FM 39: Quantum Computation: Hardware Platforms II

Time: Tuesday 14:00–16:00 Location: 3044

Invited Talk FM 39.1 Tue 14:00 3044

Applications of Quantum Computing with Superconducting Qubits — •Stefan Filipp — IBM Research - Zurich

In the recent years we have observed a rapid development of quantum technologies for the realization of quantum computers that promise to outperform conventional computers in certain types of problems. These include problems in optimization and machine learning, but also in the computation of complex many-body physical systems such as molecules or condensed matter. Assisted by conventional computing systems, hybrid quantum-classical architectures may soon allow us to solve some of today's computational challenges. Because of their relatively long coherence times and scalable fabrication methods superconducting quantum circuits are a promising candidate to realize such a quantum computing platform. We employ a variational algorithm that is based on a classical optimizer to guide the preparation of the quantum state on the quantum processor which encodes the solution to a given problem. This method is suited best for near-term applications on non-error corrected quantum hardware because it relies only on a small number of quantum operations and finishes within the coherence time of the system. First results in the field of quantum chemistry for computing the energy spectra of small molecules and in machine learning for classification protocols demonstrate the potential of this technology.

FM 39.2 Tue 14:30 3044

Fast control of quantum circuits — •Jan Goetz[1,2], Kuan Tan[1,2], Vasilii Sevriuk[1], Eric Hyyppä[1], Matti Silveri[1], Matti Partanen[1], Mate Jenei[1], Joni Ikonen[1], Visa Vesterinen[3], Leif Grönberg[3], Juha Hassel[3], and Mikko Möttönen[1,2,3] — [1]IQM, Vaisalantie 6C, 02130 Espoo, Finland — [2]QCD Labs, QTF Centre of Excellence, Department of Applied Physics, Aalto University, PO Box 13500, FI-00076 Aalto, Finland — [3]VTT Technical Research Centre of Finland Ltd, P.O. Box 1000, FI-02044, Espoo, Finland

We report on a fast in-situ control of superconducting quantum circuits. Namely, the fast tunability of an electromagnetic environment coupled to a superconducting resonator and a novel fast readout scheme for superconducting qubits. As tunable environment, we utilize a recently-developed quantum-circuit refrigerator (QCR) to experimentally demonstrate a dynamic tunability in the total damping rate of the resonator up to a factor of 30, with a consequently theoretically predicted change in the internal damping rate by four orders of magnitude. For the fast qubit readout, we experimentally implement a method of measuring a qubit by driving it close to the frequency of a dispersively coupled bosonic mode. Our experiments pave the way towards significant speedup in two relevant operations of a superconducting quantum computer, qubit reset and readout.

FM 39.3 Tue 14:45 3044

Non-equilibrium quasiparticles in superconducting circuits: photons vs. phonons — •Gianluigi Catelani[1] and Denis Basko[2] — [1]JARA Institute for Quantum Information, Forschungszentrum Jülich, Germany — [2]CNRS, Grenoble, France

We study the effect of non-equilibrium quasiparticles on the operation of a superconducting device (a qubit or a resonator), including heating of the quasiparticles by the device operation. Focusing on the competition between heating via low-frequency photon absorption and cooling via photon and phonon emission, we obtain a remarkably simple non-thermal stationary solution of the kinetic equation for the quasiparticle distribution function. We estimate the influence of quasiparticles on relaxation and excitation rates for transmon qubits, and relate our findings to recent experiments.

FM 39.4 Tue 15:00 3044

Photon-assisted charge-parity jumps in a superconducting qubit — Manuel Houzet[1], Kyle Serniak[2], •Gianluigi Catelani[3,4], Michel Devoret[2], and Leonid Glazman[2] — [1]CEA, Grenoble, France — [2]Depts. of Physics and Applied Physics, Yale University, New Haven, USA — [3]JARA Institute for Quantum Information, Forschungszentrum Jülich, Germany — [4]Yale Quantum Institute, Yale University, New Haven, USA

We evaluate the rates of energy and phase relaxation of a superconducting qubit caused by stray photons with energy exceeding the threshold for breaking a Cooper pair. All channels of relaxation within this mechanism are associated with the change in the charge parity of the qubit, enabling the separation of the photon-assisted processes from other contributions to the relaxation rates. Among the signatures of the new mechanism is the same order of rates of the transitions in which a qubit loses or gains energy. Our theory offers a natural explanation of recent measurements.

