Q 25: Quantum Information: Quantum Computation II

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

Q 25.1 Tue 14:30 C/HSO

Optical quantum memory made from single nuclear spin in nitrogen vacancy in diamond — •Sen Yang[1], Ya Wang[1], Thai Hien Tran[1], S. Ali Momenzadeh[1], Rainer Rainer Stoehr[1], Philipp Neumann[1], Hideo Kosaka[2], and Joerg Wrachtrup[1] — [1]3rd Physics Institute, Universitaet Stuttgart, Germany — [2]Yokohama National University, Yokohama, Japan

Quantum repeater is one of the key elements to realise long distance quantum communication. In the heart of a quantum repeater is quantum memory. There are a few requirements for this memory: it needs to couple to flying qubits: photon ; it needs to have long coherence time, so quantum error correction algorithm can be performed in the quantum repeater nods ; it needs to be stable under optical illuminations.

Nitrogen nuclear spin is available for every nitrogen vacancy center(NV) in diamond. Besides it can be a robust quantum memory for spin qubit operations, nitrogen nuclear spin can couple to photon by taking advantage of optically resonant excitation of spin-selective transitions in low temperature. Here we demonstrate the coherent storage of quantum information from photon into nuclear spin. We show this quantum memory fulfils requirements as quantum memory for quantum repeater. Coherent time beyond 10 seconds is measured in C13 natural abundant sample. We show nuclear spin can keep its coherence over 1Million times resonant laser excitation of electron spin.

Q 25.2 Tue 14:45 C/HSO

Efficient Production of Diamond-Based Multi-Spin Quantum Registers — •Ingmar Jakobi[1], Seyed Ali Momenzadeh[1], Julia Michl[1], Florestan Ziem[1], Matthias Schreck[2], Klas Lindfors[3], Philipp Neumann[1], Andrej Denisenko[1], and Jörg Wrachtrup[1] — [1]3. Physiklaisches Institut, Universität Stuttgart — [2]Experimentalphysik IV, Institut für Physik, Universität Augsburg — [3]MPI für Festkörperforschung, Stuttgart

Coherently coupled pairs or multimers of nitrogen-vacancy defect centers (NV) in diamond have many promising applications ranging from metrology [1] to quantum information processing [2, 3]. Especially in the case of quantum computing scalable registers are essential to the progress of the field. While the production of NV dimers by ion implantation through nano-apertures has made good progress in recent years [3,4], more efficient processes are needed for the production of larger clusters.

Here we present results from ion implantations with optimized parameters. Not only are we able to produce coupled NV pairs, suitable for entanglement experiments, with an increased probability. Also by collecting large statistics of ion to NV yield and coherence times we are able to set up an empirical model for the efficient production of dimers and higher order multimers.

[1] A. Chin, et al., PRL 109,233601 (2012)
[2] P. Neumann, et al., NPhys 6, 249-253 (2010)
[3] F. Dolde, et al., NPhys 9, 139-143, (2013)
[4] S. Pezzagna, et al., pssa 208,9 2017-2022 (2011)

Q 25.3 Tue 15:00 C/HSO

Scaling up nitrogen-vacancy center quantum nodes in diamond — •Philipp Neumann, Sebastian Zaiser, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart

The nitrogen vacancy (NV) center in diamond is a spin defect that has proven to be a valuable nanoscopic quantum sensor [1] and it promises applications in quantum communication and computation [2]. It turns out that an associated nuclear spin register is vital for all of these applications. It enables quantum nondemolition spin readout, it stores quantum information and entanglement [3] and it facilitates for instance quantum error correction [4]. However, so far, except for the nitrogen nuclear spin itself, a proper nuclear spin register required searching and thus posed an obstacle for scalability. Here we demonstrate a novel spin control tool that establishes coherent coupling of the central electron spin to on average about 10 proximal nuclear spins. Initialization, non-local gates and individual spin readout in such nuclear spin registers is possible. The method is readily applicable to other central spin systems such as Si:P.

[1] Tetienne, J.-P. et al., Science 344, 1366 (2014).
[2] Pfaff, W. et al., Science 345, 532 (2014).
[3] Dolde, F. et al., Nature Communincations 5, 3371 (2014).
[4] Waldherr, G. et al., Nature 506, 204 (2014).

Q 25.4 Tue 15:15 C/HSO

Silicon vacancy centers and their electronic-spin coherence in nanodiamonds — •Clemens Schäfermeier[1], Lachlan J Rogers[2], Andrea Kurz[2], Uwe Jantzen[2], Kay D Jahnke[2], Alexander Kubanek[2], Ulrik L Andersen[1], and Fedor Jelezko[2] — [1]Technical Universit of Denmark, Quantum Physics and Information Technology, 2800 Kongens Lyngby, Denmark — [2]Ulm University, Institute for Quantum Optics, 89081 Ulm, Germany

The spectral properties of the negatively charged silicon vacancy (SiV) centre in bulk diamond have proved to be promising.

Strong optical transitions in conjunction with lifetime limited transitions enabled a number of experiments pointing towards quantum information processing (QIP).

Specifically, successful Hong-Ou-Mandel interference and all-optical spin control of the colour centre has established the SiV centre as a candidate for the purpose of QIP.

At cryogenic temperatures, the electronic spin relaxation time is found to be 2.4 ms, while the coherence time T_2^* is tens of nanoseconds.

