A 17: Quantum Protocols and Gates SYQR 3 (with Q)

Time: Tuesday 10:30–12:15 Location: Kinosaal

A 17.1 Tue 10:30 Kinosaal

Quantum key distribution with two-segment quantum repeaters — •Hermann Kampermann, Silvestre Abruzzo, and Dagmar Bruss — Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Germany

Quantum repeaters represent one possible way to achieve long-distance quantum key distribution. One way of improving the repeater rate and decreasing the memory coherence time is the usage of multiplexing. Motivated by the experimental fact that long-range connections are practically demanding, we extend the analysis of the quantum repeater multiplexing protocol to the case of short-range connections. We derive formulas for the repeater rate and we show that short-range connections lead to most of the benefits of a full-range multiplexing protocol [1].

A less demanding QKD-protocol without quantum memories was recently introduced by Lo *et al.* We generalize this measurement-device-independent quantum key Distribution protocol to the scenario where the repeater Station contains also heralded quantum memories. We assume either single-photon sources or weak coherent pulse sources plus decoy states. We show that it is possible to significantly outperform the original proposal, even in presence of decoherence of the quantum memory. We give formulas in terms of device imperfections i.e., the quantum bit error rate and the repeater rate [2].

[1] S. Abruzzo, H. Kampermann, D. Bruß, arXiv:1309.1106v1

[2] S. Abruzzo, H. Kampermann, D. Bruß, arXiv:1306.3095v1

A 17.2 Tue 10:45 Kinosaal

Broadcast Classical-Quantum Capacity Region of Two-Phase Bidirectional Relaying Channels — Holger Boche, Minglai Cai, and •Christian Deppe — Technische Universität München, Fakultät für Elektrotechnik und Informationstechnik, Lehrstuhl für Theoretische Informationstechnik

The transmission of quantum states over long distances is essential for future applications such as quantum networks. The direct transmission is limited by unavoidable losses of the channel. A promising alternative for long distance quantum states distribution is the use of quantum repeaters. We analyze a quantum repeater protocol which takes advantage of bidirectional communication. We consider a three-node quantum network which enables bidirectional communication between two nodes with a half-duplex relay node. The message $m_2 \in M_2$ is located at node 1 and the message $m_1 \in M_1$ is located at node 2, respectively. Our goal is that the message $m_2 \in M_2$ is known at node 2 and the message $m_1 \in M_1$ is known at node 1, respectively. We simplify the problem by assuming an a priori separation of the communication into two phases. The capacity of the first phase (MAC) is known. We determine the capacity region of the second phase (broadcast).

A 17.3 Tue 11:00 Kinosaal

Quantum error correction in a solid-state hybrid spin register — Gerald Waldherr[1], Ya Wang[1], •Sebastian Zaiser[1], Mohammed Jamali[1], Thomas Schulte-Herbrueggen[2], Hiroshi Abe[3], Takeshi Ohshima[3], Junichi Isoya[4], Philipp Neumann[1], and Joerg Wrachtrup[1] — [1]3. Physikalisches Institut , University of Stuttgart — [2]Department of Chemistry, Technical University of Munich — [3]Japan Atomic Energy Agency, Takasaki — [4]Research Center for Knowledge Communities, University of Tsukuba, Tsukuba

Electron spins associated with solid state defects are promising systems for quantum information processing. Exploiting nuclear spins surrounding the defect as a quantum register provides a natural hybrid spin system. Such a system could be used for a fault-tolerant quantum repeater scheme [1] where the spins might be associated to nitrogen-vacancy (NV) centers in diamond. Here, we present a hybrid spin register based on a single NV defect in diamond coupled to three nuclear spins. The electron spin is used for control, and the nuclear spins as a long-lived quantum storage. We achieve high-fidelity initialization and single shot readout of the nuclear spin register. Implementation of a novel non-local gate combined with optimal control enables universal, high-fidelity control. With these techniques, we demonstrate three-qubit entanglement and quantum error correction. These experiments demonstrate the potential of solid state spin systems for quantum computation and communication. [1] L. Childress, et al., Phys. Rev. Lett. 96, 070504 (2006).

A 17.4 Tue 11:15 Kinosaal

A quantum byte with 10^{-4} crosstalk for fault-tolerant quantum computing — •Christian Piltz, Theeraphot Sriarunothai, Andrés Varón, and Christof Wunderlich — Department Physik, Universität Siegen, 57068 Siegen, Germany

A prerequisite for fault-tolerant and thus scalable operation of a quantum computer is the use of quantum error correction protocols. Such protocols come with a maximum tolerable gate error, and there is consensus that an error of order 10^{-4} is an important threshold. This threshold was already breached for single-qubit gates with trapped ions using microwave radiation. However, crosstalk - the error that is induced in qubits within a quantum register, when one qubit (or a subset of qubits) is coherently manipulated, still prevents the realization of a scalable quantum computer. The application of a quantum gate - even if the gate error itself is low - induces errors in other qubits within the quantum register.

