Making Topological Ladders for Fermionic Atoms in 1D Optical Lattices

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Topological states of matter represent one of the frontiers of modern condensed matter physics. Featuring tunable artificial gauge fields and spin-orbit coupling, ultracold atoms in optical lattices provide a versatile platform to realize topological states and study their phase transitions in a clean and well-controlled manner. In this talk, I present our recent experiments with ultracold fermionic 173Yb atoms to realize topological ladder systems in 1D optical lattices. In the first experiment [1], we realized a topological Creutz ladder, which is a cross-linked two-leg ladder system discussed as a minimal model for 1D topological insulators. The two-leg ladder consists of the two lowest orbital states of the optical lattice, and the cross interleg links are generated via two-photon resonant coupling between the orbitals by periodic lattice shaking. The characteristic pseudo-spin winding in the topologically non-trivial bands of the ladder system is demonstrated using momentum-resolved Ramsey-type interferometric measurements. In the second experiment [2], we realized a synthetic three-leg Hall tube. The legs of the synthetic tube are composed of three hyperfine spin states of the atoms, and the cyclic interleg links are generated by two-photon Raman transitions between the spin states, resulting in a uniform gauge flux $\varphi = 2\pi/3$ penetrating each side plaquette of the tube. Using quench dynamics, we investigate the band structure of the Hall tube system, demonstrating a critical point of band gap closing as one of the interleg coupling strengths is varied, which is consistent with a topological phase transition predicted for the Hall tube system. Finally, I will discuss further exploration of the constructed topological ladder systems.

References:

[1] J. H. Kang, J. H. Han, and Y. Shin, arXiv:1902.10304.

[2] J. H. Han, J. H. Kang, and Y. Shin, Physical Review Letters 122, 065303 (2019).