TT 17: Superconductivity: Qubits II

Time: Monday 15:00–17:00 Location: H 2053

TT 17.1 Mon 15:00 H 2053

Effective Evolution of a Driven Qubit Beyond the Rotating Wave Approximation — •Daniel Zeuch[1], Fabian Hassler[2], and David P. DiVincenzo[1,2] — [1]Peter Gruenberg Institut, Forschungszentrum Juelich, Juelich, Germany — [2]JARA-Institute for Quantum Information, RWTH Aachen University, Aachen, Germany

Decreasing the duration of quantum gates requires high-amplitude pulses. In the high-amplitude regime one needs to take into account effects beyond those captured by the rotating wave approximation. Such effects include rapid oscillations on the time scale of $1/\omega$, where ω is the qubit frequency, making it difficult to accurately describe the state evolution. For constant-amplitude pulses there is an effective Hamiltonian which describes shifts of the resonance frequency, known as the Bloch-Siegert shift [1], and of the Rabi frequency. For the case of time-dependent amplitudes of the order of the qubit frequency, we employ the Magnus expansion [2] to analytically determine an effective Hamiltonian which depends on time only through the amplitude. The time evolution due to our effective Hamiltonian is a family of rotating-frame trajectories, each of which agrees at periodic points in time with the actual state trajectory. We expect that using such effective Hamiltonians will reduce computational resources when designing pulse shapes.

[1] F. Bloch and A. Siegert, Physical Review **57**, 522 (1940).
[2] R. R. Ernst, G. Bodenhausen, A. Wokaun, Clarendon Press, Oxford (1987)

TT 17.2 Mon 15:15 H 2053

FPGA-based Quantum Feedback for Superconducting Qubits — •Richard Gebauer[1,2], Nick Karcher[1], Martin Weides[2], Oliver Sander[1], Alexey V. Ustinov[2], and Marc Weber[1] — [1]Institut für Prozessdatenverarbeitung und Elektronik, KIT — [2]Physikalisches Institut, KIT

A typical measurement setup for superconducting qubits consists of arbitrary waveform generators, signal recorders and vector network analyzers. Although sufficient for simple experiments, its applicability is limited due to long data communication delays, poor scalability and static pulse sequences. A faster and more flexible solution for qubit readout and control is FPGA-based custom hardware. It not only dramatically reduces costs and space requirements but also simplifies measurements and enables customized control schemes like quantum feedback where a low response time is critical.

We implemented an FPGA design for experiments with superconducting qubits which also enables fast feedback loops to control qubits depending on their measured state. Thus, it provides the basis for experiments and algorithms like quantum error correction or active reset. While typically the signal-to-noise ratio is improved by averaging, feedback loops require single shot measurements. Therefore, we employ a Josephson parametric amplifier with its superior noise characteristics. In the current state of development, we demonstrate arbitrary qubit rotations around X and Y axis. Furthermore, we can perform all standard measurements for qubit characterization using an FPGA and will present first results on implementing quantum feedback.

TT 17.3 Mon 15:30 H 2053

Bistability, chaos and chaos-to-hyperchaos transition in a few-qubit chain. — •Alexandre Zagoskin and Alexander Balanov — Department of Physics, Loughborough University, Loughborough, UK

Based on numerical simulations, we predict that an externally driven chain of a few qubits with dissipation will demonstrate transitions between several stable regimes and chaotic behaviour due to bistability, similar to the behaviour predicted for Rydberg atoms. The system also demonstrates a transition from chaotic to hyperchaotic behaviour as the number of qubits changes from 4 to 5. We argue that the transition is determined by the dimensionality of the Hilbert pace of the system and can be observed in a system of realistic superconducting qubits.

TT 17.4 Mon 15:45 H 2053

Coherent Revival of Ramsey Oscillations in the Fluxonium Qubit Coupled to a bath of Harmonic Oscillators — •Farshad Foroughi[1], Mattia Mantovani[2], Remy Dassonneville[1], Luca Planat[1], Javier Puertas[1], Sebastien Leger[1], Etienne Dumur[4], Yuriy Krupko[1], Wolfgang Belzig[2], Cecile Naud[1], Olivier Buisson[1], Nicolas Roch[1], Frank Hekking[1], Gianluca Rastelli[2,3], and Wiebke Guichard[1] — [1]Univ. Grenoble Alpes, CNRS, Grenoble INP, Institut Néel, Grenoble, France. — [2]Fachbereich Physik, Universität Konstanz, Konstanz, D-78457 , Germany. — [3]Zukunftskolleg, Universität Konstanz, D-78457, Konstanz, Germany — [4]The institute for Molecular Engineering, University of Chicago, Chicago, IL, United States.

We studied different fluxonium qubits in 2D and 3D cavity-structures and reached the state of the art for coherence and relaxation times. We observed a systematic increase of the relaxation time both in 3D and 2D at the optimal point of the qubit, when quasi-particle tunneling is strongly reduced. We aim to realize a 2D fluxoniums coupled to few on-chip lumped element resonators. We use a fast flux line to control the coupling between the fluxonium qubit and the resonators. We have studied theoretically the emerging spin-boson Hamiltonian for this particular circuit with the perspective of measuring revival effects in the coherent oscillations of the qubit. We started to implement measurements, revealing the effect on the qubit dynamics of a dissipative bath formed by a discrete set of harmonic oscillators.

