Contribution ID: **99** Type: **Poster**

Quantum Simulating a lattice gauge theory: thermalization, many-body scarring, dynamical quantum phase transitions and meson scattering

Sunday, 10 September 2023 22:40 (20 minutes)

Gauge theories, a fundamental framework of modern physics, govern the intricate dynamics of elementary particles that constitute the world we know of. The decades-long quest to understand quantum systems operating under gauge symmetries presents both theoretical and experimental interests, with applications ranging from early-universe cosmology and heavy-ion collisions to condensed matter systems. However, simulating the real-time dynamics of such complex quantum many-body systems on classical computers is fraught with difficulties, motivating the pursuit of alternative venues. Here, we present the quantum simulation of a U(1) lattice gauge theory where we engineer the highly constrained gauge symmetry in a Bose-Hubbard chain, allowing the study of the far-from-equilibrium dynamics through global quantum quenches. The interplay between the fermionic matter fields and dynamical gauge fields is encoded in the staggered Bose-Hubbard model facilitated by the optical superlattice. Although a closed quantum system admits no loss of information on a fundamental level, we observe the emergence of local thermal equilibrium under unitary evolution. Delving deeper, we explore the phenomenon of slowed thermalization through quantum many-body scarring, which deters relaxation and opens possibilities for coherent control of many-body systems. Employing optical superlattices, we can conduct hybrid digital-analog quantum simulation to probe dynamical quantum phase transitions, which presents nonanalytic behavior in the Loschmidt echo, providing insights into the non-equilibrium properties of the system. We further propose to quantum simulate the meson scattering dynamics by implementing particle-antiparticle pairs with state engineering. Our work enables the investigation of intriguing phenomena such as Schwinger pair production, string breaking, and confinement on synthetic quantum devices. Also, it paves the way for the quantum simulation of higher-dimensional and more complex gauge theories.

Primary authors: SU, Guoxian (Heidelberg University and USTC); Mr ZHOU, Zhao-Yu (Heidelberg University and USTC); Dr OTT, Robert (Universität Innsbruck); Dr HUDOMAL, Ana (University of Belgrade); Mr DESAULES, Jean-Yves (University of Leeds); Dr SUN, Hui (USTC); Dr YANG, Bing (Southern University of Science and Technology); Prof. HAUKE, Philipp (University of Trento); Prof. PAPIĆ, Zlatko (University of Leeds); Dr HALIMEH, Jad (Ludwig-Maximilians-Universität München); Prof. BERGES, Jürgen (Heidelberg University); Prof. YUAN, Zhen-Sheng (Heidelberg University and USTC); Prof. PAN, Jian-Wei (Heidelberg University and USTC)

Presenter: SU, Guoxian (Heidelberg University and USTC)

Session Classification: Poster Session I

Track Classification: Synthetic Gauge Fields and Topology