 HFT-TA 441

Renormalisation Through The Lens Of Quantum Convolutional Neural Networks — •Nathan A. McMahon[1], Petr Zapel[2], and Michael J. Hartmann[1] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) — [2]University of Basel, Switzerland.

A quantum convolutional neural network (QCNN) can be used to perform quantum phase recognition for the cluster-Ising model. This circuit outputs $+1$ if the input state is in the symmetry protected topological (SPT) phase, called the target phase, and 0 if it is in either of the other phases. This observation has been shown numerically and experimentally, but much less is known analytically. In this talk we first introduce a set of conditions on a QCNN that describes success at the phase recognition task restricted to a subset of possible input quantum states and proceed to show the cluster-Ising QCNN satisfies these conditions via random circuit analysis. When averaged over random circuits, if the QCNN outputs can distinguish between phases, some input states must be non-typical. In contrast, the rate of change of the QCNN outputs with respect to perturbations of the input state also has an operator representation, where all input states we consider are typical and converge to zero with QCNN depth. Since all input states can be generated from a reference state under these perturbations, this explains how the QCNN performs phase recognition and extends to incoherent perturbations.This suggests QCNNs may provide insight in how to extend the corresponding SPT phase to mixed states.

15 min. break

QI 33.5 Fri 10:45 HFT-TA 441

Magnon-magnon quantum entanglement and the phonon effects in antiferromagnetic structure — •Yuefei Liu[1], Anna Delin[1], Erik Sjöqvist[2], and Olle Eriksson[2] — [1]Department of Applied Physics, School of Engineering Sciences, KTH Royal Institute of Technology, AlbaNova University Center, SE-10691 Stockholm, Sweden — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 20 Uppsala, Sweden

Quantum correlation, such as entanglement, is a central resource in many quantum information protocols that naturally comes about in any study toward quantum technologies. This applies also to quantum magnonics. First, we investigate antiferromagnets in which sublattices with ferromagnetic interactions can have two different magnon modes, and we show how this may lead to experimentally detectable bipartite continuous variable magnon-magnon entanglement. Our current study and result not only provide original evidence for creation and observation of tunable and robust entangled quantum states of magnons in a wide range of temperature including room temperature, but also expands the magnon applications from spintronics and quantum information processing to biomedical applications. The ability to produce quantum states with tunable and robust entanglement in ambient conditions has significant implications as it would avoid costly cooling procedures, reduce the effect of thermal noise, simplify the experimental setups, and widen the range of quantum applications.

QI 33.6 Fri 11:00 HFT-TA 441

Measurement induced phase transition with an extended log-law phase in an integrability-broken transverse field Ising model — •Monalisa Singh Roy, Jonathan Ruhman, Emanuele G. Dalla Torre, and Efrat Shimshoni — Bar-Ilan University, Ramat Gan, 52900 Israel.

Measurement induced entanglement phase transitions in many-body quantum systems are a fundamental obstacle for any quantum computing platform. The unitary dynamics of these many-body systems competes against the localization of the wavefunction due to repeated measurements, resulting in a transition from the quantum entangled (volume-law) phase into a disentangled Zeno-like (area-law) phase at strong measurements, that's unsuitable for further quantum operations. Recently an extended critical phase with a logarithmic scaling of the entanglement entropy has been identified in a class of integrable models with dissipative dynamics. We extend this and study the critical transition in a non-integrable system - a one dimensional transverse field Ising model, in presence of an integrability-breaking field and no-click dissipation. First, we show that the measurement induced transitions in this system is qualitatively different from the trivial volume-law to area-law transition of the entanglement entropy in integrable systems. Then we show how these transitions can be connected via the integrability breaking field. We also identify the same phase transitions from the correlation function exponents and calculation of mutual information in each phase, and present the complete phase diagram for this non-integrable system.

QI 33.7 Fri 11:15 HFT-TA 441

Visualizing the localized electrons of a kagome flat band — •Caiyun Chen[1,2], Jiangchang Zheng[1], Ruopeng Yu[1], Soumya Sankar[1], Hoi Chun Po[1], Kam Tuen Law[1], and Berthold Jäck[1] — [1]Department of Physics, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong SAR, China — [2]Institute for Advanced Study, HKUST Jockey Club, Clear Water Bay, Kowloon, Hong Kong SAR, China

Destructive interference between electron wavefunctions on the two-dimensional kagome lattice induces an electronic flat band, which could host a variety of interesting quantum states. Key to realize these proposals is to demonstrate the real space localization of kagome flat band electrons. The extent to which the complex structure of realistic materials counteracts the localizing effect of destructive interference is hitherto unknown. We used scanning tunneling microscopy (STM) to visualize the non-trivial Wannier states of a kagome flat band at the surface of CoSn, a kagome metal. We find that the local density of states associated with the flat bands of CoSn is localized at the kagome lattice center, consistent with theoretical predictions. Our results show that these states exhibit an extremely small localization length of two to three angstroms concomitant with a strongly renormalized quasiparticle velocity, comparable to that of moire superlattices. Our findings provide fundamental insight into the electronic properties of kagome metals and present a key step for future research on emergent many-body states in these systems.

QI 33.8 Fri 11:30 HFT-TA 441

Entanglement spectrum and multifractality in monitored free fermions in two dimensions — •Karim Chahine and Michael Buchhold — Institut für Theoretische Physik, Universität zu Köln, D-50937 Cologne, Germany

We investigate the entanglement structure and wave function characteristics of continuously monitored free fermions with $U(1)$-symmetry in 2D. Using exact numerical simulations, we establish the phenomenology of the entanglement transition and explore the similarities and differences with Anderson-type localization transitions. At weak monitoring, we observe characteristic $L \log L$ entanglement growth and multifractal dimension $D_q = 2$, resembling a metallic Fermi liquid. Furthermore, excellent agreement is found with a Wigner-Dyson distribution for the entanglement spectrum statistics. At strong monitoring, exponentially localized wave functions lead to saturation, following an area law for entanglement and a Poissonian distribution for the entanglement spectrum is seen. In between, the critical point exhibits entanglement scaling consistent with emergent conformal invariance and strong multifractality. Furthermore, we numerically reveal a close link between the multifractal exponent D_q and the purification decay rate and find another witness of multifractality in the spectral form factor. Our results shape the understanding of a monitoring-induced metal-to-insulator transition in entanglement content. This establishes 2D monitored fermions as a unique platform to explore the connection between non-unitary quantum dynamics in D dimensions and quantum statistical mechanics in $D + 1$ dimensions.

QI 33.9 Fri 11:45 HFT-TA 441

Orbital and electronic entanglement in quantum teleportation schemes — •Anna Galler[1,2] and Patrik Thunström[3] — [1]Graz University of Technology, 8010 Graz, Austria — [2]Max Planck Institute for the Structure and Dynamics of Matter, 22761 Hamburg, Germany — [3]Uppsala University, 75120 Uppsala, Sweden

With progress towards more compact quantum computing architectures, fundamental questions regarding the entanglement of indistinguishable particles need to be addressed. In a solid state device, this quest is naturally connected to the quantum correlations of electrons. In this talk, I analyse the formation of orbital (mode) and particle entanglement in strongly correlated materials due to the Coulomb interaction between the electrons. To study the role of the different forms of electronic entanglement, I propose and analyse three different electronic teleportation schemes: quantum teleportation within a molecule on graphene, a nitrogen-vacancy center, and a quantum dot array.

[Galler and Thunström, Phys. Rev. Res. 3, 033120 (2021)]