# Q 51: Quantum Information (Quantum Repeater) II

Time: Thursday 14:00–15:45 Location: S HS 002 Chemie

Q 51.1 Thu 14:00 S HS 002 Chemie

**Initialization and Readout of Nuclear Spins via negatively charged Silicon-Vacancy Center in Diamond** — •Katharina Senkalla[1], Mathias Metsch[1], Michael Kern[1], Benedikt Tratzmiller[3], Petr Siyushev[1], and Fedor Jelezko[1,2] — [1]Institute for Quantum Optics, Ulm University, Germany — [2]Center for Integrated Quantum Science and Technology IQst, Ulm University, Germany — [3]Institute for Theoretical Physics, Ulm University, Germany

In the emerging field of fourth-group-based defects in diamond the $SiV^-$ is the most studied one. Due to outstanding optical properties such as high Debye-Weller Factor and superior spectral stability and the electron spin 1/2 system, it is a promising candidate as light matter interface for quantum communication and entanglement distribution applications. However, short spin coherence of the defect diminish its usability for this application. Here we show a hybrid approach which would help to overcome the poor electron spin properties. We exploit surrounding carbon-13 nuclear spins as long leaving quantum memory. The initialization of carbon-13 spin is achieved via dynamical nuclear spin polarization technique. Using the same method, the readout of coherently controlled nuclear spin is demonstrated.

Q 51.2 Thu 14:15 S HS 002 Chemie

**Towards a nitrogen-vacancy center based quantum repeater** — •Javid Javadzade, Florian Kaiser, Amlan Mukherjee, Ilja Gerhardt, and Jörg Wrachtrup — 3rd Institute of Physics, University of Stuttgart and Institute for Quantum Science and Technology IQST (Germany), Stuttgart, Germany

Quantum key distribution (QKD) enables provably secure communication. Overcoming channel loss in long-distance QKD requires a quantum repeater architecture. In this talk, I will outline how we plan to implement an elementary quantum repeater in the Q.Link.X project. Our central node will utilize a single nitrogen-vacancy center in diamond. This center is coupled to a nearby 13C nuclear spin quantum memory, which enables memory assisted QKD [1]. Our protocol is based on entanglement between spins and photonic time-bin modes. I will estimate entanglement rates and discuss further extensions and improvements.

[1] D. Luong et al. Appl. Phys. B, 122, 96 (2016)

Q 51.3 Thu 14:30 S HS 002 Chemie

**Towards quantum communication with single spins in silicon carbide** — •Florian Kaiser, Roland Nagy, Charles Babin, Izel Gediz, Erik Hesselmeier, Timo Görlitz, Rainer Stöhr, Roman Kolesov, and Jörg Wrachtrup — 3rd Institute of Physics, University of Stuttgart and Institute for Quantum Science and Technology IQST (Germany)

The only known means to establish provably secure communication are based on quantum key distribution. Long-distance quantum networking will rely on quantum repeater nodes. In this talk, we will present our first results and future visions on the realisation of such networks using optically interfaced single spins in silicon carbide [1]. We will estimate achievable communication rates and discuss possible improvements based on nuclear spin quantum memories and photonic crystal cavities.

[1] R. Nagy et al., arXiv:1810:10296 (2018)

Q 51.4 Thu 14:45 S HS 002 Chemie

**Rb vapor cell quantum memory for single photons** — •Janik Wolters[1], Gianni Buser[1], Roberto Mottola[1], Chris Müller[2], Tim Kroh[2], Richard Warburton[1], Oliver Benson[2], and Philipp Treutlein[1] — [1]University of Basel — [2]Humboldt-Universität zu Berlin

Quantum memories are an essential ingredient for quantum repeaters [1] and an enabler for advanced optical quantum simulators [2].

We implemented a broadband optical quantum memory with on-demand storage and retrieval in hot Rb vapor [3]. Operating at the Rb D2 line, the versatile memory is suited for storing single photons emitted by an GaAs droplet quantum dots [4] or single photons from spontaneous parametric downconversion (SPDC) sources [5].

We report on our recent achievements: reducing the readout noise far below the single input photon equivalent ($\mu_1 \ll 1$); increasing the memory lifetime to several $\mu s$; storage of single photons with a bandwidth of $\sim$ 150 MHz, generated by a SPDC source with 40 % heralding efficiency.

