Q 12: Quantum Communication II

Time: Monday 17:00–19:00 Location: HS 3118

Q 12.1 Mon 17:00 HS 3118

Ensemble based quantum protocol for ultra save quantum money — •Bernd Bauerhenne[1], Malwin Xibraku[1], Boris Naydenov[2], Cyril Popov[1], Martin Garcia[1], and Kilian Singer[1] — [1]Universität Kassel, Heinrich-Plett Straße 40, 34132 Kassel — [2]Helmholtz-Zentrum Berlin

We present a ensemble based quantum token protocol [1,2] that can detect counterfeiting by analysing the measurement noise. A quantum token consists now of identical qubits. Each quantum token is prepared by a bank by writing all qubits into the same state. The angles are kept secret. Multiple ensemble-based quantum tokens will have different secret states. During verification, the bank measures the qubits of the quantum token with the secret angles and if more than a given critical number of qubits are projected into the ground state, the quantum token is accepted. If from the set of quantum tokens more than a given number of quantum token is accepted, the whole set is accepted. We discuss how big the probability is that the bank accepts the counterfeit tokens. We show how resources must be scaled such that the probability that the bank accepts a counterfeit token set becomes arbitrary small.

[1] https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/diqtok [2] K. Singer, C. Popov, B. Naydenov, Verfahren zum Erstellen eines Quanten-Datentokens (DE 10 2022 107 528 A1) DE-Patent (2023)

Q 12.2 Mon 17:15 HS 3118

Robust Preparation of Ensemble-based Quantum Tokens with Trapped Ions — •Manika Bhardwaj, Jan Thieme, Bernd Bauerhenne, Moritz Göb, Bo Deng, and Kilian Singer — Institut für Physik, Universität Kassel, Heinrich-Plett-Straße 40, 34132 Kassel, Germany

Quantum tokens are an important building block for securing identification devices. Previous implementations were based on the quantum no-cloning theorem. Here we present a novel quantum token protocol [1] and its implementation with an ensemble of trapped ions. Due to long coherence times and single-shot readout, trapped ions are well-suited for implementing a robust quantum token protocol. We aim to implement the quantum token protocol on the $4^2S_{1/2} - 3^2D_{5/2}$ transition of $^{40}Ca^+$ ions. Uniform preparation of the entire ensemble of trapped ions is crucial for the protocol because errors directly influence the security of the quantum token protocol. We will present adapted composite pulses [2, 3] that address different resonance frequencies and are robust against intensity-based pulse area errors of the individual ions. [1] K. Singer, C. Popov, and B. Naydenov, Verfahren zum Erstellen eines Quanten-Datentokens (DE 10 2022 107 528 A1) DE-Patent (2023). [2] B. T. Torosov, S. S. Ivanov, and N. V. Vitanov, Narrowband and passband composite pulses for variable rotations, Phys. Rev. A 102, 013105 (2020). [3] G. T. Genov, M. Hain, N. V. Vitanov, and T. Halfmann, Universal composite pulses for efficient population inversion with an arbitrary excitation profile, Phys. Rev. A 101, 013827 (2020).

Q 12.3 Mon 17:30 HS 3118

A Photonic-Integrated Quantum-Random Number Generator — •Ömer Bayraktar[1,2], Jonas Pudelko[1,2], Christoph Pacher[3], Winfried Boxleitner[3], and Christoph Marquardt[1,2] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Max Planck Insitute for the Science of Light, Erlangen, Germany — [3]AIT Austrian Institute of Technology GmbH, Center for Digital Safety & Security, Vienna, Austria

A quantum-random number generator (QRNG) is a key componenent for quantum-key distribution systems. In addition, compared to conventional true-random number generators, it offers advantages in generation rate and modelling of the entropy source.

We present an experimental QRNG based on balanced homodyne detection of the quantum-optical vacuum state. This QRNG can also be operated under the restrictive requirements of a CubeSat.