FM 39.5 Tue 15:15 3044

cross-resonance-based gates between different superconducting quibt types — •xuexin xu[1], mohammad ansari[1], Jaseung ku[2], yebin liu[2], britton plourde[2], jared hertzberg[3], markus brink[3], and jerry chow[3] — [1]Peter Grünberg Institute, Forschungszentrum Jülich — [2]Syracuse University — [3]IBM T.J. Waston Research Center

We theoretically model an experiment on a superconducting circuit made of a capacitively shunted flux qubit (CSFQ) and a Transmon qubit both capacitively coupled to a bus resonator in dispersive regime. To model this circuit we take into account the contribution of higher excited states in qubits and block-diagonalize the Hamiltonian perturbatively in the regime of small interaction couplings compared to frequency detuning. We apply external driving microwave pulses over all energy levels and consider the transitions they impose effectively within the computational subspace. More specifically we apply entirely microwave two-qubit gate, the so called cross-resonance, on CSFQ at sweet spot and away from it. Interestingly the two-qubit fidelity is largely enhanced at certain external flux away from the sweet spot. This enhancement takes place as the result of suppressed leakage out of computational subspace. This will introduce further tunability into two-qubit gate fidelity. Our theoretical results are in agreement with experiment, showing a promising approach to controllably improve single- and two-qubit gate operations in such circuits due to the relatively large and positive anharmonicity of CSFQ.

FM 39.6 Tue 15:30 3044

Analog quantum simulation using superconducting qubits — •Stefan Oleschko[1,2], Oscar Gargiulo[1,2], Maximilian Zanner[1,2], Aleksei Sharafiev[1,2], and Gerhard Kirchmair[1,2] — [1]Institute for Quantum Optics and Quantum Information, A-6020 Innsbruck, Austria — [2]Institute for Experimental Physics, University of Innsbruck, A-6020 Innsbruck, Austria

In this talk I want to present the research activities of the Superconducting Quantum circuits group at the Institute for Quantum Optics and Quantum Information in Innsbruck. I will show how we want to use 3D circuit QED architectures to realize a platform for quantum many body simulations of dipolar XY models on 2D lattices using state of the art circuit QED technology. The central idea is to exploit the naturally occurring dipolar interactions between 3D superconducting qubits to simulate models of interacting quantum spins. The ability to arrange the qubits in essentially arbitrary geometries allows us to design spin models with more than nearest-neighbor interaction in various geometries. We will be able to investigate quantum phenomena in 2D where qualitatively new features emerge and existing numerical and analytical approaches reach their limitations.

FM 39.7 Tue 15:45 3044

Real-time precompensation for fast conditional sequence branching — •Bruno Küng, Yves Salathé, Niels Haandbaek, and Jan Sedivy — Zurich Instruments AG, Zurich, Switzerland

We present a real-time precompensation technology in an arbitrary waveform generator (AWG) for distortion corrections of superconducting qubit magnetic flux pulses [1].

In contrast to conventional precompensation of the waveform shape in software, real-time filtering applies corrections to the signal right before playback in the AWG. As a consequence, our implementation can incorporate the full history of the played pulse sequence, even when using fast conditional branching as is required for quantum error correction [2].

A signal level accuracy of 0.1% is achieved by optimized filter design which satisfies the requirement for low latency and enables to precompensate commonly occurring artifacts in cryogenic wiring.

For this precompensation method, the repeatability of flux pulses was quantified with two succeeding net-zero waveforms in [2]. The phase the qubits acquired during two subsequent fluxes pulses was identical within 1 deg and independent of the temporal separation between them.

[1] https://www.zhinst.com/products/hdawg/hdawg-pc
[2] M. A. Rol, et al. arXiv:1903:02492 [quant-ph], 2019