Symposium Lokalisierung und Verschränkung in photoinduzierten Prozessen (SYLV)

gemeinsam veranstaltet von den Fachverbänden
Atomphysik (A),
Molekülphysik (MO) und
Quantenoptik und Photonik (Q)

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Übersicht der Hauptvorträge und Fachsitzungen

(Hörsaal VMP 8 HS)

Hauptvorträge

SYLV 1.1	Mo	14:00–14:30	VMP 8 HS	**Coherence, interference and entanglement in the photoionization of homonuclear diatomic molecules** — •Reinhard Dörner, M. Schöffler, T. Jahnke, K. Kreidi, D. Akoury, L.Ph.H. Schmidt, H. Schmidt-Böcking, J. Titze, N. Neumann, T. Weber, M.H. Prior, A. Belkacem, P. Ranitovic, C.L. Cocke, A. Landers, S. Semenov, N. Cherepkov
SYLV 1.2	Mo	14:30–15:00	VMP 8 HS	**Quantum Interfaces between Nanomechanical Systems and Cold Atoms** — •Peter Zoller
SYLV 1.3	Mo	15:00–15:30	VMP 8 HS	**Electron entanglement studied by Dopppler-resolved electron spectroscopy** — •Svante Svensson
SYLV 1.4	Mo	15:30–16:00	VMP 8 HS	**Entanglement-assisted Ramsey Spectroscopy with Atomic Ensembles** — •Eugene Polzik
SYLV 2.1	Mo	16:30–17:00	VMP 8 HS	**Coherent photoelectron emission from diatoms: Influence of scattering, recoil, and dissociation** — •Kiyoshi Ueda
SYLV 2.2	Mo	17:00–17:30	VMP 8 HS	**Atom-Photon Entanglement** — •Harald Weinfurter, Florian Henkel, Julian Hofmann, Michael Krug, Norbert Ortegl, Wenjamin Rosenfeld, Jürgen Volz, Markus Weber
SYLV 2.3	Mo	17:30–18:00	VMP 8 HS	**Space-time entanglement: A realization of EPR's original proposal** — •Burkhard Langer, Uwe Becker
SYLV 2.4	Mo	18:00–18:30	VMP 8 HS	**A long-distance quantum gate between matter qubits** — •P. Maunz, S. Olmschenk, D. Hayes, D. N. Matsukevich, L.-M. Duan, C. Monroe
SYLV 2.5	Mo	18:30–19:00	VMP 8 HS	**Space-QUEST: Experiments with quantum entanglement in space** — •Rupert Ursin, Thomas Jennewein, Anton Zeilinger

Fachsitzungen

SYLV 1.1–1.4	Mo	14:00–16:00	VMP 8 HS	**SYLV I**
SYLV 2.1–2.5	Mo	16:30–19:00	VMP 8 HS	**SYLV II**

SYLV 1: SYLV I

Zeit: Montag 14:00–16:00 Raum: VMP 8 HS

Hauptvortrag SYLV 1.1 Mo 14:00 VMP 8 HS

Coherence, interference and entanglement in the photoionization of homonuclear diatomic molecules — •Reinhard Dörner[1], M. Schöffler[1], T. Jahnke[1], K. Kreidi[1], D. Akoury[1], L.Ph.H. Schmidt[1], H. Schmidt-Böcking[1], J. Titze[1], N. Neumann[1], T. Weber[2], M.H. Prior[2], A. Belkacem[2], P. Ranitovic[3], C.L. Cocke[3], A. Landers[4], S. Semenov[5], and N. Cherepkov[5] — [1]J. W. Goethe-Universität Frankfurt, Max von Laue Str. 1, D-60438 Frankfurt am Main — [2]Lawrence Berkeley National Laboratory, Berkeley CA 94720 — [3]Kansas State University, Manhattan KS 66506 — [4]Auburn University, Auburn AL 36849 — [5]State University of Aerospace Instrumentation, 190000 St. Petersburg, Russia

Emission of two electrons from N_2 and H_2 by absorption of one photon resembles a two particle double slit experiment in which both particles are entangled. We report experiments [1,2,3] in which both electrons and both ions resulting from this process are measured in coincidence showing these interference structures and the entanglement of the two electrons.

[1] Akoury et al., Science **318**, 949 (2007)
[2] Kreidi et al., Phys. Rev. Lett. **100**, 133005 (2008)
[3] Schöffler et al. Science**320**, 920 (2008)

Hauptvortrag SYLV 1.2 Mo 14:30 VMP 8 HS

Quantum Interfaces between Nanomechanical Systems and Cold Atoms — •Peter Zoller — Institut für Theoretische Physik, A-6020 Innsbruck, Austria

We propose and analyze quantum interfaces between nanomechanical systems and single atoms, or to ensembles of atoms, where the exchange of optical photons plays the role of the quantum data bus. Specific examples to be discussed include the generation of a continuous variable EPR-state and teleportation protocol between a nanomechanical oscillator and a distant atomic ensemble [1], the strong coupling of single atoms in cavities in an optomechanical setup [2], and couplings of cold atoms in an optical lattice to a moving mirror or membrane [3].