[1] N. Sangouard et al., Rev. Mod. Phys. 83, 33 (2011)
[2] J. Nunn et al., Phys. Rev. Lett. 110, 133601 (2013)
[3] J. Wolters, et al., Phys. Rev. Lett. 119, 060502 (2017)
[4] J.-P. Jahn, et al. Phys. Rev. B 92, 245439 (2015)
[5] A. Ahlrichs et al., Appl. Phys. Lett. 108, 021111 (2016)

Q 51.5 Thu 15:00 S HS 002 Chemie

**Towards an efficient quantum memory at telecom wavelength** — •Benjamin Merkel, Pablo Cova Fariña, Natalia Herrera Valencia, Kutlu Kutluer, and Andreas Reiserer — MPI for Quantum Optics, Garching, Germany

Global quantum networks will require efficient interfaces between long-lived memory nodes and photons at a telecommunications wavelength, where loss in optical fibers is minimal. In this context, ensembles of Erbium ions doped into suited crystals are a promising candidate, as they exhibit both an optical transition at 1.5 $\mu$m and spin lifetimes exceeding 100 ms. Unfortunately, dipole-dipole interactions between neighboring Erbium ions limit the ground-state spin coherence times and restrict the experiments to crystals with low dopant concentration. This severely limits the efficiency of quantum memories. We study two approaches to overcome this challenge: First, we have assembled high-finesse cavities that enhance the optical depth 10000 fold. This should allow us to implement efficient quantum memories in crystals with extremely low dopant concentration. To facilitate cryogenic operation, the disturbance of mechanical vibrations, which are abundant in closed-cycle cryostats, were minimized by an optimization of the cavity mount. Second, we also investigate the effect of microwave pulses on ensembles of Erbium spins and explore the potential of dynamical decoupling to increase coherence times. To this end, we have implemented a resonator on a printed circuit board whose microwave field is very homogeneous over the crystal. We will present the current status of the mentioned experiments.

Q 51.6 Thu 15:15 S HS 002 Chemie

**Dynamics of a single photon propagating in an inhomogeneously broadened medium** — •Tom Schmit, Luigi Giannelli, and Giovanna Morigi — Theoretische Physik, Universität des Saarlandes, 66123 Saarbrücken, Germany

We theoretically analyze the evolution of a single photon propagating through a solid-state medium when the medium is inhomogeneously broadened in the longitudinal direction. Each atom of the medium is a three-level $\Lambda$ system, where one transition couples to the electromagnetic field modes containing the single photon while the other is driven by an external laser field. The inhomogeneous broadening enters in the model as a position-dependent frequency shift $\Delta = \Delta(z)$ of the excited state. We study the single-photon storage efficiency. Moreover, we determine the spectral and temporal properties of the transmitted photon as a function of the spatial distribution $\Delta(z)$.

Q 51.7 Thu 15:30 S HS 002 Chemie

**Variable delay based on electromagnetically induced transparency in cesium at room temperature for photon storage** — Esteban Gomez Lopez[1], •Tim Kroh[1], Chris Müller[1], Janik Wolters[2], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, Germany — [2]Universität Basel, Switzerland

With the fast development of quantum information and quantum networks, the needs of reliable memories are also on the rise. These memories must be able to coherently store quantum states between two or more nodes in order to build a scalable quantum network [1].

Here, we present an experiment on controlled delaying of photons from a cavity-enhanced parametric downconversion source [2] for storage by traveling through a cesium vapor cell at room temperature. This delay is created by electromagnetically induced transparency (EIT) addressing three hyperfine states of the D1 absorption line of cesium [3], which can be interfaced with the telecommunication bands [4]. The obtained EIT windows reach a FWHM of 250 MHz, making them a good option for storing single photons produced by other quantum light sources, in particular quantum dots with comparable Fourier-limited linewidth emission [5].

[1] O. A. Collins et al., Phys. Rev. Lett. 98, 060502 (2007).
[2] A. Ahlrichs and O. Benson, Appl. Phys. Lett. 108, 021111 (2016).
[3] D. Höckel and O. Benson, Phys. Rev. Lett. 105, 153605 (2010).
[4] T. Kroh et al., Quantum Sci. Technol. 2, 034007 (2017).
[5] J. Wolters et al., Phys. Rev. Lett. 119, 060502 (2017).