Q 3: Quantum Information: Concepts and Methods I

Time: Monday 11:30–13:00 Location: K/HS1

Group Report Q 3.1 Mon 11:30 K/HS1

Paulfallen zur skalierbaren Erzeugung quantenmechanischer Systeme aus einzelnen Dotieratomen in Festkörpern — •Georg Jacob, Karin Groot-Berning, Sebastian Wolf, Stefan Ulm, Johannes Rossnagel, Ferdinand Schmidt-Kaler und Kilian Singer — QUANTUM ,Institut für Physik, Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

Eine Vielzahl der Konzepte zur Manipulation quantenmechanischer Systeme aus einzelnen Dotieratomen in Festkörpern hängen kritisch von einer räumlich exakten Positionierung dieser Atome ab. Beispielhaft sind kontrolierte Phosphoratome in hochreinem Silizium [1,2] oder Farbzentren in Diamant bzw. in YSO und YAG Kristallen [3]. Um eine Kopplung der implantierten Spins zu erreichen, sind Einzelatomdotierungen in nm-genauen zweidimensionalen Geometien erforderlich. Alternativ zu [4,5] nutzt unser Ansatz [6] die Extraktion aus einer Paulfalle in der Dotierionen, wie z.B. Molekulare N2+ Ionen, sympathetisch durch 40Ca+ lasergekühlt werden. Mittels einer elektrostatischen Einzellinse erreichen wir eine räumliche Fokussierung auf auf einen Radius von 8 nm. Um die Dotieratome nm-genau bezüglich Kontrol- und Ausleseelektroden auszurichten, haben wir den Einzelionen Strahl für Transmissionsmikroskopie verwendet [7]. [1] T. Shinada et al., Nature 437, 1128 (2005). [2] J. J. Pla et al. Nature 496, 334 (2013). [3] F. Dolde et al. Nat. Phys. 9, 139 (2013). [4] D. N. Jamieson et al., Applied Physics Letters 86, 202101 (2005). [5] Batra, A. et al., J. Appl. Phys. Lett., 91, 193502 (2007). [6] W. Schnitzler et al., Phys. Rev. Lett. 102, 070501 (2009). [7] G. Jacob et al., arxiv.org:1405.6480 (2014).

Q 3.2 Mon 12:00 K/HS1

Focused ion beam implantation technology to selectively distribute Erbium ions in a dielectric solid-state matrix — •Nadezhda Kukharchyk[1], Shovon Pal[1], Arne Ludwig[1], Pavel Bushev[2], and Andreas D. Wieck[1] — [1]Ruhr-Univertsität Bochum, Bochum, Germany — [2]University of Saarland, Saarbrücken, Germany

Rare-earth-doped dielectric crystals proved to be attractive in recent optical and microwave studies in perspective towards quantum computing applications. The dielectric crystal serves as a matrix in which the rare-earth ion's properties are positively enhanced, for example the luminescence quantum yield, the optical and the Zeeman state lifetimes. However, application of grown-doped crystals would imply difficulties in arranging arbitrarily distributed ensembles or single ion qubits on one crystal into a network. We perform focused ion beam implantation as a tool to selectively distribute spins or spin ensembles on a single crystal in a maskless ultra-high-vacuum process [1]. In this work, we present luminescence study of Erbium-implanted Yttrium Orthosilicate (Y2SiO5) crystals with varied process parameters: Implantation temperature, annealing time and annealing atmosphere. The goal of this study is to achieve the most effective implantation method with highest performance of the rare-earth optical and microwave properties. [1] Kukharchyk et al., Photoluminescence of focused ion beam implanted Er3+:Y2SiO5 crystals, Phys. Status Solidi RRL 8, 880 (2014)

Q 3.3 Mon 12:15 K/HS1

Universal composite pulses for robust rephasing of atomic coherences in a doped solid — •Daniel Schraft, Genko Genov, Thomas Halfmann, and Nikolay Vitanov — Institute of Applied Physics, Technical University of Darmstadt, Germany

Composite pulses (CP) have been used for decades in NMR, and since recently, also in quantum information processing as a powerful tool to drive excitation processes via robust pathways. Usually these CP compensate fluctuations in a single experimental parameter only. Here we introduce universal CP [1] for robust system inversion, compensating variations in *any* experimental parameter (i.e. pulse area, static detuning, etc.), which also operate independent of the pulse shape.

We demonstrate the robust performance of universal CP by inversion of atomic coherences in a rare earth ion-doped solid (Pr:YSO). Such doped solids are an attractive medium to implement solid-state quantum memories. The media exhibit long decoherence times and small homogenous optical line width, while maintaining the advantages of solids, i.e. large density and scalability. These memories rely on atomic coherences, driven in a inhomogeneously broadened medium. Hence, robust rephasing protocols are required to cope with dephasing. Our experimental data confirm improved robustness of universal CP compared to rephasing by standard π-pulses, with regard to variations in pulse area, static detuning, additional chirps, and different pulse shapes.

[1] G. T. Genov, D. Schraft, T. Halfmann, and N. V. Vitanov, Phys. Rev. Lett. 113, 043001 (2014).

Q 3.4 Mon 12:30 K/HS1

Preparation of Schrödinger cat states of a Rydberg atom — •Eva-Katharina Dietsche, Adrien Signoles, Adrien Facon, Dorian Grosso, Igor Dotsenko, Serge Haroche, Jean-Michel Raimond, Michel Brune, and Sebastien Gleyzes — Laboratoire Kastler Brossel, College de France, ENS-PSL, UPMC-Sorbonne Universite, CNRS, 11 Place Marcelin Berthelot 75005 Paris, France

The Stark manifold of a Rydberg atom is large Hilbert space in which we can create non-classical states, like a Schrödinger cat state.

We demonstrated the generation of large angular momentum nonclassical states using Quantum Zeno dynamics. Here, under the effect of a sigma+ radio-frequency field, the atom initially in the circular state behaves as a J=25 spin, which rotates between the north pole and the south pole of a generalized Bloch sphere. By repeatedly asking the system 'have you crossed a given latitude?', we can confine the evolution of the spin to the polar cap of the Bloch sphere. When the spin state reaches this limiting latitude, the phase space distribution disappears from one side of the limiting latitude to reappear on the other side, while being transiently in a superposition of two spin coherent states with different phases. This leads to the deterministic preparation of Schrödinger cat states of the angular momentum.

Quantum Zeno dynamics therefore provides a new method to tailor the Hilbert space to create non-classical superpositions of Stark sublevels. Those states are very sensitive to small variations of electric and magnetic fields, and could be used for quantum metrology beyond the standard quantum limit.

Q 3.5 Mon 12:45 K/HS1

Non-locality in a Bose–Einstein condensate — •Roman Schmied[1], Jean-Daniel Bancal[2], Baptiste Allard[1], Matteo Fadel[1], Nicolas Sangouard[1], and Philipp Treutlein[1] — [1]Department of Physics, University of Basel, Switzerland — [2]Centre for Quantum Technologies, National University of Singapore

By observing non-locality, it is possible to demonstrate that a system cannot be described by a local (classical) theory, even if the underlying local variables are hidden [1]. As a consequence, provably secure randomness can be extracted from any non-local system.

We present a robust experimental technique for detecting nonlocality in a two-mode Bose–Einstein condensate. Among a family of Bell inequalities whose violation witnesses non-locality, we maximize the experimental signal-to-noise ratio in the presence of several types of noise. We report on the status of an experiment to detect nonlocality in a BEC using this technique.

[1] N. Brunner *et al.*, Rev. Mod. Phys. 86, 419 (2014).