23: Radio-frequency reflectometry at low temperature on silicon quantum dots

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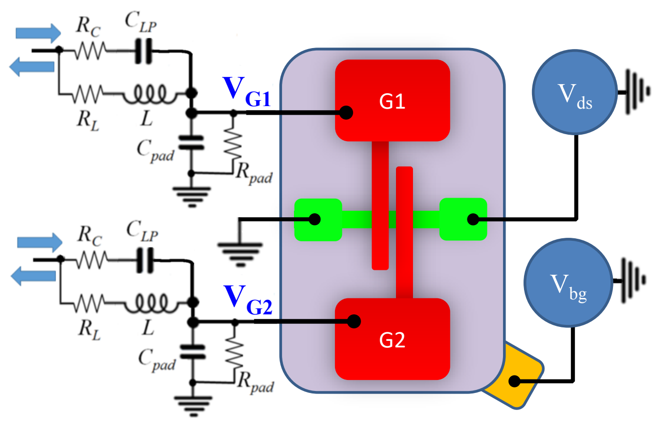
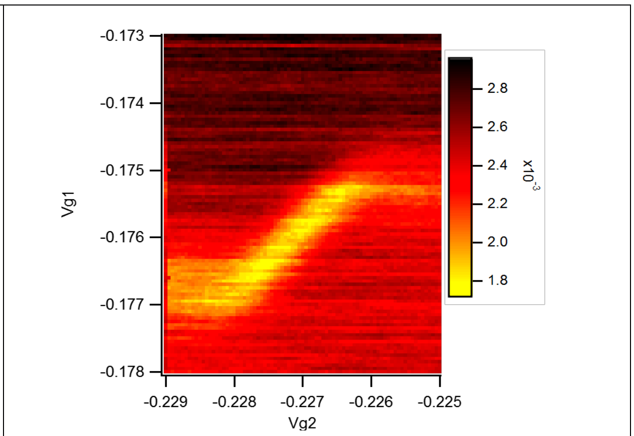
Radio-Frequency reflectometry (RFR) is a technique that allows to characterize the properties of transmission lines by observing reflected waveforms. It has been widely used in a variety of applications, ranging from the detection of faulty wires in cables and objects buried in the ground to soil moisture detectors and the measurement of dielectric properties of blood.

More recently it has been applied to nanoelectronics at low temperature, by embedding the nanoscale device under test in a resonator. A very tiny microwave power (typically -70 dBm) is sent to the device and monitoring the amplitude and phase of the reflected signal gives precious information on the sample that may be impossible to access otherwise. For instance, unlike transport spectroscopy which requires a current to flow through the whole device and hence through each barrier if any, we can access “internal” processes such as the transfer of single electrons or holes between two quantum dots in series even if the barriers to source and drain remain completely opaque.

In this lab session we will apply this technique to nano-scale silicon quantum dots derived from the microelectronics industry, produced on 300 mm wafers and which gave rise recently to the first CMOS spin quantum bit [1,2].



Sketch of the dual channel reflectometry experiment. Blue arrows indicate RF incoming and reflected signals at two different frequencies.



RFR data at 60 mK in a double-dot system showing mostly the interdot transition (tilted yellow segment) and a faint dot1/lead transition.

Practically we will briefly review the main features of our samples (fabrication, characterization…) and how they can yield to single and coupled quantum dots at low temperature. We will use an RFR setup and perform measurements with a high-speed lock-in amplifier as demodulator [3]. We will simulate the response of the tank circuit and see how to improve the nominally poor quality factor of the resonator, in a 4K test setup.

[1] R. Maurand et al., A CMOS silicon spin qubit, Nature Comm. 7, 13575 (2016) http://dx.doi.org/10.1038/ncomms13575

[2] A. Corna et al., Electrically driven electron spin resonance mediated by spin/valley/orbit coupling in a silicon quantum dot, npj Quantum Information 4, 6 (2018) http://dx.doi.org/doi:10.1038/s41534-018-0059-1

[3] A. Crippa et al., Level Spectrum and Charge Relaxation in a Silicon Double Quantum Dot Probed by Dual-Gate Reflectometry, Nano Letters 17, 1001 (2017) http://dx.doi.org/10.1021/acs.nanolett.6b04354