Designing Majorana Quasiparticles in InAsP Quantum Dots in InP Nanowire

Ibsal Assi[(1,*)], Mahan Mohseni[(1,*)] , Daniel Miravet[(1)], Hassan Allami[(1)],Marek Korkusinski[(1,2)] and Pawel Hawrylak[(1)]

(1) Department of Physics, University of Ottawa, Ottawa, K1N6N5, Canada
(2) Security and Disruptive Technology, NRC, Ottawa, Canada

(*) iassi@uottawa.ca , mghaf073@uottawa.ca

Abstract:

There is currently interest in topologically protected qubits based on braiding of Majorana quasiparticles [1-3]. Majorana quasiparticles are predicted to appear at the edges of a Kitaev chain, a chain of quantum dots hosting spinless Fermions in contact with p-type superconductor [1-4]. The Kitaev chain requires p-type superconductors which is difficult to achieve. It was suggested that the Majorana Fermions may appear in a semiconductor nanowire hosting spinfull Fermions in contact with s-type superconductor in the presence of strong spin orbit interaction and strong magnetic field [5,6].

In this work, we present new results on designing Majorana quasiparticles in an array of InAsP quantum dots in InP nanowire placed on superconducting substrate that supports s-wave pairing between electron in a nanowire. The Hamiltonian describes the tunneling between neighboring quantum dots, coupling of spin and orbital motion (SO), Zeeman interaction including quantum dot and nanowire g factors , electron-electron interaction in the extended Hubbard model including on-site and intersite repulsion and s-type pairing due to proximity with s-type superconductor. The parameters of our Hamiltonian, such as the tunneling matrix elements, g-factors, the SO coupling strength, and extended Hubbard matrix elements are extracted from multimillion atom , atomistic, microscopic models of two InAsP quantum dots with one electron each in InP nanowire [7]. The pairing amplitude and pairing correlation length is left as a fitting parameter. The wavefunction of the nanowire is expanded as a coherent combination of configurations with different electron numbers, then the ground state is found as a function of the chemical potential using exact diagonalization and density matrix renormalization group-matrix product state (DMRG-MPS) tools. Majorana modes are identified from degeneracies of the even and odd parity states. The results of this work will determine whether high quality quantum dots in InP nanowires can host Majorana fermions.

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