QI 5: Implementations: Solid State Systems

Time: Tuesday 14:00–16:00 Location: H4

Invited Talk QI 5.1 Tue 14:00 H4

Recent progress with superconducting fluxonium qubit — •Vladimir Manucharyan — University of Maryland, College Park, USA

Fluxonium consists of a superconducting loop interrupted by over 100 Josephson junctions, strips of insulating material a few nanometers thick sandwiched between superconducting layers. Consequently, the loop has an exceptionally large value inductance, which makes fluxonium distinct and useful. Having so many junctions per qubit has been generally viewed as a liability for establishing long coherence times. Yet, we observed coherence in excess of 1 millisecond and conclude that even longer coherence time should be possible by upgrading our fabrication procedures to the state of the art. The exceptional combination of fluxonium's high coherence and strong anharmonicity can be utilized for improving the fidelity of logical gates and constructing analog simulators of strongly interacting quantum spin models.

Invited Talk QI 5.2 Tue 14:30 H4

Quantum information processing with semiconductor technology: from qubits to integrated quantum circuits — •Menno Veldhorst — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, 2600 GA Delft, The Netherlands

Quantum computation with quantum dots has now been studied for more than two decades after the original proposal by Loss and DiVincenzo. Developments have been across the full-stack. Materials science progressed from GaAs heterostructures, to silicon, and most recently to strained germanium. These advances led to demonstrations of single qubit gates with fidelities close to 99.99%, high-fidelity two-qubit gates, and culminated in the realization a four-qubit quantum processor where qubits are positioned in a 2x2 array.

In this talk I will present the past achievements made with semiconductor qubits, highlight the current state-of-the-art, and provide a perspective on future efforts toward scaling to large-scale quantum computing. In particular I will focus on our efforts on germanium quantum technology, show implementations of rudimentary algorithms and initial error correction schemes such as the phase-flip code. Taken together, this talk provides an introduction to the field and motivates why semiconductor qubits are one of the most promising platforms for quantum technology.

QI 5.3 Tue 15:00 H4

Crosstalk analysis for single-qubit and two-qubit gates in spin qubit arrays — •Irina Heinz and Guido Burkard — University of Konstanz, Konstanz, Germany

Scaling up spin qubit systems requires high-fidelity single-qubit and two-qubit gates. Gate fidelities exceeding 98% were already demonstrated in silicon based single and double quantum dots, whereas for the realization of larger qubit arrays crosstalk effects on neighboring qubits must be taken into account. We analyze qubit fidelities impacted by crosstalk when performing single-qubit and two-qubit operations on neighbor qubits with a simple Heisenberg model. Furthermore we propose conditions for driving fields to robustly synchronize Rabi oscillations and avoid crosstalk effects. In our analysis we also consider next to nearest neighbor crosstalk and show that double synchronization leads to a restricted choice for the driving field strength, exchange interaction, and thus gate time. Considering realistic experimental conditions we propose a set of parameter values to perform a nearly crosstalk-free CNOT gate and so open up the pathway to scalable quantum computing devices.

QI 5.4 Tue 15:15 H4

Evaluating Atomically Thin Quantum Emitters for Quantum Key Distribution — •Timm Gao[1], Martin v. Helversen[1], Carlos Anton-Solanas[2], Christian Schneider[2], and Tobias Heindel[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany

Single photon sources are considered key building blocks for future quantum communication networks. In recent years, atomic monolayers of transition metal dichalcogenides (TMDCs) emerged as a promising material platform for the development of compact quantum light sources. In this work, we evaluate for the first time the performance of a single photon source based on a strain-engineered WSe_2 monolayer [1] for quantum key distribution (QKD). Employed in a QKD-testbed emulating the BB84 protocol, we analyze the single-photon purity in terms of $g^{(2)}(0)$ and secret key rates as well as quantum bit error rates to be expected in full implementations of QKD. Furthermore, we exploit routines for the performance optimization previously applied to quantum dot based single-photon sources [2]. Our work represents a major step towards the application of TMDC-based devices in quantum technologies.

[1] L. Tripathi et al., ACS Photonics 5, 1919-1926 (2018)
[2] T. Kupko et al., npj Quantum Inform. 6, 29 (2020)

QI 5.5 Tue 15:30 H4

Nuclear Spin Readout in a Cavity-Coupled Hybrid Quantum Dot-Donor System — •Jonas Mielke[1], Jason R. Petta[2], and Guido Burkard[1] — [1]Department of Physics, University of Konstanz, Konstanz D-78457, Germany — [2]Department of Physics, Princeton University, Princeton, New Jersey 08544, USA

Nuclear spins show long coherence times and are well isolated from the environment, which are properties making them promising for quantum information applications. Here, we present a method for nuclear spin readout by probing the transmission of a microwave resonator. We consider a single electron in a silicon quantum dot-donor device interacting with a microwave resonator via the electric dipole coupling and subjected to a homogeneous magnetic field and a transverse magnetic field gradient. In our scenario, the electron spin interacts with a ^{31}P defect nuclear spin via the hyperfine interaction. We theoretically investigate the influence of the P nuclear spin state on the microwave transmission through the cavity and show that nuclear spin readout is feasible with current state-of-the-art devices. Moreover, we identify optimal readout points with strong signal contrast to facilitate the experimental implementation of nuclear spin readout.

QI 5.6 Tue 15:45 H4

Ancilla assisted discrete quantum time crystal with nitrogen-vacancy center in diamond — •Jianpei Geng, Vadim Vorobyov, Durga Dasari, and Jörg Wrachtrup — 3. Physics Institute, University of Stuttgart, Stuttgart 70569, Germany

Time crystal is a phase of matter of which the time-translation symmetry is spontaneously broken. Though continuous quantum time crystal is controversial, discrete quantum time crystal has been experimentally demonstrated in various systems. The interplay of periodic driving, disorder, and interaction plays an essential role in stabilizing the time crystal phase against perturbations. Here we extend the study to even non-interacting systems and show how a non-interacting system could be stabilized to the time-crystal phase by coupling to an ancillary system. We show that the coupling between the system and the ancilla, even if just an ancilla qubit, could introduce an effective interaction in the system, and thus enables the emergence of the time-crystal phase. We demonstrate the time-crystal signature of non-interacting nuclear spins by simulation and experiment on nitrogen-vacancy center in diamond.