[1] K. Hammerer, M. Aspelmeyer E.S. Polzik, and P. Zoller, Phys. Rev. Lett. in press
[2] K. Hammerer, M. Wallquist, H.J. Kimble, J. Ye and P. Zoller, in preparation
[3] P. Treutlein, S. Camerer, D. Hunger, T. W. Hänsch, M. Wallquist, K. Hammerer, C. Genes and P. Zoller, in preparation

Hauptvortrag SYLV 1.3 Mo 15:00 VMP 8 HS

Electron entanglement studied by Dopppler-resolved electron spectroscopy — •Svante Svensson — Uppsala University, Uppsala, SWEDEN

A review of the research on x-ray quantum optics based on the studies of emitted electrons and ions will be given. The starting point is the discovery of the Auger Doppler effect and the far reaching consequences of the possibility to "mark" core ionized species in an ultra-fast dissociation process. The presentation will end in the most recent results on the subject.

Hauptvortrag SYLV 1.4 Mo 15:30 VMP 8 HS

Entanglement-assisted Ramsey Spectroscopy with Atomic Ensembles — •Eugene Polzik — The Niels Bohr Institute, Copenhagen University, Blegdamsvej 17, Copenhagen, Denmark

Ultimate quantum fluctuations which limit the fundamental precision in metrology can be only reduced by entanglement of particles. In particular, squeezing of the fluctuations called the spin projection noise by means of generation of entanglement in an ensemble of atoms can improve the precision of Ramsey spectroscopy and of atomic clocks. A powerful tool for generation of multiparticle entanglement is a quantum nondemolition measurement (QND). We will describe the fundamentals of QND measurement of atomic collective state with light and present a recent experiment [1] where this method has been used to reduce the projection noise on the clock transition in an ensemble of 105 cold and trapped Cesium atoms. Nondestructive probing can be also used to monitor classical properties and dynamics of atoms with excellent S/N ratio [2].

[1] J. Appel, P. J. Windpassinger, D. Oblak, U. B. Hoff, N. Kjærgaard, and E. S. Polzik. Quantum noise squeezing and entanglement on the atomic clock transition. Submitted for publication. arXiv:0810.3545
[2] Windpassinger, P. J., Oblak, D., Petrov, P. G., Kubasik, M., Saffman, M., Alzar, C. L. Garrido, Appel, J., Mueller, J. H., Kjærgaard, N., and Polzik, E. S. Nondestructive probing of Rabi oscillations on the cesium clock transition near the standard quantum limit. Phys. Rev. Lett., 100, 103601 (2008); Windpassinger, P. J., Oblak, D., Hoff, U.B., Appel, J., Kjærgaard, N., and Polzik, E. S., Inhomogeneous light shift effects on atomic quantum state evolution in non-destructive measurements. New J. of Physics, 10, 053032 (2008).

SYLV 2: SYLV II

Zeit: Montag 16:30–19:00 Raum: VMP 8 HS

Hauptvortrag SYLV 2.1 Mo 16:30 VMP 8 HS

Coherent photoelectron emission from diatoms: Influence of scattering, recoil, and dissociation — •Kiyoshi Ueda — Tohoku University, Sendai, Japan

Coherent photoelectron emission from diatoms such as N_2 and O_2 can be regarded as Young's double-slit experiment. In this context, we address how electron and nuclear dynamics, such as photoelectron scattering, photoelectron recoil, and molecular dissociation, affect the double-slit interference fringes. Photoelectron emission from the N $1\sigma_{g,u}$ core orbitals of N_2 is described as a superposition of two phase-coherent waves emitted from the two centers. The resulting interference pattern observed in the ratio of the N $1\sigma_{g,u}$ photoionization cross sections reveals that photoelectron scattering as well as photoelectron recoil causes significant phase shift of the double-slit interference fringes but neither reduce the visibility of the fringes nor increase the which-way predictability. Resonant photoemission from O_2 via O $1\sigma_g \rightarrow 3\sigma_u^*$ excitation that takes place in competition with ultrafast dissociation, on the other hand, provides a showcase example that which-way predictability increases rapidly to 1 along the dissociation.

Hauptvortrag SYLV 2.2 Mo 17:00 VMP 8 HS

Atom-Photon Entanglement — •Harald Weinfurter[1,2], Florian Henkel[1], Julian Hofmann[1], Michael Krug[1], Norbert Ortegl[1], Wenjamin Rosenfeld[1], Jürgen Volz[3], and Markus Weber[1] — [1]Ludwig-Maximilians-Universität München — [2]Max-Planck-Institut für Quantenoptik — [3]Laboratoire Kastler Brossel de l E.N.S.