The optical part of the QRNG is monolithically integrated on an Indium-Phosphide photonic-integrated circuit and is placed on a 10x10 cm^2 printed-circuit board accomodating necessary electronics. We show first conclusive results obtained with this system and discuss its operation in space.

Q 12.4 Mon 17:45 HS 3118

Tailored composite pulses for NV-colour centres towards the realization of ensemble based quantum tokens — •Jan Thieme, Josselin Bernardoff, Ricky-Joe Plate, Bernd Bauerhenne, and Kilian Singer — Universität Kassel, Kassel, Germany

We present numerical and experimental results of the application of tailored composite pulses [1] to robustly address ensembles of nitrogen-vacancy colour centres used in a novel protocol for quantum tokens [2,3]. By using analytical methods applied to the Rosen-Zener excitation model [4], we derive excitation profiles for a broadband excitation profile with respect to detuning and pulse duration to compensate for experimental deviations of resonance frequencies and pulse area in the quantum token. Towards this goal we are using an arbitrary waveform generator to supply these pulses to single nitrogen-vacancy colour centres [5]. In the outlook we will describe how this scheme can be improved to suppress sensitivity to technical limitations [6].

[1] B. T. Torosov and N. V. Vitanov, Phys. Rev. A 83, 053420 (2011). [2] https://www.forschung-it-sicherheit-kommunikationssysteme.de/projekte/diqtok [3] K. Singer, C. Popov, B. Naydenov, Verfahren zum Erstellen eines Quanten-Datentokens (DE 10 2022 107 528 A1) DE-Patent (2023) [4] N. Rosen and C. Zener, Phys. Rev. 40, 502 (1932). [5] A. Schmidt, J. Bernardoff, K. Singer, J. P. Reithmaier and C. Popov, Physica Status Solidi A, 216, 1900233 (2019). [6] G. T. Genov, M. Hain, N. V. Vitanov, and T. Halfmann, Phys. Rev. A, 101, 013827(2020).

Q 12.5 Mon 18:00 HS 3118

Nonlinear Quantum Photonics with a Tin-Vacancy Center Coupled to a Diamond Waveguide — Matteo Pasini, Nina Codreanu, •Tim Turan, Adria Riera Moral, Christian F. Primavera, Lorenzo De Santis, Hans K. C. Beukers, Julia M. Brevoord, Christopher Waas, Johannes Borregaard, and Ronald Hanson — QuTech and Kavli Institute of Nanoscience, Delft University of Technology, PO Box 5046, 2600 GA Delft, The Netherlands

Color-centers integrated with nanophotonic devices have emerged as a compelling platform for quantum science and technology. Here we integrate tin-vacancy centers in a fiber-coupled diamond waveguide and investigate the interaction with light at the single-photon level. We observe single-emitter-induced extinction of the transmitted light up to 25% and measure the nonlinear effect on the photon statistics.

With this system, we demonstrate fully tunable interference between the reflected single-photon field and laser light back-scattered at the fiber end. The reflected field shows a corresponding change between bunched and anti-bunched photon statistics. Furthermore, we comment on progress towards using tin-vacancy centers in diamond waveguides as efficient quantum network nodes.

Q 12.6 Mon 18:15 HS 3118

Microwave control of the Tin-Vacancy center using magnetic field alignment — •Jeremias Resch[1], Ioannis Karapatzakis[1], Marcel Schrodin[1], Luis Kussi[1], Philipp Fuchs[2], Michael Kieschnick[3], Jan Meijer[3], Christoph Becher[2], Wolfgang Wernsdorfer[1], and David Hunger[1] — [1]Karlsruher Institut für Technologie, DE — [2]Universität des Saarlandes, DE — [3]Universität Leipzig, DE