We present an experimental study using quantum registers consisting of microwave-driven trapped $^{171}Yb^{+}$ ions in a static magnetic gradient. We demonstrate a quantum register of three qubits with a next-neigbour crosstalk of $6(1)\cdot 10^{-5}$ that for the first time breaches the error correction threshold. Furthermore, we present a quantum register of eight qubits - a quantum byte - with a next-neighbour crosstalk error better than $2.9(4)\cdot 10^{-4}$. Importantly, our results are obtained with thermally excited ions far above the motional ground state.

A 17.5 Tue 11:30 Kinosaal

Strain-induced active tuning of the coherent tunneling in quantum dot molecules — •Eugenio Zallo[1], Rinaldo Trotta[2], Yongheng H. Huo[1], Paola Atkinson[3], Fei Ding[1], Armando Rastelli[2], and Oliver G. Schmidt[1] — [1]Institute for Integrative Nanosciences, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany — [2]Institute of Semiconductor and Solid State Physics, Johannes Kepler University Linz, Altenbergerstr. 69, A-4040 Linz, Austria — [3]Institut des NanoSciences des Paris, UPMC CNRS UMR 7588,4 Place Jussieu Boite courier 840, Paris 75252 Cedex 05, France

Quantum dot molecules (QDMs) are formed by orbital hybridization of wavefunctions in two closely positioned quantum dots (QDs), and they are important for a coherent manipulation of qubits in quantum information applications. The coupling strength is the key parameter determining the operation rate of quantum gates based on QDMs. Recently, ultrafast optical control of the entangled state of two electron spins interacting through tunneling in a QDM was demonstrated. Despite the extensive efforts in the community, it is a formidable task to actively tune the tunnel coupling in a single QDM obtained by vertical stacking of two semiconductor quantum dots. In this presentation, a novel class of devices that allow large strain and electric fields to be applied to single QD and QDM will be introduced first. Then, the experimental achievement of this active tuning will be demonstrated. By means of externally induced strain fields the coupling strength of holes confined in vertically coupled InGaAs/GaAs QDs was varied by more than 14%.

A 17.6 Tue 11:45 Kinosaal

Harnessing the diamond spin bath — Jan Honert[1], Martin Hohmann[1], Nan Zhao[2], •Helmut Fedder[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut and Research Center SCoPE, University Stuttgart, Germany — [2]Beijing Computational Science Research Center, Beijing, China

^{13}C nuclear spins in diamond are the predominant source of decoherence for electron spin qubits such as the NV center [1] or ST1 [2] defect. At the same time, they are a valuable resource for the implementation of nuclear spin quantum registers [3]. Addressing distant and thus weakly coupled bath spins would enable us to scale up nuclear spin registers to sizes relevant to small scale quantum algorithms such as stabilizer codes that are particularly relevant to quantum repeaters. In here we show that dynamical decoupling techniques can be used to detect a single ^{13}C nuclear spin that is coupled to an NV center with a dipole coupling strength as weak as 400 Hz. We discuss protocols for initializing and coherently controlling such weakly coupled bath spins.

[1] P. Neumann et al. Multipartite entanglement among single spins

in diamond. Science 320, 1326 (2008)
[2] S.-Y. Lee et al. Readout and control of a single nuclear spin with a metastable electron spin ancilla. Nature nano. 8, 487 (2013)
[3] G. Waldherr et al. Quantum error correction in a solid-state hybrid spin register. arXiv:1309.6424v2 (2013).

A 17.7 Tue 12:00 Kinosaal

Towards long coherent time quantum memory based on NV center in low temperature — •Sen Yang[1], S. Ali Momenzadeh[1], Thai Hien Tran[1], Ya Wang[1], Naofumi Abe[2], Hideo Kosaka[2], Helmut Fedder[1], Philipp Neumann[1], and Joerg Wrachtrup[1] — [1]3rd Physics Institute, Universitaet Stuttgart, Germany — [2]Research Institute of Electrical Communication, Tohoku University, Japan

The Nitrogen-Vacancy (NV) center in diamond is a promising system for quantum communication/computation. Low temperature gives us not only ultralong spin lifetime but also the ability to address excited states individually. Optically resonant excitation of spin-selective transitions and single shot readout of electron spin in low magnetic field improve initialization and readout fidelity. This opens up the opportunities of making quantum devices based on the fine structure of excited states and photon NV interaction. Long coherence time makes nuclear spin a good choice as quantum memory. $M_s = \pm 1$ ground states and A1 excited state form Λ system which make optical writing possible. Here, we presents recent results of this quantum memory scheme. this quantum memory could be an important component for building quantum repeater based on NV center in diamond.