QuanTalks

IISc Quantum Technologies Initiative (IQTI) Seminar Series

Title: Hybrid Circuit Quantum Electrodynamics with Semiconductor QDs and Superconducting Resonators

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Meeting Link
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Biography: Pasquale Scarlino obtained his master's degree in Physics at the University of Salento, Lecce (Italy) in February 2011. He implemented the Quantum Point Contact Radio-Frequency Reflectometry technique, during his external Master thesis project at the Quantum Transport Group at TU Delft, under the supervision of Prof. L.M.K. Vandersypen at the Kavli Institute of Nanoscience-Qutech (TU Delft). He went on to obtain his Ph.D. degree in February 2016 with the same group where he led the Si/SiGe spin qubits project, collaborating with the M. Eriksson Group at Wisconsin University. Further, he underwent post-doctoral training in Prof. A. Wallraff (Quantum Device Lab) group at ETH Zurich where he in collaboration with the group of Prof. K. Ensslin and Prof. T. Ihn worked on integrating semiconductor and superconductor technologies.

From June 2019 till September 2020, he worked as Senior Researcher at Microsoft Station Q Copenhagen and at the Center for Quantum Devices in Copenhagen, focusing on developing semiconductor-superconducting hybrid hardware for topologically protected quantum computation. Since November 2020, he is a tenure track Assistant Professor of Physics in the School of Basic Sciences at the EPFL, where he founded the Hybrid Quantum Circuit (HQC) laboratory.

Abstract: 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 Ohm 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 um [4].

We have further investigated how to in-situ tuning 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 $\omega_r/2\pi \sim 5.6$ GHz, we observe a coupling strength of $g/2\pi \sim 630$ 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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[6] A. Landig*, J. Koski*, et al., Nature 560, 179-184 (2018).