

TT 14 Symposium Superconducting Quantum Systems

Zeit: Samstag 13:45–16:45

Raum: TU H104

Hauptvortrag

TT 14.1 Sa 13:45 TU H104

Flux Qubits — ●HANS MOOIJ — Kavli Institute of Nanoscience, Delft University of Technology, 2628 CJ Delft, The Netherlands

We investigate superconducting flux quantum bits. The qubits are fabricated of aluminum and consist of a loop with three junctions. The basic quantum states have persistent currents of opposite sign. Measurements are performed with a SQUID. Quantum operations are performed by applying microwave pulses with a frequency that is resonant with the energy splitting of the qubit. We have studied the coherence of the systems and have measured relaxation and dephasing times. The best decoherence times are of the order of 1 microsecond, while qubit operations can be performed in a few nanoseconds. We have coupled a qubit to a harmonic oscillator and we have been able to transfer a single photon. We have coupled two qubits and are able to perform conditional two-qubit operations. In the talk the general status and the latest results will be discussed.

Hauptvortrag

TT 14.2 Sa 14:15 TU H104

Single-Shot State Measurement of Coupled Phase Qubits — ●JOHN MARTINIS — Physics Department, University of California, Santa Barbara, CA 93106, USA

The Josephson junction is an ideal solid-state system for building electrical "atoms" that can function as quantum bits for a quantum computer. I will discuss experimental work based on large-area "phase" qubits, where experiments have demonstrated qubit state preparation and measurement with good fidelity, as well as manipulation of the qubit state via the observation of Rabi oscillations.

A more advanced measurement technique, based on a fast pulse in the current bias, has reduced the measurement time for our phase qubits from 100 ns to less than 2 ns. With this improvement, we have recently been able to perform experiments on capacitively-coupled qubits, demonstrating coherent oscillations corresponding to the i -swap operation $|01\rangle \leftrightarrow |10\rangle$. This is the first experiment with Josephson qubits to achieve simultaneous single-shot state measurements of both qubit states. During the oscillations, the states $|01\rangle$ and $|10\rangle$ are found to be anti-correlated, as expected for an entangled quantum state.

Detailed measurements show that the two measurement pulses have to be timed within about 1 ns of each other in order for large crosstalk in the state probabilities not to appear in the measurement data. A semiclassical theory explaining this phenomenon will be presented.

With these developments, we will shortly be able to demonstrate CNOT gates with full state analysis using process tomography. I will present the simple theory describing these future experiments.

Fachvortrag

TT 14.3 Sa 14:45 TU H104

Quantum Electrometry using the Radio-Frequency Single-Electron Transistor — ●TIM DUTY, KEVIN BLADH, JONAS BYLANDER, DAVID GUNNARSSON, and PER DELSING — Chalmers University of Technology, Göteborg, Sweden

The fastest and most sensitive way to measure charge is based upon the radio-frequency single-electron transistor (RF-SET). We have employed RF-SET electrometers both as a read-out device for Josephson charge qubits, and to count individual electron and Cooper-pair charge solitons passing through an 1-D array of tunnel junctions.

Our experimental studies of Josephson charge qubits demonstrate how to mitigate the effects of non-equilibrium quasiparticles and produce Cooper-pair boxes with robust even-parity ground states. Coherent free-precession with a large visibility has been observed, and measurements of dephasing indicate the presence of low-frequency background charge fluctuations. Measured relaxation times are generally shorter than expected and not yet fully understood.

The quantum mechanical tunnelling of single charges in a one-dimensional array is time correlated and consequently the detected signal exhibits the frequency $f=I/e$, where I is the current and e is the electron charge. For Cooper-pairs, one observes $f=I/2e$. We present the first direct observation of time-correlated single-electron and Cooper-pair tunnelling oscillations.

