Q 9: Quantum Communication II

Time: Monday 17:00–19:00 Location: P 3

Q 9.1 Mon 17:00 P 3

A single ion coupled to UV fiber cavity — •Pascal Kobel[1], Timothy Ballance[1], Kilian Kluge[1], Konstantin Ott[2], Hendrik M. Meyer[1], Jakob Reichel[2], and Michael Köhl[1] — [1]Physikalisches Institut, Universität Bonn, Wegelerstraße 8, D-53115 Bonn, Germany — [2]Laboratoire Kastler-Brossel, ENS/UPMC-Paris 6/CNRS, F-75005 Paris, France

We investigate the integration of fiber cavities into ion traps for use in quantum networks.

Up to now, fiber-cavities have been combined with trapped ions only in the infra-red spectral range. Since ions typically have their strongest dipole transition in the ultra-violet (UV), the extension of fiber cavities to work in the UV is important.

We present coupling of a single Ytterbium ion to a 150 μm long fiber-cavity, which is resonant with the electric dipole transition at 370 nm. We achieve a coherent coupling rate of a single ion to the cavity of about $g/2\pi = 60$ MHz, which exceeds previous realizations by more than one order of magnitude. Using the Purcell effect, we demonstrate single photon generation by continuous and pulsed ion excitation and investigate correlation between the photon polarization and the spin state of the ion.

Q 9.2 Mon 17:15 P 3

Controlled absorption of a single photon — •Luigi Giannelli[1], Tom Schmit[1], Susanne Blum[1,4], Daniel M. Reich[2,3], Christiane P. Koch[2], Tommaso Calarco[5], and Giovanna Morigi[1] — [1]Universität des Saarlandes, 66123 Saarbrücken, Germany — [2]Universität Kassel, 34132 Kassel, Germany — [3]Aarhus University, 8000 Aarhus C, Denmark — [4]Theodor-Heuss-Gymnasium, 73730 Esslingen am Neckar, Germany — [5]Universität Ulm, 89069 Ulm, Germany

We numerically analyse the dynamics of a single photon propagating in free space and incident on the mirror of an optical cavity, in which an atom is localized. Our purpose is to identify the parameter regimes and dynamics which allow for perfect absorption of the photon by the atom. The cavity is modeled by a single mode, while the relevant electronic states of the atom form a three-level Lambda system: one transition is coupled to the quantized field of the cavity via Jaynes-Cummings interaction, while the other transition is driven by a classical control field $\Omega(t)$, whose temporal behaviour is optimized for the purpose of controlling absorption. We consider dissipative processes and compare the efficiency of adiabatic protocols, such as in [1-3], with the ones which employ optimal control in order to speed up the process. We also discuss the quantum speed limit of this process.

[1] M. Fleischhauer, et al., Opt. Commun. 179, 395 (2000).
[2] A. V. Gorshkov, et al., Phys. Rev. A 76, 033804 (2007).
[3] J. Dilley, et al., Phys. Rev. A 85, 023834 (2012).

Q 9.3 Mon 17:30 P 3

Low temperature spectroscopy of Germanium vacancy center — •Mathias H. Metsch[1], Lachlan J. Rogers[1], Aroosa Ijaz[2], Jan M. Binder[1], Petr Siyushev[1], and Fedor Fedor[1] — [1]Institute for Quantum Optics, Ulm University, D-89081 Germany — [2]Institute of Quantum Electronics, ETH Zurich, CH-8093 Zurich

The negatively-charged Germanium vacancy (GeV) center in diamond has recently attracted interest as a quantum emitter. Systems offering a spin degree of freedom and efficient optical access are highly sought after in the quantum information processing context. Currently known color centers in diamond offer either good spin properties (Nitrogen vacancy) or good optical properties (Silicon vacancy). The GeV center in diamond has similar chemical structure to the SiV. In this talk the spectroscopy of single GeV is presented, highlighting outstanding spectral stability and brightness. Its brightness indicates a high quantum yield, making GeV even more appealing as a light matter interface than Silicon vacancy. Furthermore, preparation of a coherent superposition state is demonstrated using coherent population trapping.

Q 9.4 Mon 17:45 P 3

ODMR on diamond's negatively charged defects based on IV group of elements — •Petr Siyushev, Mathias Metsch, Lachlan Rogers, Aroosa Ijaz, and Fedor Jelezko — Institute for Quantum Optics and IQST, Ulm University, Ulm, Germany

Growing interest to the defects based on elements of IV group of the periodic table such as silicon-vacancy (SiV) or germanium-vacancy (GeV) is stimulated by their good optical properties. Besides high Debye-Waller factor, they exhibit exceptional spectral stability which is rare for solid state systems vulnerable to the surrounding charge fluctuations. This property is dictated by the physical structure of these defects. However, their electronic structure does not allow simple access to electron spin by microwave field which technique is widely used for the well-known NV center. Here, we discuss the way how to overcome this problem and demonstrate optically-detected magnetic resonance on a single GeV defect.

