Topological Kondo insulators in one dimension: Continuous Haldane-type ground-state evolution from the strongly-interacting to the non-interacting limit

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We study, by means of the density-matrix renormalization group (DMRG) technique, the effect of correlations on (an otherwise non-interacting) 1D $\mathbb{Z}_2$-topological band insulator, the 1D “sp-ladder” model. Specifically, we study the evolution of its ground state from the non-interacting to the strongly-interacting limit, where the model can be mapped onto the “p-wave” Kondo-Heisenberg model, and supports a Haldane-type ground state. We focus on a toy model Hamiltonian (i.e., the interacting “sp-ladder” model), which could be experimentally realized in optical lattices with higher orbitals loaded with ultra-cold fermionic atoms. Our goal is to shed light on the emergence of the strongly-interacting ground state and its topological classification as the Hubbard-U interaction parameter of the model is increased.

We compute the entanglement entropy, entanglement spectrum, and the string-order parameter of the system, which are quantities typically used to characterize the Haldane phase. In addition, we compute the charge- and spin-excitation gaps, and the charge and spin profiles of the topologically-protected end states as a function of $U$.

Our results show an adiabatic evolution of all ground-state properties as the interaction parameter $U$ is increased, and the absence of topological quantum phase transitions (TQPT), suggesting that the ground state can be generically classified as a symmetry-protected topological phase (SPT) of the Haldane-type, even in the non-interacting case $U = 0$ where the system can be additionally classified as a time-reversal $\mathbb{Z}_2$-topological insulator. This finding is surprising, as these two ground states are usually considered to be qualitatively different, and naively a topological quantum phase transition separating these phases could be expected.