TP25 – Realtime detection of a single electron in silicon quantum dots

Teacher: Pierre Hamonic, Institut Néel (CNRS), UGA

In the context of quantum information processing, one of the main challenges is to find a good quantum two-level system to be used as a quantum bit (or *qubit*), the elementary building block of a quantum processor. Electron spins in silicon nanostructures are good candidates, thanks to their low spin-orbit coupling, and the small abundance of nonzero spin nuclei, thus enhancing the coherence time of such qubits.

The goal of the Grenoble Quantum Silicon project is to trap individual electrons into quantum dots formed in industry-like silicon nanostructures, very similar to usual CMOS transistors present in everyday microelectronics. If one can demonstrate reproducible initialization, manipulation, control and readout of a few CMOS electron spin qubits, scaling up to an industrial processor containing dozens of them would be insured by leveraging the available CMOS foundry [1].

In this practical, we offer to go through the first usual steps of an experiment meant to manipulate such electron spin qubits, using a Single-Electron Transistor (SET) as a charge sensor. We will work on a transistor-like nanostructure (fig. 1) placed in a dilution cryostat already cooled down to a few tens of milli-Kelvin. We will first check the transistor-like behavior of the device by looking for the first Coulomb peaks appearing when opening the silicon channel. We will then measure the charge stability of the device (fig.2), to find an electric gate voltage configuration where we trap a single electron in the qubit dot. Finally, we propose to see real-time tunneling processes of an electron in and out of the qubit dot, by monitoring the current through the SET (fig.3), whose conductance is highly sensitive to the charge occupation of the qubit dot.

[1] Maurand, R., et al. "A CMOS silicon spin qubit." *Nature communications* 7.1 (2016): 1-6.

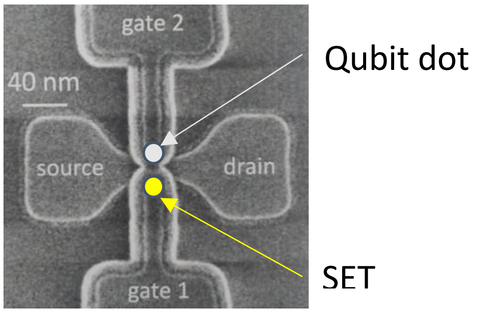

Fig.1. Typical transistor-like split gate device. The voltage on the “gate 2” metal electrode is used to trap one electron whose spin is to be used as a qubit. The voltage on “gate 1” will be used to monitor the Single-Electron Transistor conductance.

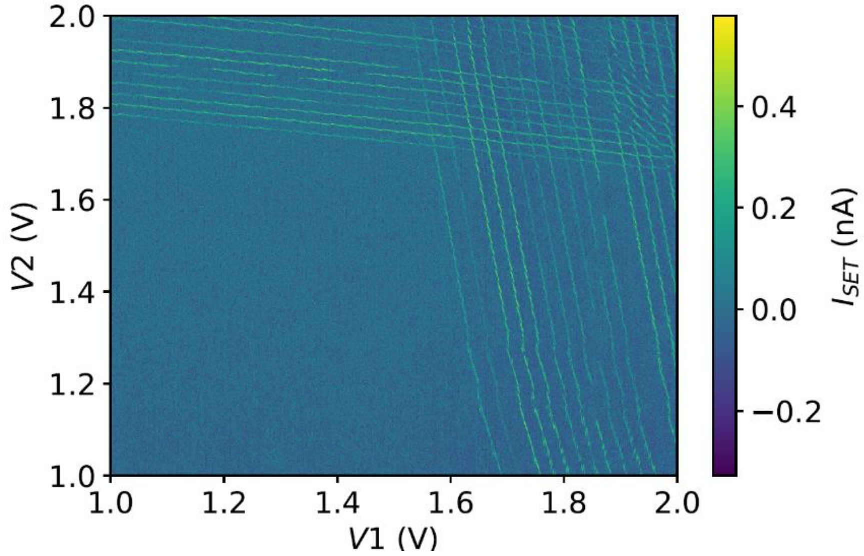

Fig.2. Typical stability diagram for devices on the fig.1 type. By opening the channel under both gates, electrons can tunnel in the respective dots individually. Between the current peaks, the system is in a Coulomb blockade state.

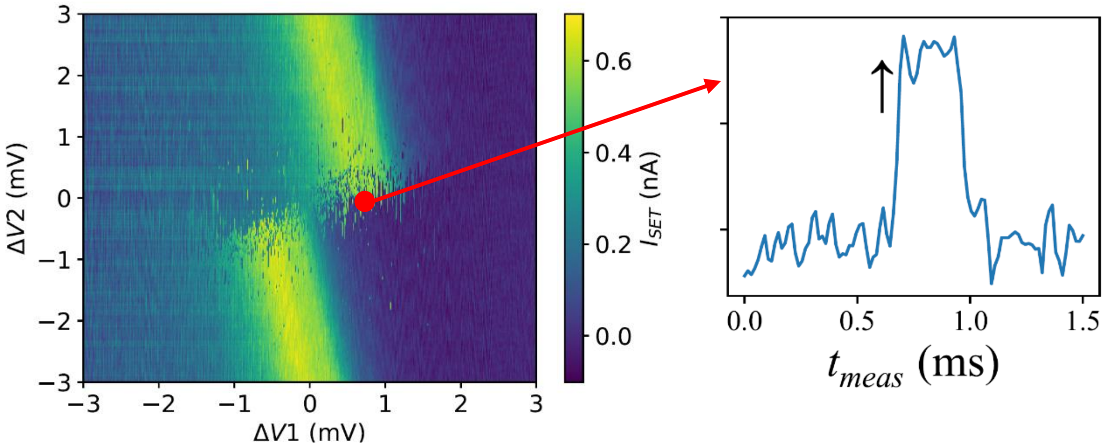

Fig.3. (Left) Zoom on the charge stability diagram of fig.2, where a Coulomb peak of the SET shifts due to a change in the qubit dot charge occupation. (Right) Time trace taken at a point of degeneracy for the qubit dot charge state : an electron can tunnel in or out of the dot, and this signature is recorded in real time in the SET current.