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Quantum Simulation with Rydberg-atom Synthetic Dimensions (25+5)

Monday, January 13, 2025 2:00 PM (30 minutes)

A synthetic dimension, in which a discrete degree of freedom in a well-controlled quantum system can be mapped to the states of particles moving in a real-space lattice potential, is a powerful tool for quantum simulation because it provides control over the Hamiltonian and the ability to create configurations difficult to access in real space. I will describe the creation of a synthetic dimension from Rydberg levels in an 84-Sr atom, in which coupling between the states is induced with millimeter-waves. Tunneling amplitudes between synthetic lattice sites and on-site potentials are set by the millimeter-wave amplitudes and detunings respectively. The potential of this platform is demonstrated by realizing the single-particle Su-Schrieffer-Heeger Hamiltonian (SSH), a paradigmatic model of topological matter with alternating weak and strong tunneling in a one-dimensional configuration. Band structure is measured through the Rydberg photo-excitation rate into the manifold[1]. Using selective field-ionization of the Rydberg atoms, particle dynamics in the synthetic dimension are tracked with single-site resolution[2]. Bulk-states and topologically-protected edge states are clearly distinguished through their spectral and transport properties. (Funding has been provided by Rice University, NSF grants 1904294, 1848304, and 2110596, the AFOSR under Grant No. FA9550-17-1-0366, and the FWF (Austria) under Grant No. FWF-P35539-N and Doctoral College FWF W 1243 (Solids4Fun).)

[1] S. K. Kanungo, J. D. Whalen, Y. Lu, M. Yuan, S. Dasgupta, F. B. Dunning, K. R. A. Hazzard, and T. C. Killian, Realizing topological edge states with Rydberg-atom synthetic dimensions. Nat. Commun. 13, 972 (2022). https://doi.org/10.1038/s41467-022-28550-y

[2] Y. Lu, C. Wang, S. K. Kanungo, S. Yoshida, F. B. Dunning, and T. C. Killian, Wave packet dynamics and long-range tunneling within the SSH model using Rydberg-atom synthetic dimensions, Phys. Rev. A 109, 032801 (2024). https://doi.org/10.1103/PhysRevA.109.032801

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