Galilean Invariance and Lattice Dynamics in a Zeeman Lattice

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Quantum gases at near absolute zero temperature exhibit pronounced quantum mechanical effects which make them powerful testbeds for probing complex dynamics connected to open questions in other areas of modern physics, such as quantum optics, quantum information, or condensed matter physics. In this work, we demonstrate one of the applications of quantum gases to the study of condensed matter physics. Two cornerstones of modern condensed matter physics are periodic band structures and spin-orbit coupling. Spin-orbit coupling does not directly lead to a periodic lattice structure in the plane-wave regime and breaks the Galilean invariance. In this work, we demonstrate that the confluence of a spin-orbit coupled BEC and an external radio-frequency field results in an emergent optical lattice structure called the Zeeman lattice, even though neither of the two ingredients is periodic in space. In our experiments, we probe the emerging Zeeman lattice using Bloch oscillations and band spectroscopy. We also show that the broken Galilean symmetry is restored in the Zeeman lattice. This work paves the way to the exploration of spin-selectivity and flat-band properties using Zeeman lattices. We gratefully acknowledge funding from NSF under grant PHY-1912540.

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