Fachvortrag

TT 14.4 Sa 15:15 TU H104

Circuit Quantum Electrodynamics: Doing Quantum Optics with Superconductors — ●ANDREAS WALLRAFF — Department of Applied Physics, Yale University, New Haven, CT 06520, USA

I will describe recent experiments in which the strong coupling limit of cavity quantum electrodynamics has been realized for the first time using superconducting circuits [1]. In our approach, we use a Cooper-pair box as an artificial atom, which is coupled to a one-dimensional cavity formed by a transmission line resonator. In the case when the Cooper-pair box qubit is tuned into resonance with the cavity, we observe the vacuum Rabi splitting of the cavity mode, indicating that the strong coupling regime is attained, and coherent superpositions between the qubit and a single photon are generated. When the qubit is detuned from the cavity resonance frequency, we perform high-fidelity dispersive quantum non-demolition readout of the qubit state. Using this readout technique, we have characterized the qubit properties spectroscopically, performed Rabi oscillations of the qubit, and attained coherence times greater than 500 ns, indicating that this architecture is extremely attractive for quantum computing and control [2].

[1] A. Wallraff, D. I. Schuster, A. Blais, L. Frunzio, R.-S. Huang, J. Majer, S. Kumar, S. M. Girvin and R. J. Schoelkopf, *Nature (London)* 431, 162 (2004)

[2] A. Blais, R.-S. Huang, A. Wallraff, S. M. Girvin and R. J. Schoelkopf, *Phys. Rev. A* 69, 062320 (2004)

Fachvortrag

TT 14.5 Sa 15:45 TU H104

Quantum communication with Josephson arrays — ●ROSARIO FAZIO¹, ALESSANDRO ROMITO¹, and CHRISTOPH BRUDER² — ¹NEST-INFM & Scuola Normale Superiore, 56126 Pisa, Italy — ²Department of Physics and Astronomy, University of Basel, Klingelbergstrasse 82, 4056 Basel, Switzerland

Josephson junction arrays can behave as a quantum channels and used to transfer quantum information between distant sites. We discuss simple protocols to realize, without external control, state transfer [1] and cloning [2] with high fidelity in Josephson chains. The great advantage of these schemes is that they not require complicate gating but they simply use the natural dynamics of a properly designed array. We propose an experiment, realizable with present day technology, that may allow to implement these protocols. Communication is only mildly affected by the presence of unavoidable defects in the Josephson array.

[1] A. Romito, R. Fazio and C. Bruder, *cond-mat/0408057*.

[2] G. De Chiara et al. *quant-ph/0402071*.

Fachvortrag

TT 14.6 Sa 16:15 TU H104

Optimizing two-qubit quantum logic gates for superconducting systems — ●FRANK WILHELM — Department Physik und CeNS, LMU, Theresienstr. 37, 80333 München

With the maturation of superconducting qubits it is now possible to implement two-qubit quantum logic operations such as the controlled-not (CNOT) gate [1]. We describe the necessary ingredients: i) An suitable interaction. I will describe a scheme for coupling flux qubits controlled by an external current [2]. ii) An appropriate pulse sequence. We will use optimum control theory, well known in nuclear magnetic resonance, to derive optimum smooth pulses. For untunable interaction [3], a substantial improvement of gate fidelity (to 0.99) and time (50 ps) compared to [1] can be achieved by pulse shaping. In the tunable case, the optimum pulse is much simpler [2]. iii) Sufficient coherence. We will discuss the sensitivity of the gate performance to decoherence and the benefit of encoding into decoherence-free subspaces (DFSs) [4].

[1] T. Yamamoto, Y.A. Pashkin, O. Astafiev, Y. Nakamura, and J.S. Tsai, *Nature* 425, 941 (2003).

[2] B.L.T. Plourde, J.Zhang, K.B. Whaley, F.K. Wilhelm, T.L. Robertson, T. Hime, S. Linzen, P.A. Reichardt, C.-E. Wu, and John Clarke, *Phys. Rev. B(R)* 70, 140501 (2004).

[3] V. Bergholm, A. Spoerl, T. Schulte-Herbrueggen, S.J. Glaser, M.J. Storz, and F.K. Wilhelm, in preparation.

[4] M.J. Storz, J. Vala, K.R. Brown, J. Kempe, F.K. Wilhelm, and K.B. Whaley, *cond-mat/0407780*.