By investigating SiV centres present in nanodiamonds less than 100 nm in size, we were not only able to confirm the understanding of the underlying decoherence processes. More importantly, the T_2^* could be increased.

Q 25.5 Tue 15:30 C/HSO

Coherent optical access to spin in the negative silicon vacancy centre in diamond — •Mathias H. Metsch[1], Lachlan J. Rogers[1], Kay D. Jahnke[1], Alp Sipahigil[2], Jan M. Binder[1], Tokuyuki Teraji[3], Hitoshi Sumiya[4], Junichi Isoya[5], Mikhail D. Lukin[2], Philip Hemmer[6], and Fedor Jelezko[1] — [1]Institute for Quantum Optics, University of Ulm, D-89081 Germany — [2]Department of Physics, Harvard University, 17 Oxford Street, Cambridge, MA 02138, USA — [3]National Institute for Materials Science, 1-1 Namiki, Tsukuba, Ibaraki 305-0044, Japan — [4]Advanced Materials R&D Laboratories, Sumitomo Electric Industries Ltd., Itami, Hyogo 664-0016, Japan — [5]Research Center for Knowledge Communities, University of Tsukuba, 1-2 Kasuga, Tsukuba, Ibaraki 305-8550, Japan — [6]Electrical & Computer Engineering Department, Texas A&M University, College Station, TX 77843, USA

The silicon vacancy (SIV) centre has excellent optical properties and is a promising candidate for single photon sources. It also possess degenerate spin states, and there has been considerable interest in gaining access to this as a qubit system. Here we used an external magnetic field to lift the spin degeneracy, and used resonant excitation to access the spin sub levels. We used the phenomenon of coherent population trapping to produce coherent superposition states of the electron spin. Combining the optical properties of the SIV with the ability to control spin promotes a SIV as a candidate for a wide range of quantum information applications.

Q 25.6 Tue 15:45 C/HSO

Engineered microwave control for $^{9}\mathrm{Be}^{+}$ — •Martina Wahnschaffe[1,2], Matthias Kohnen[1,2], Amado Bautista-Salvador[1,2], Timko Dubielzig[2,1], Sebastian Grondkowski[2,1], Henning Hahn[2,1], and Christian Ospelkaus[2,1] — [1]Physikalisch-Technische Bundesanstalt, Braunschweig, Germany — [2]Institut für Quantenoptik, Leibniz Universität Hannover, Germany

Trapped ions are a promising system for quantum information processing. Here, instead of the more commonly used laser-based approach for controlling ions, we focus on the integration of microwave conductors into surface-electrode ion traps for controlling quantum states of ions. In this near-field microwave approach, amplitude gradients from conductors in the trap structure induce the spin-motional coupling required for entangling operations. To prevent off-resonant carrier transitions, we need to suppress the field amplitude while maintaining a strong gradient. In our experiment, a single meander-like microwave conductor structure provides the desired field configuration. Numerical simulations were used to optimize the electrode structure of the trap including rf, dc and microwave electrodes. The structure has been micro-fabricated in a clean room environment and has recently trapped single ^{9}Be$^+$ ions. We are currently evaluating the trap and present recent results on trap loading and trap characterization.

Q 25.7 Tue 16:00 C/HSO

Internal state fidelity during ion transport — •Peter Kaufmann, Timm F. Gloger, Delia Kaufmann, M. Tanveer Baig, Thomas Collath, Michael Johanning, and Christof Wunderlich — Faculty of Science and Technology, Department of Physics, University of Siegen, Walter Flex Str. 3, 57072 Siegen, Germany

A promising scheme to built scalable quantum simulators and computers is the separation of a larger system into smaller subsystems. A prerequisite for this divide and rule approach is the ability to transfer quantum information between subsystems. One possibilty to realize this for ion traps is the transport of ions carrying this information encoded to the internal state.

We report on the preserving of a superposition state of a ^{171}Yb$^+$ ion during movement in a microstructured Paul trap. The state is encoded in the hyperfine levels of the ion's ground state. The shuttling potentials are calculated using a boundary element method simulation of the trap, adjusted for micromotion compensation and generated by an arbitary waveform generator [1] operated up to 12.5 MHz update rate. The fidelity per shuttling is determined by analysis of the contrast decay of a Ramsey type measurement with the shuttling procedure repeatedly executed during the free precession time. For a shuttling distance of 280μm we observe a shuttling internal state fidelity better than 0.999.

[1] M. T. Baig, M. Johanning, A. Wiese, S. Heidbrink, M. Ziolkowski, Chr. Wunderlich, Rev. Sci. Instrum. 84, 124701 (2013).

Q 25.8 Tue 16:15 C/HSO

Experimental simulation of gauge field theories with trapped ions — •Esteban Martinez[1], Daniel Nigg[1], Marcello Dalmonte[2], Enrique Rico Ortega[2], Thomas Monz[1], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, 6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Technikerstraße 21a, 6020 Innsbruck, Austria

Gauge field theories are at the heart of many fundamental phenomena in particle physics and condensed matter. However, they have proven to be very difficult to study either analytically or by numerical simulations on classical computers, and are thus excellent candidates for quantum simulation. In this work we present some proof-of-principle experiments on simulating high-energy physics using a trapped-ion quantum processor. We will cover some recent experimental results and give an outlook of future experiments.