Postdoc positions available in HQC lab (EPFL-Switzerland)

Strong and Ultrastrong Coupling with QD-Cavity Hybrid Architecture

The Hybrid Quantum Circuits Lab (HQC) at the École Polytechnique Fédérale de Lausanne (EPFL) is seeking a highly motivated postdoctoral researcher to contribute to the design, fabrication, and characterization of superconducting-semiconducting hybrid devices. This position is available immediately, and applications will be reviewed on a rolling basis.

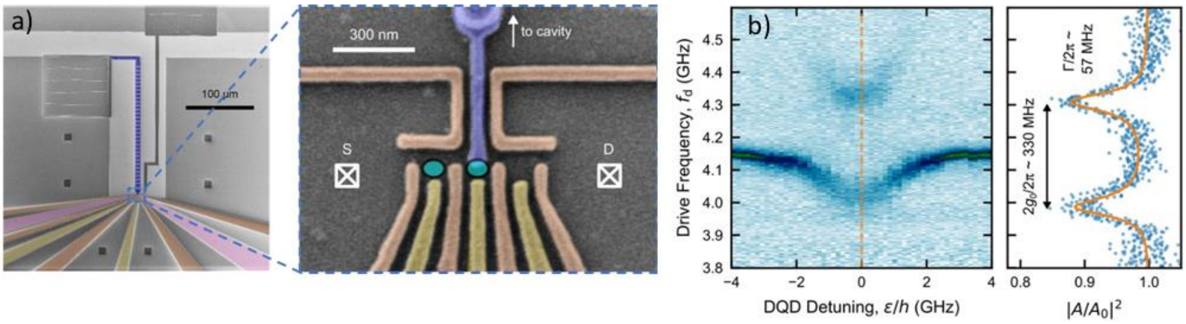

Fig. 1 a) SEM picture of a triple quantum dot (TQD) device coupled to a superconducting frequency-tunable SQUID array resonator. (b) Vacuum-Rabi splitting of the cavity mode, indication of the strong coupling regime.

Project description:

A quantum dot (QD) embedded in a circuit quantum electrodynamics (cQED) architecture offers a promising platform for both quantum information processing and the study of fundamental light-matter interactions, as well as enabling analog quantum simulations. Recent experiments have demonstrated strong coupling in semiconducting QD-cavity hybrid devices, where resonator microwave photons interact with the charge [1,3,4] or spin [2,5,6] degrees of freedom in QDs via their electric dipolar interaction.

A particularly compelling direction for future research is achieving ultrastrong coupling [7,8] between superconducting cavity photons and QD electrons, which could be realized by increasing resonator impedance, enhancing electric field fluctuations, and optimizing gate lever arms [8,10].

Our research focuses on double quantum dots (DQDs) defined in planar Germanium [9] and crystal-phase-defined DQDs within InAs nanowires [10,11]. The strong spin-orbit interaction (SOI) in these semiconductor materials simplifies spin qubit design, enabling rapid spin manipulation through electrical signals and eliminating the need for micromagnets.

Building on these properties, strong coupling between microwave photons and charge qubits in planar Ge [9], as well as charge [10] and singlet-triplet qubits [11] in InAs nanowires, has recently been demonstrated. These advancements pave the way for significant progress in quantum technologies, making this an exciting and impactful field of research.

Postdoctoral Project Objectives:

The postdoctoral project focuses on two main goals:

- Maximizing light-matter interaction strength: Our aim is to surpass 1 GHz coupling with the charge degree of freedom and approach the bare resonator and qubit energies (4–8 GHz), thereby achieving the ultrastrong coupling regime.
- Using photons as a quantum bus: This will enable long-distance spin-spin entanglement, a key advancement for scalable quantum networks.

These goals will be pursued by:

- Increasing resonator impedance through the use of superconducting Josephson junctions/SQUID arrays or ultracompact GrAl resonators.
- Optimizing the coupling lever arm between the resonator and the double quantum dot with tailored gate designs.

Achieving ultrastrong coupling will establish a distinctive platform for exploring fundamental quantum phenomena and advancing quantum technology applications. Success in this project could unlock new research directions at the intersection of semiconductor and superconducting quantum technologies. The long-term aim is to integrate these platforms coherently, significantly broadening the scope of solid-state quantum hardware and introducing innovative strategies for quantum information technology.

References

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Job description / Responsibilities:

The successful candidate will work on integrating QD devices defined in planar Ge heterostructures and crystal-phase-defined DQDs within InAs nanowires with superconducting high-impedance resonators. Device fabrication, including manipulation and transfer of nanowires, will take place in the Center of Micro-Nanotechnology (CMi) cleanroom at EPFL, which is fully equipped with advanced tools for nanofabrication. High-quality semiconductor materials will be provided through collaborations with our project partners at Lund University and the University of Basel. The hybrid structures will be tested in a dilution refrigerator at 10 mK, using both cryogenic and room-temperature microwave electronics. The candidate will perform low-noise cryogenic and high-frequency measurements to characterize the coupling of charge and spin states in artificial atoms with the high-impedance environment. Success in this role will leverage our in-house expertise in nanofabrication, state-of-the-art microwave measurements, and the collaborative network within our research group.

Responsibilities may include:

- Device fabrication using photolithography, electron-beam lithography, and subtractive processing techniques.
- Manipulation and assembly of nanowires.
- Design and layout of microwave superconducting circuits, including conceptual and physical circuit design.
- Conducting microwave and time-domain characterization measurements.

Profile/Qualifications:

We are seeking highly motivated candidates with a strong interest in quantum technology involving semiconducting and/or superconducting quantum circuits. Proficiency in English (reading, writing, and scientific discussion) is essential, along with excellent teamwork and communication skills.

- PhD in physics, quantum engineering, or electrical engineering, ideally with a focus on semiconducting/superconducting devices.
- Extensive experience in nanofabrication, cryogenics, microwave design, and microwave measurements. Expertise in fabricating electrically defined QDs and nanowire-based quantum devices is a plus.
- Strong research skills with a demonstrated ability to conduct independent research.
- Proven ability to collaborate effectively within a team.
- Demonstrated initiative, results-oriented mindset, strong organizational skills, and creativity.
- Proficiency in programming languages for data analysis.

Application procedure:

Please submit your application in English as a PDF file. Applications should be sent electronically to pasquale.scarlino@epfl.ch and include the following:

CV: detailing education, previous employment, publication list, and contact information for at least two references.

Personal Letter: introducing yourself, describing your previous research areas and main research achievements, and outlining your future goals and research interests.

For questions, please contact:

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