FM 40: Poster: Quantum Computation: Hardware Platforms

Time: Tuesday 16:30–18:30 Location: Tents

FM 40.1 Tue 16:30 Tents

Tunable refrigerator for superconducting quantum circuits — •Hao Hsu and Gianluigi Catelani — Forschungszentrum Jülich, Jülich, Germany

Fast initialization with high reset fidelity is a necessary criterion for realizing quantum computing. Recently, a "quantum circuit refrigerator" (QCR) was demonstrated which can cool superconducting resonators [1]. Here we extend the theory [2] to study a QCR coupled to generic superconducting circuits. We identify two working temperature regimes, depending on the QCR electron temperature T_N: the thermal activation regime and the low-temperature regime. In the thermal activation regime, the effective temperature T_T at which the circuit is cooled is proportional to T_N, while T_T is independent of T_N in the low-temperature regime. In typical transmon and capacitively shunted flux qubits, we find that in both regimes, the effective temperature limits the reset fidelity. In the practically relevant low-temperature regime, we predict 99.99 % reset fidelity in a reset time of few tens of nanoseconds.

[1] K. Y. Tan et.al., Nat. Commun. 8 15189 (2017) [2] M. Silveri et.al., Phys. Rev. B 96, 094524 (2017)

FM 40.2 Tue 16:30 Tents

Individually controlled Ion Trap Arrays for Quantum Simulations — •Frederick Hakelberg, Philip Kiefer, Deviprasath Palani, Lennart Guth, Jan-Philipp Schröder, Matthias Wittemer, Ulrich Warring, and Tobias Schaetz — Uni Freiburg

Trapped ions present a promising system for quantum simulations [1]. Surface-electrode traps in contrast to conventional ion traps offer the advantage of scalability to larger system size and dimension while maintaining individual control: Dedicated radio-frequency electrode shapes allow the creation of two-dimensional trap arrays [2] while control electrodes allow localized manipulation of the trapping potential tuning motional frequencies and mode orientations [3].
Our setup consists of a basic but scalable array of three Mg^+ ions individually trapped in an equilateral triangle with 40 μm inter-site distance. We present the first realization of inter-site coupling, until now only realized for one-dimensional arrangements [4]. We demonstrate its tuning in real time, and show interference of large coherent states [5]. Furthermore we employ the individual control for modulation of the local trapping potentials to realize phonon-assisted tunnelling between adjacent sites [6].

[1] T. Schaetz *et al.*, New J. Phys. **15**, 085009 (2013)
[2] R. Schmied *et al.*, Phys. Rev. Lett. **102**, 233002 (2009)
[3] M. Mielenz *et al.*, Nature Communications **7**, 11839 (2016)
[4] K. Brown *et al.* & M. Harlander *et al.*, Nature **471**, 196-203 (2011)
[5] F. Hakelberg *et al.*, arXiv:1812.08552, 196-203 (2018)
[6] A. Bermudez *et al.*, Phys. Rev. Lett. **107**, 150501 (2011)

FM 40.3 Tue 16:30 Tents

A spin qubit in ^{28}Si/SiGe with 60 ppm ^{29}Si — •Floyd Schauer[1], Tom Struck[2], Arne Hollmann[2], Andreas Schmidbauer[1], Carlo Peiffer[1], Veit Langrock[2], Helge Riemann[3], Nikolay V. Abrosimov[3], Lars R. Schreiber[2], and Dominique Bougeard[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany — [2]JARA-FIT Institute Quantum Information, Forschungszentrum Jülich GmbH and RWTH Aachen University, Aachen, Germany — [3]Leibniz-Institut für Kristallzüchtung, Berlin, Germany

^{28}Si is a strong candidate for hosting spin qubits, promising long qubit coherence times in a technologically scalable environment. Electrostatically-defined quantum dots in ^{28}Si/SiGe heterostructures have been proven to robustly allow the implementation of spin qubits, as long as their device-inherent valley splitting energy is sufficiently large to operate the qubit.

Here, we present the characterization of a gate-defined single spin qubit in a quantum dot layout with an integrated nanomagnet. The qubit is hosted in a molecular-beam epitaxy-grown ^{28}Si/SiGe heterostructure presenting only 60 ppm residual ^{29}Si. We determine the relevant single electron quantum dot energies, finding a robust valley splitting beyond 200 μeV and a well separated orbital energy beyond 1 meV. Below the valley splitting energy, we observe spin relaxation times T_1>1 s which are independent of the externally applied magnetic field. Using electron dipole spin resonance, the manipulation of the qubit yields $T_2^* \sim 22\,\mu$s and long $T_2^{echo} \sim 127\,\mu$s.