Spontaneous emission can be the origin of entanglement between an atom and the emitted photon. This nonclassical property is a key resource for experiments on the foundations of quantum physics and its applications in the field of quantum information, the generic scheme can be easily transferred to many other quantum systems.

Here we exemplarily describe the observation of such entanglement between the spin of a single Rubidium atom captured by an optical dipole trap and the polarization of the emitted photon. In several experiments we characterize the common state of atom and photon, analyze the (de)coherence of the state, and demonstrate in a first quantum communication protocol the remote preparation of the atomic state via a manipulation of the photon.

Hauptvortrag SYLV 2.3 Mo 17:30 VMP 8 HS

Space-time entanglement: A realization of EPR's original proposal — •Burkhard Langer[1] and Uwe Becker[2] — [1]Freie Universität Berlin — [2]Fritz-Haber-Institut der MPG

In their famous paper Einstein, Podolsky and Rosen[1] questioned 1935 the completeness of quantum mechanics concerning a local realistic description of our reality. They argued on the basis of superpositions of position and momentum states against the inherent non-locality and loss of information on prior conditions by quantum mechanics.

This pioneering proposal was, however, too vague to be implemented in any experimental proof. Consequently, angular momentum related variables such as the polarisation of light became the working horse of all experiments proving the EPR predictions on the basis of their quantitatively reformulated version by John Bell 1964. Since that all experiments beginning from the pioneering work by Alain Aspect over the Stirling experiment of Hans Kleinpoppen to the world wide publicity gaining quantum teleportation experiments by Anton Zeilinger used the polarization properties of light as spin equivalent to prove the predictive power of quantum mechanics. However, the spin and its related polarization properties are abstract quantities compared to position and momentum. Here we present the first evidence that nonlocality and loss of prior quantum state information occurs also for position in ordinary space. This shows that the tunnelling effect and entanglement are inherently correlated. This will be a subject of future studies on the foundations of quantum physics.

[1] A. Einstein, B. Podolsky and N. Rosen, Phys. Rev. **47**, 777, 1935.

Hauptvortrag SYLV 2.4 Mo 18:00 VMP 8 HS

A long-distance quantum gate between matter qubits — •P. Maunz[1], S. Olmschenk[1], D. Hayes[1], D. N. Matsukevich[1], L.-M. Duan[2], and C. Monroe[1] — [1]Joint Quantum Institute and Department of Physics, University of Maryland, College Park, MD 20742 — [2]FOCUS Center and Department of Physics, University of Michigan, Ann Arbor, MI 48109

We demonstrate a probabilistic entangling quantum gate [1] between two distant trapped ytterbium ions. The gate is implemented between the hyperfine "clock" state atomic qubits and mediated by the interference of two emitted photons carrying frequency encoded qubits [2]. The successful operation of the gate is heralded by the coincidence detection of these photons.

On average, the gate has a fidelity of 90% and a success probability of 2.2×10^{-8}. For one pair of input states for which we expect the antisymmetric Bell state as output, we perform full tomography of the output state and obtain a fidelity of $F = 0.87$. We also apply this gate to teleport a quantum state between ytterbium ions separated by one meter [3].

This entangling gate together with single qubit operations is sufficient to generate large entangled cluster states for scalable quantum computing [4].

[1] L. Duan et al. Phys. Rev. A **73**, 062324 (2006).
[2] D. L. Moehring et al. Nature **449**, 68 (2007).
[3] S. Olmschenk et al. Science, to be published (2009).
[4] L. Duan and R. Raussendorf. Phys. Rev. Lett. **95**, 080503 (2005).

Hauptvortrag SYLV 2.5 Mo 18:30 VMP 8 HS

Space-QUEST: Experiments with quantum entanglement in space — •Rupert Ursin, Thomas Jennewein, and Anton Zeilinger — Faculty of Physics, University of Vienna, Austria

Quantum communications is becoming a field of increasingly broad technological interest. It has matured from a purely fundamental quantum physics research area to an applied science with huge potential economic impact. The most promising application, quantum cryptography, has been demonstrated in various scenarios, and initial systems are already commercially available. A fascinating technological challenge is the establishment of a quantum communication network, which eventually allows quantum communication on a global scale. Most existing implementations of quantum communication schemes are based on the transmission and detection of single photons or entangled photon pairs. With present technology, the distance that can be bridged is limited, basically by attenuation and detection noise, to some hundred kilometers in fiber systems. These limitations could be overcome by the use of space and satellite technology. The European Space Agency (ESA) has supported a range of studies in the field of quantum physics and quantum information science in space for several years, and consequently a mission proposal Space-QUEST (Quantum Entanglement for Space Experiments) was submitted to the European Life and Physical Sciences in Space Program. This proposal envisions to perform space-to-ground quantum communication tests from the International Space Station (ISS). Here we present the proposed experiments in space as well as the design of a space based quantum communication payload.