Q 9.5 Mon 18:00 P 3

Robustness of orbital-angular-momentum photons under perturbations. — •Giacomo Sorelli, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs Universität, Freiburg i. Br., Germany

Photons with a helical phase front have a definite orbital angular momentum (OAM) of $l\hbar$, with l an arbitrary integer. Since this spatial degree of freedom spans an infinite-dimensional Hilbert space, it can increase the channel capacity and enhance security of quantum communication. Despite these promising applications, the information encoded in OAM photonic states is fragile with respect to disturbance along the transmission path. In particular, quantum entanglement between photon pairs, which is required for many quantum protocols, rapidly decays when photons propagate through a turbulent atmosphere.

In this talk we compare the robustness of entanglement when encoded in Laguerre Gauss (LG) and Bessel Gauss (BG) modes for two kinds of perturbations. First, we provide an accurate theoretical description of an experiment [1] where entangled biphotons in BG and LG modes were subjected to a circular obstruction. Second, we consider the propagation of such entangled biphotons through a turbulent atmosphere in order to identify which of the two sets of modes is a more resilient one.

[1] M. McLaren et al., Nat. Commun. 5: 3248 (2014)

Q 9.6 Mon 18:15 P 3

Universal entanglement decay of twisted photons in a weakly turbulent atmosphere — •David Bachmann, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg i. Br., Germany

The propagation of entangled twisted photons that carry orbital angular momentum (OAM) through turbulent atmosphere has become a rapidly developing research area. This topic is motivated by the potential uses of the underlying unbounded Hilbert space associated with the OAM for quantum communication. However, atmospheric turbulence introduces random phase shifts to the photons' phase profile, which is used for encoding quantum information, and eventually results in a loss of entanglement. Recently, it has been shown [1] that the entanglement decay of OAM qubit states in a weakly turbulent atmosphere is a universal function of a single parameter – the ratio between the OAM beam's phase correlation length and the turbulence correlation length, but the explicit form of the decay law was not yet obtained.

In this talk, we present analytical expressions for the universal entanglement decay law of a biphoton state in weak atmospheric turbulence. These results are obtained for different models of the turbulence phase structure function, using asymptotic methods. Thereby, we establish the explicit relationship between the turbulence-induced coupling strength between different OAM modes and the specific form of the decay law.

[1] N. D. Leonhard et al., Phys. Rev. A **91**, 012345 (2015).

Q 9.7 Mon 18:30 P 3

Quantum-Limited Measurements of Optical Signals from a Geostationary Satellite — •Kevin Günthner[1,2], Imran Khan[1,2], Dominique Elser[1,2], Birgit Stiller[1,2], Ömer Bayraktar[1,2], Christian R. Müller[1,2], Karen Saucke[3], Daniel Tröndle[3], Frank Heine[3], Stefan Seel[3], Peter Greulich[3], Herwig Zech[3], Björn Gütlich[4], Ines Richter[4], Sabine Philipp-May[4], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany. — [2]Department of Physics, University of Erlangen-Nuremberg (FAU), Germany. —

[3]Tesat-Spacecom GmbH & Co. KG, Backnang, Germany. — [4]German Aerospace Center (DLR), Space Administration, Bonn, Germany.

Quantum key distribution protocols have already been implemented in metropolitan networks all around the world. A promising method to provide the still missing long-haul link between such networks is optical satellite communication. To this end, existing Laser Communication Terminals (LCTs) can be upgraded to be suitable for quantum communication. An important step towards this objective is to precisely characterize the quantum noise behaviour of the system including the channel. We have performed quantum-limited measurements of optical signals from the Alphasat TDP1 LCT in geostationary Earth orbit. We show that quantum coherence is preserved after propagation of the quantum states over 38600 km. An upper bound for the excess noise that the states could have acquired after propagation is estimated [1].

[1] K. Günthner, I. Khan *et al.*, arXiv:1608.03511 (2016).

Q 9.8 Mon 18:45 P 3

Progress on continuous-variable high-speed quantum key distribution compatible with telecom networks — Imran Khan[1,2], Birgit Stiller[1,2,3], Ulrich Vogl[1], •Stefan Richter[1,2], Kevin Jaksch[1,2], Kevin Günthner[1,2], Christian Peuntinger[1,2,4], Dominique Elser[1,2], Christoph Pacher[5], Christoph Marquardt[1,2], and Gerd Leuchs[1,2,6] — [1]Max Planck Institute for the Science of Light, Staudtstraße 2, 91058 Erlangen, Germany — [2]IOIP, Friedrich-Alexander University Erlangen-Nuremberg (FAU), Staudtstr. 7/B2, 91058 Erlangen, Germany — [3]Centre for Ultrahigh Bandwidth Devices for Optical Systems (CUDOS), School of Physics, The University of Sydney, NSW 2006, Australia — [4]Department of Physics, University of Otago, 730 Cumberland Street, Dunedin, New Zealand — [5]AIT Austrian Institute of Technology, Donau-City-Strasse 1, 1220 Vienna, Austria — [6]Department of Physics, University of Ottawa, 25 Templeton, Ottawa, ON, Canada

For efficient and practical quantum key distribution (QKD), high key rates and compatibility with existing communications infrastructure are important aspects. This work shows the recent progress of our group in Erlangen on the implementation of a continuous-variable QKD setup achieving GHz transmission rates in a telecom fiber environment. We discuss the challenges of employing modulation schemes like quadrature phase-shift keying (QPSK) and Gaussian-modulated coherent states (GMCS). We also demonstrate the experimental feasibility of these schemes for our setup using optical heterodyne detection in the GHz regime.