TT 17.5 Mon 16:00 H 2053

Nonreciprocal scattering of two superconducting qubits coupled to a waveguide — •Andres Rosario Hamann[1], Clemens Mueller[1], Markus Jerger[1], Joshua Combes[1], Maximilian Zanner[2], Martin Weides[2], Thomas M. Stace[1], and Arkady Fedorov[1] — [1]ARC Centre of Excellence for Engineered Quantum Systems, The University of Queensland, St Lucia QLD 4072, Australia — [2]Physikalisches Institut, Karlsruhe Institute of Technology (KIT), 76131 Karlsruhe, Germany

Recent theoretical studies of a pair of atoms in a 1D waveguide show that the system responds asymmetrically to incident fields from opposing directions at low powers. In this work we present an experimental implementation of this nonreciprocal system by using two superconducting transmon-like qubits embedded in a copper waveguide. We show that the asymmetry arises from the formation of a quasi-dark-state of the two atoms, which saturates at extremely low powers. The nonlinear saturability of the system explicitly breaks the assumptions of the Lorentz reciprocity theorem. Two external coils provide control over the flux threading the transmons, thus allowing us to individually tune their transition frequencies and to change the effective coupling between the incident fields and the quasi-dark-state.

TT 17.6 Mon 16:15 H 2053

Simple Impedance Response Formulas for the Dispersive Interaction Rates in the Effective Hamiltonians of Low Anharmonicity Superconducting Qubits — •Firat Solgun[1], David DiVincenzo[2,3], and Jay Gambetta[1] — [1]IBM T.J. Watson Research Center, Yorktown Heights, NY 10598, USA — [2]Institute for Quantum Information, RWTH Aachen, Germany — [3]Peter Grünberg Institute: Theoretical Nanoelectronics, Research Center Jülich, Germany

For superconducting quantum processors consisting of low anharmonicity qubits such as transmons we give a complete microwave description of the system in the qubit subspace. We assume that the qubits are dispersively coupled to a distributed microwave structure such that the detunings of the qubits from the internal modes of the microwave structure are stronger than their couplings. We define qubit ports across the terminals of the Josephson junctions and drive ports where transmission lines carrying drive signals reach the chip and we obtain the multiport impedance response of the linear passive part of the system between the ports. We then relate interaction parameters in between qubits and between the qubits and the environment to the entries of this multiport impedance function: in particular we show that the exchange coupling rate J between qubits is related in a simple way to the off-diagonal entry connecting the qubit ports. Our treatment takes into account all the modes (possibly infinite) that might be present in the distributed electromagnetic structure and provides an efficient method for the modeling and analysis of the circuits.

TT 17.7 Mon 16:30 H 2053

Tunable ohmic environment using Josephson junction chains
— •Gianluca Rastelli[1] and Ioan M. Pop[2] — [1]Zukunftskolleg & Fachbereich Physik, Universität Konstanz, Konstanz, Germany — [2]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

We analyse a scheme to implement a tunable resistance using a double chain of Josephson junctions. The two parallel chains are formed by N dc-SQUIDs, acting as linear and tunable inductance L. The chains are coupled capacitively through a capacitance C much larger than the capacitance of the individual dc-SQUID. The system sustains electromagnetic modes forming a large but discrete set of damped harmonic oscillators. This set yields an impedance Z, that is a smooth and continuous function versus frequency. Moreover, the system can be connected to an external measurement setup, and the dissipation can be continuously monitored. We show that, by varying L, the double chain can operate as tunable ohmic resistance in a frequency band spanning several GHz, with a resistance that can exceed the quantum resistance. We argue that the circuit complexity is within reach using current Josephson junction technology.

TT 17.8 Mon 16:45 H 2053

Quantum Process Tomography of a Quantum Memory —
•Michael Renger[1,2], Edwar Xie[1,2,3], Frank Deppe[1,2,3], Peter Eder[1,2,3], Michael Fischer[1,2,3], Stefan Pogorzalek[1,2], Kirill G. Fedorov[1,2], Achim Marx[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich (NIM), 80799 München, Germany

In order to realize a quantum memory, a memory protocol for a superconducting qubit coupled to a 3D cavity resonator is realized with a Z fidelity of 85%. By exploiting the multimode structure of the 3D cavity, we combine readout and storage capability in a single device, thereby significantly enhancing scalability. With the goal of accurately characterizing the information loss during the protocol, the overall process fidelity has to be measured. To this end, we perform quantum process tomography on our quantum memory system. The protocol consists of four pulses with a total length of 240ns. The qubit density matrix is reconstructed with standard quantum state tomography for a suitable set of qubit states. The comparison of the measured outcome with the theoretical value gives us knowledge about the process matrix χ. We present tomography data and compare the quantum process fidelity to the Z fidelity.

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