Manipulation of hole spins under realistic electric and strain fields in quantum dots

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In recent years, there has been a growing interest in utilizing hole spins in silicon and germanium for quantum information processing. One reason for this is the strong spin-orbit interaction present in the valence band of these materials, which allows for versatile interactions with electric fields. As a result, there have been demonstrations of fast electrical manipulation of hole spin qubits [1] and strong spin-photon interactions [2], which are useful for generating long-range entanglement, all mediated by spin-orbit interactions. Interestlingly, recent experiments in Ge hole qubits have shown efficient manipulation with in-plane magnetic fields [3], which cannot be easily explained by the expected spin-orbit mechanisms, such as cubic Rashba or g-tensor modulation resonance.

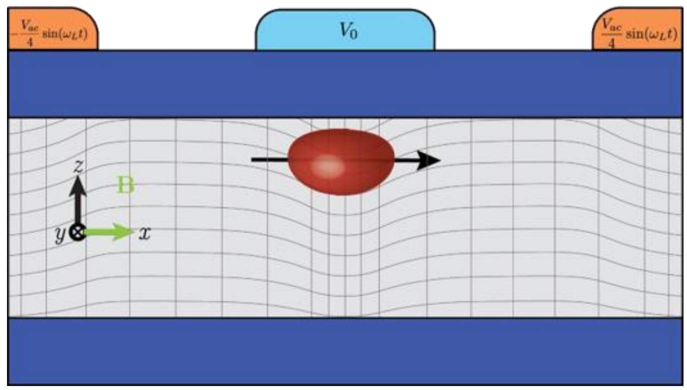

Fig.1. Hole spin qubit in a heterostructure with inhomogeneous strain

In this work, we go beyond the usual models for electrical spin manipulation in semiconductor quantum dots. We perform simulations of realistic Ge devices and find that both the electrostatics [4] and the strain [5] display inhomogeneities that dominates the performance of hole spin qubits. In particular, we identify overlooked spin-orbit mechanisms mediated by strains and the interfaces [6] that enable manipulation under in-plane magnetic fields and enhance the expected Rabi frequencies. Our simulations show that these mechanisms are dominating the physics of isotropic hole spin qubits.

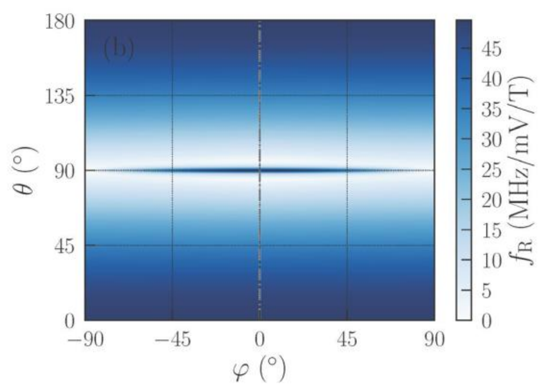

Fig.2. Rabi frequency as a function of magnetic field orientation. Poles are the vertical direction; middle of the plot is along the shaking direction.

References

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