

Design of quantum logic gates by optical manipulation of proximized quantum spin Hall edge states

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Abstract: We show that, by applying suitable electromagnetic pulses to quantum spin Hall edge states embedded in Josephson junctions, it is possible to design NOT and Hadamard quantum logic gates.

Electric dipole transitions between counterpropagating helical edge states of a quantum spin Hall (QSH) system are known to be forbidden by the selection rules imposed by their very helical nature. However, the recently realized magnetic doping of QSH systems [1,2] might open up new perspectives in optoelectronics of topological systems.

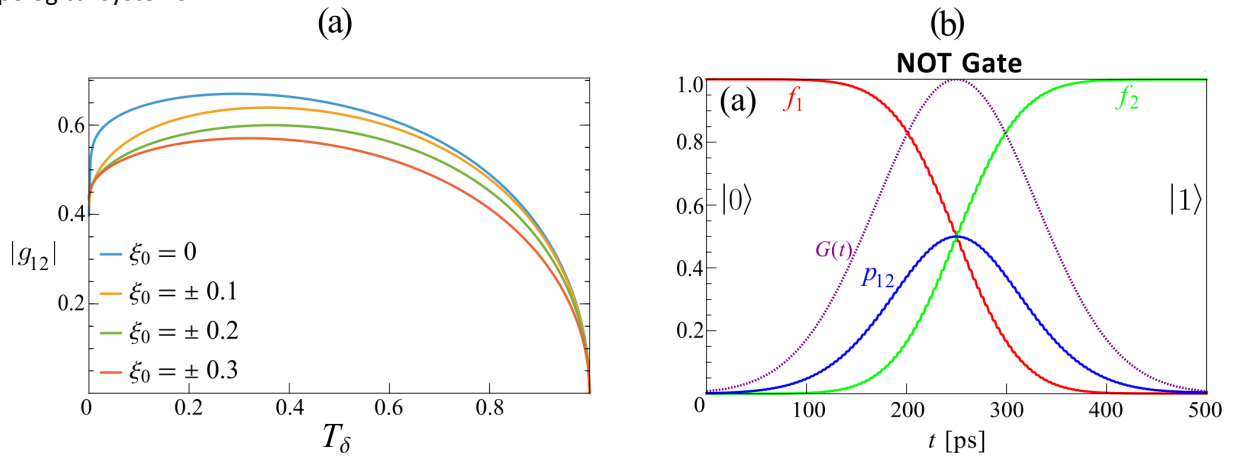


Fig. 1 (a) The magnitude $|g_{12}|$ of the optical transition amplitude between two ABS is shown as a function of the transmission amplitude T_δ for different magnetic barrier positions ξ_0 (in units of junction length). **(b)** Simulation of the implementation of a NOT gate in the QSH Insulator-based Andreev Spin Qubit.

Here, by considering different types of magnetic disorder present along a QSH edge, from localized to extended impurities, we show that a significant optical transition amplitude can be induced even by a weak magnetic doping, i.e. by a transmission that weakly deviates from 1. We apply this result to the case of a QSH edge proximized by two superconductors, showing that the resulting Andreev bound states can be optically manipulated thanks to the spin texture modifications induced by the magnetic doping (see Fig.1(a)). Specifically, by considering the coupling with a suitable electromagnetic Gaussian pulse, we demonstrate that NOT and Hadamard quantum logic gates can be designed in such QSH Josephson junction (see Fig.1(b)). Our quantum dynamical simulations reveal high-fidelity population transfer between the two Andreev states for realistic device parameters, with gate operations occurring on sub-nanosecond timescales. Our analysis indicates that, even in a worst-case scenario of typical decoherence times in the nanoscale, the proposed architecture could enable multiple coherent quantum operations [1].

References

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