7th RQC Seminar

Hybrid Circuit Quantum Electrodynamics with Semiconductor QDs and Superconducting Resonators

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This seminar will be recorded and made available for about 10 days after the event. The link to the recording will be notified later.

Semiconductor qubits rely on the control of charge and spin degrees of freedom of electrons or holes confined in quantum dots (QDs). Typically, semiconductor qubit-qubit coupling is short range, effectively limiting qubit distance to the spatial extent of the wavefunction of the confined particle (a few hundred nanometers). This is a significant constraint towards scaling of the QD-based architectures to reach dense 1D or 2D arrays of QDs. Inspired by techniques originally developed for circuit QED, we demonstrated the strong coupling limit of individual electron charges [1,2] confined in GaAs quantum dots, by using the enhancement of the electric component of the vacuum fluctuations of a resonator with impedance beyond the typical 50 Ω of standard coplanar waveguide technology.

By making use of this hybrid technology, we recently realized a proof-of-concept experiment, where the coupling between a transmon and a double QD (DQD) is mediated by virtual microwave photon excitations in a high impedance SQUID array resonator, which acts as a quantum bus enabling long-range coupling between dissimilar qubits [3]. Similarly, we achieved coherent coupling between two DQD charge qubits separated by approximately ~50 μm [4].

We have further investigated how to in-situ tune the strength of the electric dipole interaction between the DQD qubit and the resonator [5]. We find that the qubit-resonator coupling strength, qubit decoherence, and detuning noise can be tuned systematically over more than one order of magnitude. By employing a Josephson junction array resonator with an impedance of ~4 kΩ and a resonance frequency of $\omega_r/2\pi$~5.6 GHz, we observe a coupling strength of $g/2\pi$~630 MHz, demonstrating the possibility to achieve the ultra-strong coupling regime for electrons hosted in a semiconductor DQD. The methods and techniques developed in this work are transferable to QD devices based on other material systems and can be beneficial for spin-based hybrid systems [6].

References

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[4] D. J. van Woerkom*, P. Scarlino* *et al.*, Phys. Rev. X **8**, 041018 (2018)
[5] P. Scarlino *et al.*, arXiv:2104.03045
[6] A. Landig*, J. Koski* *et al.*, Nature **560**, 179 (2018)

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