Q 19: Quantum information: Quantum computers

Time: Monday 16:30–18:30 Location: E 214

Group Report Q 19.1 Mon 16:30 E 214

Interfacing Ions and Photons at the Single Quantum Level

— •Matthias Keller, Michale Belayneh, Stephen Begley, Markus Vogt, and Hiroki Takahashi — University of Sussex

The complementary benefits of trapped ions and photons as carriers of quantum information make it appealing to combine them in a joint system. To interface the quantum states of ions and photons efficiently, we use calcium ions coupled to an optical high-finesse cavity. For strong ion-cavity coupling, deterministic transfer of quantum states between ions and photons is possible. Each basis state of the ion is linked with one polarization mode of the cavity. Through a partially transparent cavity mirror, a freely propagating photon is generated which can be used to distribute quantum information. For moderate coupling, quantum entanglement may be generated probabilistically. Ions coupled to two orthogonally polarized cavity modes are projected to an entangled state upon detection of photons emitted from the cavity with different polarization. The realization of these schemes requires the development of novel techniques to combine ion traps with miniature optical cavities, as the strength of the ion-photon coupling increases with shrinking cavity mode volume. We are presently testing two different setups, optimized for the respective interaction regimes mentioned above.

Q 19.2 Mon 17:00 E 214

Room temperature entanglement between single defect spins in diamond.

— •Ingmar Jakobi[1], Florian Dolde[1], Boris Naydenov[1,2], Nan Zhao[1], Sébastien Pezzagna[3], Jan Meijer[3], Philipp Neumann[1], Fedor Jelezko[1,2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Research Center SCoPE, and IQST, Universität Stuttgart, Germany — [2]Institut für Quantenoptik, and IQST, Universität Ulm, Germany — [3]RUBION, Ruhr Universität Bochum, 44780 Bochum, Germany

Entanglement is an important element of quantum technology providing new algorithms to quantum computers, the basis for quantum cryptography and increased sensitivity in quantum metrology.

Here we experimentally demonstrate entanglement between two single solid state spin quantum bits (qubits) at ambient conditions and present a method to preserve entangled states on a time-scale of milliseconds [1]. The qubits are associated with two engineered nitrogen-vacancy (NV) defect centers in diamond separated by a distance of 25 nm.

The experiments mark an important step towards a scalable room temperature quantum device.

[1] Dolde et al., Room temperature entanglement between distant single spins in diamond, arXiv:1212.2804, (2012)

Q 19.3 Mon 17:15 E 214

Collectively Enhanced Interactions in Solid-state Spin Qubits

— •Hendrik Weimer — Institut für Theoretische Physik, Leibniz Universität Hannover

I will show how to engineer collective enhancement of dipolar interactions in random spin networks. While disordered interactions typically lead to localization of all eigenstates, the presence of a transverse magnetic field can result in the appearance of a single delocalized mode suitable for the mediation of long-range quantum logic between remote spin registers [1]. I will discuss a specific implementation based on nitrogen-vacancy defects in diamond.

[1] H. Weimer, N. Y. Yao, M. D. Lukin, arXiv:1210.3622 (2012).

Q 19.4 Mon 17:30 E 214

Precisely timing dissipative quantum information processing

— •Michael Kastoryano[1], Jens Eisert[1], and Michael Wolf[2] — [1]FU Berlin — [2]TU München

Dissipative engineering constitutes a framework within which quantum information processing protocols are powered by system-environment interaction rather than by unitary dynamics alone. This framework embraces noise as a resource, and consequently, offers a number of advantages compared to one based on unitary dynamics alone, e.g., that the protocols are typically independent of the initial state of the system. However, the time in- dependent nature of this scheme makes it difficult to imagine precisely timed sequential operations, conditional measurements or error correction. In this work, we provide a path around these challenges, by introducing basic dissipative gadgets which allow us to precisely initiate, trigger and time dissipative operations, while keeping the system Liouvillian time-independent. These gadgets open up novel perspectives for thinking of timed dis- sipative quantum information processing. As an example, we sketch how measurement based computation can be simulated in the dissipative setting.