Scalable quantum information processing requires spectrally stable interfaces between photons and solid-state qubits. Group-IV color centers exhibit an inversion symmetry protecting them from surface charge noise. By an optimized spectroscopy method, we identify hour-long charge-state and spectrally stable SnV centers with Fourier-limited optical linewidth using resonant excitation. To control the electron spin with high fidelity, the use of microwave fields is required. However, the magnetic transitions are heavily suppressed in unstrained emitters. This limitation can be circumvented by using naturally strained [1] or strain-engineered [2] SnV centers. Alternatively, a precise alignment of the DC magnetic field orientation allows for manipulation of the electron spin using microwave fields even at lower strain values. Hence, we implement a 3D vector magnet in a confocal microscope setup at mK temperatures. By aligning the DC magnetic field with respect to the SnV symmetry axis, we determine the angle dependent splitting of the electron spin ground and excited state and show the full fit to the SnV electron spin Hamiltonian. [1] Rosenthal et al., Phys.

Rev. X 13, 031022 (2023) [2] Guo et al., arXiv:2307.11916v2 (2023)

Q 12.7 Mon 18:30 HS 3118

Coherent control of the Tin-Vacancy center with superconducting waveguides at mK temperatures — •Ioannis Karapatzakis[1], Jeremias Resch[1], Marcel Schrodin[1], Luis Kussi[1], Philipp Fuchs[2], Michael Kieschnick[3], Jan Meijer[3], Christoph Becher[2], David Hunger[1], and Wolfgang Wernsdorfer[1] — [1]Karlsruher Institut für Technologie, DE — [2]Universität des Saarlandes, DE — [3]Universität Leipzig, DE

Robust quantum networks require an interface between photons and long-lived spin degrees of freedom. Due to its strong spin-orbit splitting, the Tin-Vacancy center possesses long electron spin lifetimes around 1K. For high fidelity control, the use of microwave fields is required. However, the magnetic transitions are heavily suppressed in unstrained emitters. This limitation can be overcome by inducing strain and precisely aligning the DC magnetic field orientation. Recent work has shown the manipulation of the electron spin using aluminum wire bonds [1] and on-chip gold waveguides [2]. Both methods suffer from Ohmic losses in the microwave line, restricting coherence through heat induction. To overcome this challenge, we fabricate a superconducting coplanar waveguide made from Niobium on a diamond membrane through all-optical lithography. We induce strain in the diamond by using a polymer with a high coefficient of thermal expansion for fixation. We demonstrate coherent manipulation of the electron spin and evaluate the decoherence properties for different magnetic field orientations at mK temperature. [1] Rosenthal et al., Phys. Rev. X 13, 031022 (2023) [2] Guo et al., arXiv:2307.11916v2 (2023)

Q 12.8 Mon 18:45 HS 3118

Addressing single nuclear spins at telecommunication wavelength — Alexander Ulanowski[1], •Adrian Holzäpfel[2], Olivier Kuijpers[2], and Andreas Reiserer[1,2] — [1]Max-Planck-Institut für Quantenoptik, 85748 Garching, Germany — [2]TU München and Munich Center for Quantum Science and Technology, 85748 Garching, Germany

Single emitters in solids are a particularly promising building block for large-scale quantum networks because their integration in micro- and nanodevices offers great potential for scalability. Previously, our group has demonstrated the coherent manipulation and efficient optical interfacing of individual erbium emitters in a micrometer-thin yttrium orthosilicate membrane by integrating it into a high finesse Fabry-Perot resonator [1]. In recent devices, we achieve a Purcell enhancement of their optical transition in the telecom C-band of up to 110. The coherence of our system could be greatly increased by encoding the information stored onto long-lived nuclear spins. We investigate two different approaches. First, we consider the superhyperfine interaction of a single erbium electron spin with the nuclear spin of neighboring yttrium ions. In a second approach, we study the 7/2 nuclear spin of the isotope Er167, opening a promising path to quantum repeater nodes with second-long coherence.

[1] A. Ulanowski, B. Merkel & A. Reiserer, Sci. Adv. 8, (2022).