Q 8: Quantum Optics II

Time: Monday 14:30–16:30 Location: C/HSO

Q 8.1 Mon 14:30 C/HSO

Towards all optical gates with molecular photons — Mohammad Rezai, Kim Kafenda, Joerg Wrachtrup, and •Ilja Gerhardt — Universität Stuttgart 3. Physikalisches Institut

Single photons originating from single molecules under cryogenic conditions are extremely narrow-band (~15MHz) and simultaneously exhibit a high flux (> 1 Mio detected counts/sec) [1]. On the other hand some of these single photon sources can be efficiently matched to atoms so that by using Faraday anomalous dispersion optical filtering technique [2] one can filter out background light to get perfect indistinguishable single photons. This outstanding sources make non-classical interference experiments (e.g. Hong-Ou-Mandel type) with high visibility possible [3]. All-optical gates can benefit from these properties and allow to generate quantum entangled states, to take a step forward in quantum information science.

[1] - P. Siyushev Nature, 2014, 509, 66-70 [2] - W. Kiefer Scientific Reports, 2014, 4, 6552 [3] - R. Lettow, PRL, 2010, 104,123605

Q 8.2 Mon 14:45 C/HSO

Ground state phonon processes of silicon vacancy centres in diamond and their implications for spin coherence — •Kay Jahnke[1], Alp Sipahigil[2], Jan Binder[1], Marcus Doherty[3], Mathias Metsch[1], Lachlan Rogers[1], Neil Manson[3], Mikhail Lukin[2], and Fedor Jelezko[1] — [1]Institute for Quantum Optics and IQST, Ulm University, Ulm, Germany — [2]Department of Physics, Harvard University, Cambridge, Massachusetts, USA — [3]Laser Physics Centre, Research School of Physics and Engineering, Australian National University, Canberra, Australia

Silicon vacancy (SiV^-) centres in diamond have an orbitally degenerate ground state doublet of E symmetry. We investigated the ground state phonon processes by looking at orbital relaxation time. From the linear temperature dependence of the T1 time on temperature we concluded the dominant process to be a single-phonon transfer between orbital states. T1 corresponds closely to the observed spin dephasing time T2*, which gives insight into the fundamentally limiting factor for ground state coherence in this centre. We propose numerous techniques to overcome this limit by either modifying the involved phonon densities or the coupling. This may enable the SiV^- centre to overcome its limitation and become the dominating colour centre in diamond.

Q 8.3 Mon 15:00 C/HSO

Temperature dependence of the diamond silicon vacancy zero phonon line and the resulting electron-phonon interaction model — •Jan M. Binder[1], Kay D. Jahnke[1], Alp Sipahigil[2], Marcus W. Doherty[3], Mathias Metsch[1], Lachlan J. Rogers[1], Neil B. Manson[3], Mikhail D. Lukin[2], and Fedor Jelezko[1] — [1]Institute for Quantum Optics and IQST, Ulm University, Albert-Einstein-Allee 11, D-89081 Ulm, Germany — [2]Department of Physics, Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA — [3]Laser Physics Centre, Research School of Physics and Engineering, Australian National University, ACT 0200, Australia

We investigated the linewidth and position of the zero phonon line (ZPL) of the negatively charged silicon vacancy centre (SiV^-) in diamond using photoluminescence excitation (PLE) spectroscopy. We also measured its flourescence lifetime using pulsed excitation measurements at temperatures ranging form 4 K to 350 K. The resulting linear linewidth dependency below 20K can be explained with a first-order model of electron-phonon interactions. Explaining the T^3 dependency for linewidth and lineshift at higher temperatures requires second-order interactions to be included. This situation is similar to that found in the NV^-, but the inversion symmetry of SiV^- leads to T^3 instead of T^5. The radiative lifetime results can de described by a Mott-Seitz mechanism.

Further implications of this model will be discussed in the talk by Kay Jahnke, a preprint version of the associated paper is available as arXiv:1411.2871 [quant-ph].

Q 8.4 Mon 15:15 C/HSO

Coherence studies of light emitting quantum-dot superluminescent diodes — •Franziska Friedrich, Sebastien Hartmann, Wolfgang Elsässer, and Reinhold Walser — Institut für Angewandte Physik, TU Darmstadt, Germany

During the last years broadband emitting quantum-dot superluminescent diodes (QD-SLEDs) became an essential element in modern research due to their high potential in industrial applications, e.g. in optical coherence tomography or fiber sensor technology. But also in fundamental research, QD-SLEDs appear to be fascinating semiconductor devices, because of their unusual behavior at a characteristic temperature regime: a reduction of $g^{(2)}(0)$ from 2 to 1.33 was observed in the laboratory in 2011 [1].

We develop a theoretical explanation of this experimental result. As a first step, we postulate a quantum state considering the light characteristics of the QD-SLED and study the first and second order correlation function, yielding information about the frequency spectrum and the photon statistics. In order to verify the validity of the chosen light state, we study $g^{(2)}(\tau)$ of mixed light originating from a QD-SLED and a single mode laser. A comparison with the experimental results exhibits very good agreement [2].