FM 40.4 Tue 16:30 Tents

Rydberg atoms in strong electric fields and in superconducting microwave cavities — •Andreas Günther[1], Conny Glaser[1], Manuel Kaiser[1], Lorinc Sárkány[1], Dieter Kölle[1], Reinhold Kleiner[1], David Petrosyan[2], and József Fortágh[1] — [1]Universität Tübingen, Auf der Morgenstelle 14, 72076 Tübingen, Germany — [2]Institute of Electronic Structure and Laser, FORTH, GR-71110 Heraklion, Crete, Greece

Using a novel quantum gas microscope, we directly measure the excitation blockade for strongly Stark-shifted Rydberg states close to the classical ionization limit. Therefore, we developed a novel scheme for tuning the interactions and controlling the ionization rate, using an avoided crossing in the corresponding Stark map. We investigate the dipole blockade by analyzing the spatial correlations of the excited Rydberg atoms for different values of the initial dipole moment and compare our findings to theoretical simulations.

Interparticle interactions, such as the dipole-dipole blockade, are of specific importance for Rydberg based quantum gates. In view of such a scheme, we study the coupling of Rydberg atoms to a superconducting coplanar microwave cavity. Depending on the microwave power, we observe Rabi oscillations at different frequencies, which allow for coherent state manipulations and may lead to coupling of Rydberg state pairs via the cavity field.

FM 40.5 Tue 16:30 Tents

Static and dynamic quantum speed limit of single neutral atoms in optical lattices — •Manolo Rivera[1], Thorsten Groh[1], Natalie Peter[1], Jan Uckert[1], Gal Ness[4], Carsten Robens[1], Wolfgang Alt[1], Dieter Meschede[1], Antonio Negretti[2], Tommaso Calarco[3], Simone Montagero[3], and Andrea Alberti[1] — [1]Institut für Angewandte Physik, Bonn, Germany — [2]Zentrum für Optische Quantentechnologien, Hamburg, Germany — [3]Institut für komplexe Quantensysteme, Ulm, Germany — [4]Physics Department, Technion - IIT, Haifa, Israel

We report on fast, high-fidelity transport of single atoms in spin-dependent optical lattices with a high-precision polarization synthesizer, which allows us to displace the lattice potentials with angstrom precision. The transport sequences computed from quantum optimal control theory are believed to reach the fundamental speed limit of our optical lattice system (dynamical quantum speed limit), corresponding to one lattice site in $30\mu s$. During transport operations close to the quantum speed limit the atoms are excited, but are then refocused to the ground state at the end of the transport. This is confirmed by measuring the fraction of atoms in the ground state after transport using a novel detection scheme based on microwave sideband spectroscopy. Our transport sequences preserve the coherence of the two spin states, this has been shown by single atom interferometry. Additionally we verify the Mandelstam-Tamm inequality which poses a lower bound to the time evolution between an initial state to an orthogonal state in the static lattice (static quantum speed limit).

FM 40.6 Tue 16:30 Tents

Digital single-atom interferometer in a two-dimensional state-dependent optical lattice — •Gautam Ramola, Richard Winkelmann, Muhib Omar, Karthik Chandrashekara, Wolfgang Alt, Dieter Meschede, and Andrea Alberti — Institute for Applied Physics, Bonn, Germany

We demonstrate a single atom interferometer with a Caesium atom, localized on a two-dimensional state-dependent optical lattice, where we achieve robust and precise control over both the external and internal degrees of the freedom of the particle [1]. Such precise control over the atomic wave packet allows for nondestructive probing of microscopic quantum systems and measuring potential gradients at ultrashort length scales [2]. The two-dimensional state-dependent lattice enables us to enclose large areas between the interfering arms, while the trapped nature of the interferometer allows us to insert an arbitrary amount of probing time. Both these factors contribute to increasing the sensitivity of our interferometer, which is proportional to the space-time area enclosed. Furthermore, precise control over the atom's position allows us to create arbitrary interferometric geometries, paving the way for implementing novel protocols to study multi particle interactions. One such proposal we plan to implement is the direct interferometric measurement of the exchange phase between two indistinguishable Caesium atoms [3].

