Canadian Association of Physicists

Association canadienne des physiciens et physiciennes

Contribution ID: **316** Type: **Oral Competition (Graduate Student) / Compétition orale (Étudiant(e) du 2e ou 3e cycle)**

(G*) Waveguide QED toolboxes for universal quantum matter

Wednesday 9 June 2021 16:03 (4 minutes)

The simulation of quantum systems is inherently difficult due to the exponentially scaling of the state that must be simulated for a general system. One clear way to get around this problem is to utilize the properties of the quantum physics it's self, ergo simulate quantum physics on quantum physics. An exciting frontier in quantum information science is the realization and control of complex quantum many-body systems for just this. Within this realm, we here harness the engineered coupling between spin and quantum motion of neutral atoms in a 1D photonic crystal waveguides for the realization of analog quantum simulation. In particular our platform realizes analog simulation of synthetic quantum material for universal 2-local Hamiltonian graphs. To do this, we develop a low-energy theory for the external motional states of the trapped atoms in the bandgap regime of waveguide QED, then generalize our microscopic theory to the development of dynamical gauge fields. In the spirit of gauge theories, we investigate emergent lattice models for strongly coupled SU(n)-constrained excitations driven by an underlying multi-body interaction. As a minimal model in the infrared, we explore the realization of an archetypical strong coupling quantum field theory, SU(n) Wess-Zumino-Witten model, and discuss a diagnostic tool to extract the entire conformal data of the field theory by the static and dynamical correlators of the fluctuating photons in the guided mode.

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Session Classification: W3-1 Quantum Information: Theory (DAMOPC) / Information quantique: théorie (DPAMPC)

Track Classification: Atomic, Molecular and Optical Physics, Canada / Physique atomique, moléculaire et photonique, Canada (DAMOPC-DPAMPC)