Sensitive Radio-Frequency Measurements of Charge States and Tunnel Couplings in Ge/Si Core/Shell Nanowire Quantum Dots

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Ge/Si core/shell nanowire is predicted to possess the strong spin-orbit interaction (SOI) and lack of the nuclear spin scattering making it a promising candidate to host a spin qubit with long spin coherence times and fast operation in all electric control. By placing the nanowires on atomically flat hexagonal Boron Nitride (hBN) substrates those lying on the pre-patterned finger gates with the separation of 60nm, stable quantum dots are defined along the Ge/Si core/shell wires with the formation of local energy barrier by electrical gating. Radio-frequency reflectometry is widely used for the fast detection of charge dynamics in quantum devices because such technique is avoided of the RC delay that often limits the measurement speed of the conventional DC electrical transport. We use the radio-frequency reflectometry to analysis the orbital states of holes trapped in the quantum dots as well as address the inter-dot tunnel couplings at dilution refrigerator temperature (~50mK). The quantum dot device is connected to a proximate LC (inductor-capacitor) tank circuit where the resonance frequency sits at ~150MHz with a bandwidth of 3MHz, enabling the information extraction of the quantum conductance and capacitance in microseconds time scale from the response of reflected signal. This work provides us valuable knowledge of the appropriate device design and the control of charge states and the tunnel coupling strength, which is crucial in future in-depth study of few holes spin states and the coherent spin control in Pauli blockade regime.

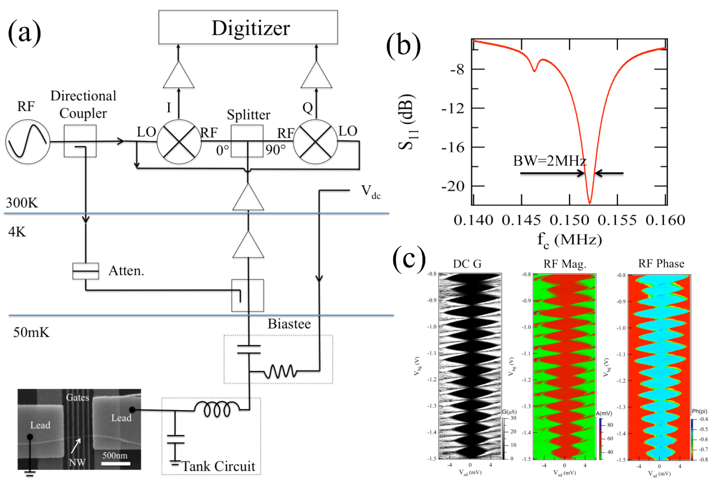

Figure. (a) Circuit diagram of a radio-frequency reflectometry setup. The LC resonator is connected with the source of a Ge/Si core/shell nanowire quantum dot device. (b) Amplitude of reflected signal as a function of frequency measured by a network analyzer. (c) Comparison of DC transport conductance (left), RF resonance magnitude (middle) and phase (right) response of a single quantum dot as a function of source-drain bias and back gate. Similar diamond pattern indicates the RF-sensor is working for the charge detection.