[1] M. Blazek and W. Elsässer, Phys. Rev. A **84**, 063840 (2011)
[2] to be submitted

Q 8.5 Mon 15:30 C/HSO

Experimental investigations on photon statistics of a pseudothermal light source at 1300nm — •Simone Kuhn, Sébastien Hartmann, and Wolfgang Elsässer — Institut für Angewandte Physik, Technische Universität Darmstadt, Germany

Already invented in 1956 by Martiensen and Spiller, pseudothermal light sources are nowadays widely used for fundamental coherence studies as well as for imaging applications, not only exploiting their high spatial incoherence but also their thermal-like 2^{nd} order correlations. In this contribution, we present an experimental realization of a pseudothermal light source at the telecommunication wavelength of 1300nm, reaching ideal thermal light values for 2^{nd} order correlations $g^{(2)}(0) = 2$. By implementing a time-resolved photon-counting experiment, we can directly extract the probability distribution p(n) and subsequently $g^{(2)}(0)$ [1]. We observe significant changes of the photon statistics from incoherent ($g^{(2)}(0)$=2) to coherent ($g^{(2)}(0) = 1$) behavior when light from the pseudothermal source is strongly attenuated. Additionally a $g^{(2)}(0)$ reduction is unveiled depending on the spatial profile characteristics of the implemented pseudothermal source. The here discussed correlation reduction mechanisms point out the delicate operating conditions when applying pseudothermal sources.

[1] P. Koczyk, P. Wiewiór, and C. Radzewicz, Am. J. Phys. **64**, 240-245 (1996)

Q 8.6 Mon 15:45 C/HSO

A heralded single photon source for telecom wavelengths based on a PPLN waveguide — •Matthias Bock, Andreas Lenhard, and Christoph Becher — Universität des Saarlandes, FR 7.2 Experimentalphysik, Campus E2.6, 66123 Saarbrücken

Photon pair sources are a relevant part of quantum networks and quantum repeaters with photons serving as flying qubits. Especially for long distance communication between remote quantum nodes, it is reasonable to guide the photons with optical fibers. For such an application light sources generating correlated photon pairs at telecom wavelengths are required.

We present the characterization of such a pair source based on spontaneous parametric downconversion (SPDC) in a periodically-poled lithium niobate (PPLN) ridge waveguide. With one photon at 1312 nm (telecom O-band) and one photon at 1557 nm (telecom C-band) the source is suitable for long distance quantum communication applications. Furthermore, both channels can be filtered down to a standard channel spacing of 100 GHz with fiber-based filter systems. The source features a good efficiency, which is confirmed by photon pair rates up to 1 MHz with a heralding efficiency of 30%. At the same time we benefit from a conversion efficiency of about 10^{-6} resulting in high signal-to-background ratios. The heralded single photon properties are confirmed by photon statistics measurements with a Click/No–Click method and by the heralded $g^{(2)}$–function. A minimum value for $g^{(2)}(0)$ of 0.04 indicating a clear antibunching has been observed.

Q 8.7 Mon 16:00 C/HSO

Telecom-Heralded Single Photon Source for Single Atom, Single Photon Quantum Interface — •Andreas Lenhard,

Matthias Bock, Stephan Kucera, José Brito, Pascal Eich, Philipp Müller, Jürgen Eschner, and Christoph Becher — FR 7.2 (Experimentalphysik), Universität des Saarlandes, 66123 Saarbrücken

In a quantum network, remote quantum systems containing stationary qubits have to be interconnected with flying qubits. For long-range connections these flying qubits should be photons at telecommunication wavelengths offering minimal loss in fiber links. However, techniques are necessary to bridge the gap between near infrared atomic transitions and telecom wavelengths.

Here we report on a source of correlated photon pairs based on spontaneous parametric downconversion (SPDC) in a singly resonant optical parametric oscillator (OPO). The signal photons are tuned to a resonance in $^{40}Ca^{+}$ at a wavelength of 854 nm while the corresponding idler photons are at 1411 nm. The spectrum of the photons is tailored by the OPO cavity to a frequency comb with a linewidth of 7 MHz for each mode. With an additional fiber Bragg grating a single mode is cut out in the telecom band. With this system we demonstrate single photon spectroscopy of the $D_{5/2}$-$P_{3/2}$ transition in a single trapped $^{40}Ca^{+}$-ion. As a basic building block for quantum networks we demonstrate the absorption of a single 854 nm photon by the ion, heralded by a telecom photon.

Q 8.8 Mon 16:15 C/HSO

Single photon absorption by a single atom heralded by a telecom-converted single photon — •Stephan Kucera, José Brito, Andreas Lenhard, Pascal Eich, Philipp Müller, Christoph Becher, and Jürgen Eschner — Experimentalphysik, Universität des Saarlandes, Saarbrücken, Germany

The use of hybrid atom-photon quantum systems takes advantage of the best features of the involved platforms: long storage times, fast processing capabilities, high quality entanglement and long haul fiber transmission. Such properties are prerequisites for the implementation of a quantum communication network.

We present a system where the absorption of a single photon by a single trapped ion is heralded at a telecommunication wavelength by the detection of a frequency-converted single photon. Twin photons are generated by a spontaneous parametric down conversion heralded photon source. One of the photons of the pair is sent to, and absorbed by, a single trapped $^{40}Ca^{+}$ ion while its partner photon is sent through 90 meters of fiber and converted to telecom wavelength using a waveguide-based frequency converter set-up placed in a different laboratory. The time correlation between the detection of the converted photon and a quantum jump at the ion's side shows a successful single photon absorption by the trapped ion.