

University of Maryland

Department of Physics

Notice of Doctoral Defense

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Dissertation Title: Topological dispersion relations in spin-orbit coupled Bose gases

Date and Time: Monday, December 2 at 2:00 p.m.

Location: PSC 2136

Dissertation Committee Chair: Dr. Alicia Kollár

Committee: Dr. Ian Spielman

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Abstract:

Quantum degenerate gases have proven to be an ideal platform for the simulation of complex systems. Due to their high level of control it is possible to readily design and implement systems with effective Hamiltonians in the laboratory. This thesis presents new tools for the characterization and control of engineered quantum systems and describes one application in the engineering and characterization of a topological system with Rashba-type spin-orbit coupling.

The underlying properties of these engineered systems depend on their single particle energies. I describe a Fourier transform spectroscopy technique for characterizing the single particle spectrum of a quantum system. We tested Fourier spectroscopy by measuring the dispersion relation of a spin-1 spin-orbit coupled Bose-Einstein condensate (BEC) and found good agreement with our predictions.

Decoherence due to uncontrolled fluctuations of the environment presents fundamental obstacles in quantum science. I describe an implementation of continuous dynamical decoupling (CDD) in a spin-1 BEC. We applied a strong radio-frequency magnetic field to the ground state hyperfine manifold of Rubidium-87 atoms, generating a dynamically protected dressed system that was first-order insensitive to changes in magnetic field. The CDD states constitute effective clock states and we observed a reduction in sensitivity to magnetic field of up to four orders of magnitude. I show that the CDD states can be coupled in a fully connected geometry and thus enable the implementation of new models not possible using the bare atomic states.

Finally, I describe the engineering of Rashba-type SOC using Raman coupled CDD states. Our system had non-trivial topology but no underlying crystalline structure that yields integer valued Chern numbers in conventional materials. We validated our procedure using Fourier transform spectroscopy to measure the full dispersion relation containing only a single Dirac point. We measured the quantum geometry underlying the dispersion relation and obtained the topological index using matter-wave interferometry. In contrast to crystalline materials, where topological indices take on integer values, our continuum system reveals an unconventional half-integer Chern number.