Assessing effective models of double quantum dot Andreev molecules

Kacper Wrześniewski

Institute of Spintronics and Quantum Information, Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznań 61-614, Poland

We systematically investigate the phase diagram of a parallel double-quantum-dot Andreev molecule, where the two quantum dots are coupled to a common superconducting lead. Using the numerical renormalization group method (NRG), we study the evolution of the ground state across a broad parameter space, including level detuning, superconducting gap size, lead couplings, and interdot hopping. The resulting phase diagrams feature singlet, doublet, and a relatively uncommon triplet ground states, with the latter being a distinct signature of strong lead-mediated interactions between the quantum dots.

To assess the reliability of simplified approaches, we benchmark the applicability of effective models, including the atomic limit and zero-bandwidth approximations. Our results highlight significant limitations of these models. Except for the extended version of the zero-bandwidth approximation, all effective models fail to reproduce the triplet ground state. These findings offer important guidance for interpreting experimental data and designing superconducting devices based on quantum dot structures.