Modeling of silicon two qubit gates

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PhD may follow: Yes

Summary :

"Quantum computers" may soon be able to solve problems beyond the reach of conventional computers. Such computers no longer manipulate electrons as particles, but as waves that maintain phase relationships and can interfere. The preparation, coherent manipulation and "reading" of quantum states is extremely challenging. One promising option for making "quantum bits" (qubits) is to divert silicon MOS transistors in order to store a few electrons and manipulate their spin. The CEA Grenoble fabricates and characterizes such devices, and develops appropriate tools for their modeling. The objective of this Master training is to study the dynamics of two (or more) qubit gates by solving the time-dependent SchrÃ¶dinger equation in the presence of electronic interactions in a realistic geometry. Our purpose is to understand how to manipulate information in these devices in order to implement the elementary operations of a quantum computer. This study will be conducted in close collaboration with the experimental physics teams working on this topic, in the frame of a European ERC project on 2D arrays of silicon qubits.

Full description :

The "classical" MOS transistors control the passage of a current between "source" and "drain" contacts by applying an electric field on a "gate" electrode that attracts or repels electrons. At low temperature, this control becomes so sharp that it is possible to trap one (or a few) electron(s) under the gate. These electrons (in particular their spin) can then be manipulated by applying magnetic fields and/or radio frequency pulses to the gate. A particular spin state can thus be prepared as superposition of "up" and "down" states, then rotated, or coupled with another spin under a neighboring gate (through tunnel and Coulomb interactions) in order to entangle their dynamics and realize a two (or more) qubit gate able to perform some elementary operations of a quantum computer. All these operations can be modeled by solving the time-dependent SchrÃ¶dinger equation in the presence of electronic interactions, which the "TB_Sim" code developed at CEA Grenoble can do in a realistic geometry (see image). In addition, electrons can undergo many kinds of parasitic, unwanted interactions with their environment (coupling to the spins of atomic nuclei, noise on magnetic and electric fields, charged defects, etc ...). These interactions limit the control on their quantum state and cause "decoherence" (loss of phase information stored by this state). These processes will be integrated in the time-dependent SchrÃ¶dinger equation in order to understand exactly how they impact the dynamics of the system and how they can be mitigated.

This study will be carried out in close collaboration with the experimental teams of CEA/LETI, CEA/INAC et CNRS/NÃ©el in the context of the European ERC Synergy project quCUBE, which aims at developing 2D arrays of silicon qubits.

Requested skills :

Taste for modeling, numerical simulation and mathematics