TT 49: Quantum Coherence and Quantum Information Systems I

Time: Thursday 11:30–13:00 Location: HSZ 304

TT 49.1 Thu 11:30 HSZ 304

Inter-lab quantum microwave teleportation — •Michael Renger[1,2], Simon Gandorfer[1,2], Wun Kwan Yam[1,2], Florian Fesquet[1,2], Kedar Honasoge[1,2], Fabian Kronowetter[1,2,3], Yuki Nojiri[1,2], Achim Marx[1], Rudolf Gross[1,2,4], and Kirill G. Fedorov[1,2] — [1]Walther-Meißner-Institut, BadW, 85748 Garching, Germany — [2]TUM School of Natural Sciences, Technische Universität München, Garching, Germany — [3]Rohde & Schwarz GmbH & Co. KG, 81671 Munich, Germany — [4]Munich Center for Quantum Science and Technology, 80799 Munich, Germany

Quantum communication enables secure and efficient information exchange among different quantum nodes. To avoid inefficient frequency conversion for data transfer between superconducting quantum processors, we implement our quantum communication protocols with propagating quantum microwave states, directly in the microwave frequency regime which relies on ambient temperatures below 100 mK. To realize such a microwave quantum channel, we connect two dilution refrigerators over a distance of 6.5 m via a cryogenic link, operating at a base temperature of 52 mK. We employ our system to demonstrate inter-lab quantum teleportation of coherent microwave states, where we achieve the teleportation fidelity of 55%, exceeding the classical threshold. We discuss quantum advantage and security of this protocol and provide an outlook into the future of microwave quantum communication.

TT 49.2 Thu 11:45 HSZ 304

A co-design superconducting quantum circuit for quantum simulations — •Daria Gusenkova, Jayshankar Nath, Hsiang-Sheng Ku, Julia Lamprich, Nicola Wurz, Stefan Pogorzalek, Florian Vigneau, Ping Yang, Frank Deppe, Antti Vepsäläinen, Alessandro Landra, Vladimir Milchakov, Caspar Ockeloen- Korppi, Wei Liu, Lan-Hsuan Lee, Seung-Goo Kim, Hermanni Heimonen, Manish Thapa, and Inés de Vega — IQM Germany GmbH, Nymphenburger Str. 86, 80335 Munich

The co-design concept of building application-specific quantum processors is a viable strategy for reaching quantum advantage with noisy intermediate-scale quantum computers. We consider many-body problems which map onto a Hamiltonian with all-to-all interacting qubits. Here, a prototypical example is the simulation of a nanoscale NMR system consisting of an NV center coupled to multiple nuclear spins. We discuss the implementation on a star-topology circuit developed in IQM. Compared to the general-purpose square-grid topology, the star reduces the number of SWAP gates in the algorithm implementation, and thus tolerates higher gate errors for a given computational precision [1]. In order to allow for hardware scaling, we use a distributed-element resonator as a center component in the circuit. To use this resonator as a computational element, we develop qubit-resonator SWAP and CZ gates. In this talk, we present the experimental progress towards digitally simulating the nanoscale NMR problem.

[1] M. G. Algaba et. al., Phys. Rev. Research 4, 043089 (2022)

TT 49.3 Thu 12:00 HSZ 304

Showcasing the effective direct interaction between a readout resonator and a strongly coupled junction defect mediated by a transmon qubit — •Alexander K. Händel, Alexander Bilmes, Alexey V. Ustinov, and Jürgen Lisenfeld — Physikalisches Institut, Karlsruhe Institute of Technology, 76131 Karlsruhe, Germany

Decoherence from material defects constitutes a principal problem on the way to improve superconducting quantum bits. Strongly coupled defects residing in the Josephson junction pose a particular challenge, demonstrating coupling strengths of multiple MHz. This strong coupling leads to avoided level crossings when qubit and defect come into resonance, and spoils qubit performance. In this work, we reveal an additional decoherence channel that occurs due to the resonant interaction between defects in the qubit's Josephson junction with the qubit's readout resonator, through an interaction mediated by the qubit. We investigate this effect using multi-photon spectroscopy and QuTiP simulations of the tripartite energy level spectrum.