Q 19.5 Mon 17:45 E 214

Selfassembling hybrid diamond-biological quantum devices

— •Andreas Albrecht[1], Alex Retzker[2], Guy Koplovitz[3], Fedor Jelezko[4], Shira Yochelis[3], Yuval Nevo[5], Oded Shoseyov[5], Yossi Paltiel[3], and Martin B Plenio[1] — [1]Institut für Theoretische Physik, Universität Ulm, Germany — [2]Racah Institute of Physics, The Hebrew University of Jerusalem, Israel — [3]Department of Applied Physics, The Hebrew University of Jerusalem, Israel — [4]Institut für Quantenoptik, Universität Ulm, Germany — [5]The Robert H. Smith Institute of Plant Sciences and Genetics in Agriculture, The Hebrew University of Jerusalem, Israel

Scalable arrangements of nitrogen vacancy centers (NV) in diamond remain an open key challenge on the way to efficient quantum information processing, quantum simulation and magnetic sensing applications at the quantum limit. Here we provide a solution for creating a scalable system of individually addressable NV centers based on the self-assembling capabilities of biological systems in combination with the bridging of the bio-nano interface by means of surface functionalized nanodiamonds. We provide a detailed theoretical analysis on the feasibility of multiqubit quantum operations in such systems, exploiting the significant dipolar coupling on the nanometer scale and address the problems of decoherence, imperfect couplings and the randomness of the NV symmetry axes. We show that this allows for the high-fidelity creation of entanglement, cluster states and quantum simulation applications. In addition we present the first experimental demonstration of connecting nanodiamonds with biological systems (SP1 complexes).

Q 19.6 Mon 18:00 E 214

A toolbox for measurement based quantum computation on encoded data

— •Michael Zwerger[1], Wolfgang Dür[1], and Hans Jürgen Briegel[1,2] — [1]Institut für theoretische Physik, Universität Innsbruck, Österreich — [2]Institut für Quantenoptik und Quanteninformation, Innsbruck, Österreich

We propose a toolbox for measurement based quantum computation on encoded data. It consists of small elementary building blocks, which can perform encoding/decoding, a single qubit rotation and a two qubit gate. They can be combined via Bell measurements to achieve resource states that can perform quantum gates on encoded qubits and simultaneously quantum error correction. We also discuss possible realizations of the building blocks and measurement based quantum error correction with present day technology.

Q 19.7 Mon 18:15 E 214

Optimal control of single spins in diamond

— •Florian Dolde[1], Ingmar Jakobi[1], Ya Wang[1], Ville Bergholm[2,5], Sebastien Pezzagna[3], Jan Meijer[3], Boris Naydenov[4], Fedor Jelezko[4], Philipp Neumann[1], Thomas Schulte-Herbrüggen[2], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Research Center SCoPE, and IQST, Universität Stuttgart, Germany — [2]Dept. Chemistry, Technical University Munich (TUM), D-85747 Garching, Germany — [3]RUBION, Ruhr Universität Bochum, 44780 Bochum, Germany — [4]Institut für Quantenoptik, and IQST, Universität Ulm, Germany — [5]Institute for Scientific Interchange Foundation (ISI), I-10126 Turin, Italy

Recent progress in the quantum information experiments with the Nitrogen-Vacancy center (NV) in diamond have allowed for entanglement of two NVs forming a starting point for a quantum register. However the demonstrated fidelity of 0.67 ± 0.04 is not practical for quantum algorithms. The low fidelity was attributed not to decoherence effects but to pulse errors in the entanglement protocol [1].

In this work we investigate the usage of optimal control to perform high fidelity quantum gates on the NV center. Optimal control quantum gates were used to create coherence on a single electron spin and to store electron spin coherence in a long living nuclear spin.

[1] arXiv:1212.2804