Atomic & molecular physics

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Topological phase transitions between chiral and helical spin textures in a lattice with spin-orbit coupling and a magnetic field

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We consider the combined effects of large spin-orbit couplings and a perpendicular magnetic field in a 2D honeycomb fermionic lattice. This system provides an elegant setup to generate versatile spin textures propagating along the edge of a sample. The spin-orbit coupling is shown to induce topological phase transitions between a helical quantum spin Hall phase and a chiral spin-imbalanced quantum Hall state. Besides, we find that the spin orientation of a single topological edge state can be tuned by a Rashba spin-orbit coupling, opening an interesting route towards quantum spin manipulation. We discuss the possible realization of our results using cold atoms trapped in optical lattices, where large synthetic magnetic fields and spin-orbit couplings can be engineered and finely tuned. In particular, this system would lead to the observation of a time-reversal symmetry-broken quantum spin Hall phase.

Spin-charge-density wave in a rounded-square Fermi surface for ultracold atoms

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We derive and discuss an experimentally realistic model describing ultracold atoms in an optical lattice including a commensurate, but staggered, spin-flip term. The resulting band structure is quite exotic; fermions in the third band have an unusual rounded picture-frame Fermi surface (essentially two concentric squircles), leading to imperfect nesting.
We develop a generalized theory describing the spin and charge degrees of freedom simultaneously at the random-field-approximation level, and show that the system can develop a coupled spin-charge-density wave order. Our generic approach can be used to study spin and charge instabilities in many materials, such as high-T_c superconductors, organic compounds, graphene, and iron pnictides.