TT 49.4 Thu 12:15 HSZ 304

Modular flip-chip architecture for generalized flux qubits — •Soeren Ihssen[1], Simon Geisert[1], Martin Spiecker[2], Patrick Winkel[2], Wolfgang Wernsdorfer[1,2], and Ioan M. Pop[1,2] — [1]Institute for Quantum Materials and Technologies, Karlsruhe Institute of Technology, Germany — [2]Physikalisches Institut, Karlsruhe Institute of Technology, Germany

Superconducting circuits are a promising and widely-used platform to implement quantum information processing hardware. However, scaling up to more sophisticated devices requires major engineering efforts due to the complexity of the mandatory coupling, readout and control circuitry. To investigate innovative coupling and scaling strategies, we developed a modular flip-chip architecture, in which the various circuit elements reside on dedicated chips that are capacitively coupled. A unit cell of our architecture consists of a qubit chip that is flipped above a control chip. The qubit chip contains a single generalized flux qubit (GFQ) and a harmonic readout mode, through which dispersive readout is possible. The control chip is used to excite, read out and flux bias the qubit. We tested our architecture by characterizing the GFQs in all conventional flux qubit regimes by modifying the qubit loop inductance as well as the shunt capacitance and the Josephson energy of the alpha junction. This resulted in qubit frequencies between 150 MHz and 7.5 GHz, and dispersive shifts of 60 kHz to 6 MHz. Coupling between unit cells may be achieved through coupler chips, so that our unit cell can be used as a basic building block of a scalable qubit array.

TT 49.5 Thu 12:30 HSZ 304

Improving Fabrication Methods for Highly Coherent Superconducting Qubits — •Niklas Bruckmoser[1,2,3], Leon Koch[1,2,3], David Bunch[1,2,3], Tammo Sievers[1,2,3], Kedar E. Honasoge[1,2,3], Thomas Luschmann[1,2,3], and Stefan Filipp[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Superconducting qubits and resonators with long coherence times pave the way towards useful quantum processors. Significant improvements in coherence time have already been made over the last years. However, the fidelity is still limited by decoherence due to noise and losses arising in the local environment of the qubit. It is thus an integral endeavor of fabrication efforts to mitigate these effects. Here, we demonstrate that qubit lifetimes well beyond 0.1 ms can be achieved by a combination of substrate cleaning, etching optimization and post-process sample cleaning. By improving on these processes we reach quality factors above 4×10^6 for thin-film niobium coplanar waveguide resonators in the single photon regime and qubit lifetimes of more than 0.2 ms for niobium based transmons.

TT 49.6 Thu 12:45 HSZ 304

Dynamics of superconducting qubit coherence times due to fluctuations of two-level systems — •Ivan Tsitsilin[1,2] and Stefan Filipp[1,2] — [1]Technical University of Munich, TUM School of Natural Sciences, Physics Department, 85748 Garching, Germany — [2]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany

Recent studies have shown that the stability of coherence times is strongly affected by two-level systems (TLSs). This is caused by chaotic frequency fluctuations of TLSs, which, when in proximity to the qubit resonance, significantly reduce its T_1 times. Understanding and mitigating this behavior is crucial to realize functional quantum processing devices based on superconducting qubits. In this work, we perform a long-time stability analysis of the qubit T_1 times as a function of qubit frequency utilizing the AC-Stark shifting technique[1]. We present an extensive analysis of the TLS distributions and their impact on T_1 times for different qubit sample materials and RF line configurations. Furthermore, our results provide insight into the effect of the noise spectrum on the behavior and density of TLSs.

[1] Carroll et al., arXiv:2105.15201