Stiprios toliveikės sąveikos ir geometrinė frustracija trumpesnėse už bangos ilgį Ramano gardelėse

Strong long-range interactions and geometrical frustration in subwavelength Raman lattices

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Non-local interactions are the key building block to allow for a spontaneous breaking of the translational symmetry. The latter represents one of the most fundamental symmetries in physics as it reflects the formation of periodic structures of mass and electric charge. Quantum matter with such a feature falls in the class of spontaneously symmetry broken (SSB) many-body phases with broken translational invariance. Although this peculiar symmetry breaking fixes the most energetically favourable distance between elementary constituents, examples of these SSB phases occur in physical systems with characteristic lengths scale. These range from electronic systems and liquid of ^{4}He to neutron stars. This recurrence has made the investigation and creation of such states of matter of central importance. In this respect, quantum simulators made of ultracold magnetic atoms with large magnetic dipolar momentum (e.g., erbium) represent a promising and powerful resource. However, current setups only explore frustrated regimes with weak local interactions or regimes where quantum fluctuations are supressed. To the best of our knowledge, there are no experimental schemes able to simultaneously realize long-range interactions and geometrical frustration.

Here we consider a possible alternative to current setups - a recently realized [1] subwavelength lattice formed by a pair of counter-propagating lasers driving two photon Raman transitions in an ensemble of ultracold atoms [2]. It was shown that one may precisely control the tunneling amplitude, range, and phase by tuning the detunings. One also achieves significantly stronger interactions in the proposed scheme due to its subwavelength nature. Thus, one may realize intriguing phases of matter, such as density waves and chiral superfluids. Our results show three possible scenarios may occur, depending on the lattice depth and detunings. For deep optical lattices, we find quasi long-range order of the single particle Green's function, thus signalling the presence of a normal superfluid. For lower lattice depths, a regime characterized by long-range order takes place. This phase is characterized by spontaneously generated chiral currents and therefore, is an example of a chiral superfluid. Finally, density waves of period two or three were observed for a large range of detuning values.

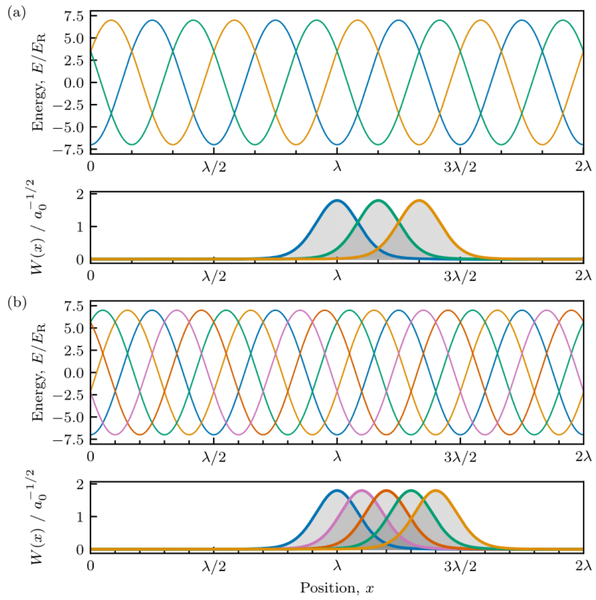

Fig. 1. (a) Subwavelength lattice for $N = 3$ internal states and Raman coupling $\Omega = 3.5E_R$.
(b) Subwavelength lattice for $N = 5$, $\Omega = 3.5E_R$. Different colors indicate different dressed state sinusoidal potentials. The Wannier functions $W(x - na)$ are also plotted below the lattices.

Keywords: optical lattice, ultracold atoms, long-range interactions, Bose-Hubbard model, geometrical frustration, synthetic dimension, Wannier functions.

Literature

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