[1]C. Robens et al.,Phys. Rev. A. **9**, 034016 (2018)
[2]A. Steffen et al., Proc. Natl. Acad. Sci. USA **109**, 9770 (2012).
[3]C. F. Roos et al., Phys. Rev. Lett. **119**, 160401 (2017)

FM 40.7 Tue 16:30 Tents

Optimization of the Readout of a Superconducting Qutrit — •Susanna Kirchhoff — Theoretical Physics, Saarland University, 66123 Saarbrücken, Germany

Superconducting qubits can be read out by driving a resonator coupled to the qubit and measuring the response. An arbitrary qubit state can be reconstructed using the responses of the basis states. For a three level system (qutrit) the readout is more challenging. In this work methods to improve the readout of a three level system are explored. The simulation data is based on the solution of a Bloch-type system of equations that was derived using the Jaynes-Cummings Hamiltonian with and without dispersive approximation. The results are compared to experimental data.

FM 40.8 Tue 16:30 Tents

Testing a photonic chip with entangled photons — •Bülent Demirel, Weikai Weng, Shreya Kumar, and Stefanie Barz — University of Stuttgart, FMQ, Stuttgart, Germany

Multipartite entangled states are useful for applications such as quantum networking and computing but also enable intriguing experiments on fundamental questions of quantum physics. Today's quantum technologies are based on the properties of large ensembles of particles, however, increasing the number of entangled parties is not a trivial process and requires increasing the number of components. Here, we show the generation of 4-photon entanglement, in particular a maximally entangled 4-photon GHZ state and a cluster state. We show how to generate those states using integrated optics. The presented results form the basis for subsequent few-photon experiments and future tests of quantum protocols on photonic chips.

FM 40.9 Tue 16:30 Tents

Optimal control pulses for a scalable quantum memory — •Nicolas Wittler, Shai Machnes, and Frank K. Wilhelm — Saarland University

Achieving high fidelities for operations on systems with low anharmonicity and complex crowded spectra, such as transmon qubits, is in general required for scalable quantum technologies.

A promising implementation of a quantum memory for a transmon consists of using an electromagnetic mode of the 3D cavity that is already used for readout and control of the transmon, as shown in an experiment by Frank Deppe's group at the Walther-Meißner-Institute in Munich.

The read and write operations for this memory are exchanges of excitations between the qubit and cavity. In order to profit of the life time of the cavity state ($T_1 = 9.5\mu s, T_2 = 13\mu s$) compared to the transmon ($T_1 = 1.4\mu s, T_2 = 3.5\mu s$), these gates must be fast and accurate. The high drive power needed to reach short gate times makes it necessary to control leakage out of the computational subspace into higher transmon states.

With theoretical pulse shaping techniques such as DRAG and GOAT that engineer the frequency spectrum of a control pulse, unwanted transitions can be suppressed and an increase in fidelity or shortening of the gate time can be achieved.

FM 40.10 Tue 16:30 Tents

Parametric amplification of broadband microwave signals — •Michael Renger[1,2], Kirill G. Fedorov[1,2], Stefan Pogorzalek[1,2], Qi-Ming Chen[1,2], Matti Partanen[1], Achim Marx[1], Frank Deppe[1,2,3], 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]Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, 80799 Munich, Germany

Phase-preserving amplification of quantum signals is a crucial part of many protocols in microwave quantum information processing, such as quantum teleportation or remote state preparation. Superconducting Josephson parametric amplifiers (JPA's) allow amplification close to the quantum limit, implying a fundamental bound of 1/2 for the maximal quantum efficiency η for narrow-band input signals. We demonstrate that this bound does not hold for broadband input signals. We find that $\eta = 70\%$ can be achieved by exploiting a JPA for amplification of broadband thermal signals. Furthermore, we study the noise properties of non-degenerate and degenerate amplification of two serially connected JPA's.

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FM 40.11 Tue 16:30 Tents

A sustainable sub-Kelvin cooling technology for quantum electronics — •Klaus Eibensteiner[1,2], Alexander Regnat[1,2], Jan Spallek[1,2], Tomek Schulz[1,2], Christopher Duvinage[1], Nico Huber[1], Carolina Burger[1], Anh Tong[1], and Christian Pfleiderer[1] — [1]Physik-Department, Technical University of Munich, Germany — [2]kiutra GmbH, Munich, Germany

Cooling devices providing temperatures well below 1 K are a key prerequisite for modern research and development, e.g. in materials science, quantum electronics and the cooling of sensors and detectors. Commercially available state-of-the art cooling solutions require typically the rare and costly helium isotope, helium-3. Here we present a versatile and compact demagnetization refrigerator for the cryogen-free, continuous generation of sub-Kelvin temperatures based on prevalent and affordable solid-state cooling media.