Symposium Single Atoms (SYSA)

jointly organized by
the Quantum Optics and Photonics Division (Q) and
the Atomic Physics Division (A)

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Overview of Invited Talks and Sessions

(lecture room A 320)

Invited Talks

SYSA 1.1	Th	10:30–11:00	A 320	**Cavity EIT with single atoms** — •Stephan Ritter, Martin Mücke, Eden Figueroa, Jörg Bochmann, Carolin Hahn, Celso J. Villas-Boas, Gerhard Rempe
SYSA 1.2	Th	11:00–11:30	A 320	**Optical detection of single trapped atoms with less than one spontaneous emission** — Jürgen Volz, Roger Gehr, Guilhem Dubois, Jérôme Estève, •Jakob Reichel
SYSA 1.3	Th	11:30–12:00	A 320	**Substantial interaction between a singe atom and a focused light beam** — •Gleb Maslennikov, Syed Abdullah Aljunid, Brenda Chng, Florian Huber, Meng Khoon Tey, Timothy Liew, Valerio Scarani, Christian Kurtsiefer
SYSA 1.4	Th	12:00–12:30	A 320	**Exploring Quantum Physics with Single Neutral Atoms** — •Artur Widera
SYSA 2.1	Th	14:00–14:30	A 320	**Detecting single ultra cold atoms** — •Jörg Schmiedmayer
SYSA 2.2	Th	14:30–15:00	A 320	**Entanglement of two individual neutral atoms using Rydberg blockade** — •Tatjana Wilk, Alpha Gaëtan, Charles Evellin, Janik Wolters, Yevhen Miroshnychenko, Philippe Grangier, Antoine Browaeys

Sessions

SYSA 1.1–1.4	Th	10:30–12:30	A 320	**Single Atoms I**
SYSA 2.1–2.2	Th	14:00–15:00	A 320	**Single Atoms II**

SYSA 1: Single Atoms I

Time: Thursday 10:30–12:30 Location: A 320

Invited Talk SYSA 1.1 Th 10:30 A 320
Cavity EIT with single atoms — •Stephan Ritter, Martin Mücke, Eden Figueroa, Jörg Bochmann, Carolin Hahn, Celso J. Villas-Boas, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

A single atom trapped at the center of a high-finesse optical cavity is an ideal starting point for studying the coherent interaction between light and matter. At the same time, it provides great possibilities for quantum information processing, exemplified by our demonstration of efficient, lossless hyperfine state detection based on the Purcell effect. Making use of the rich level structure of ^{87}Rb, it is possible to go beyond the Jaynes-Cummings physics. A three-level system in a lambda configuration inside the cavity allows for the efficient generation of single photons with their temporal, spectral and polarization properties accurately controlled. This allows for the generation of atom-photon and photon-photon entanglement, an ideal starting point for the realization of a distributed quantum network. Quantum interference in the amplitudes of the two optical transitions can lead to electromagnetically induced transparency (EIT), where the presence of a weak control beam drastically alters the optical properties of the medium. Inside an optical cavity, this effect is highly enhanced and expected to be observable for a few or even single atoms. The high electric field per photon should allow for nonlinear interactions between single photons mediated by single atoms, which is appealing for future applications in quantum information processing. We discuss prospects for cavity-based EIT with single atoms and present first experimental results.

Invited Talk SYSA 1.2 Th 11:00 A 320
Optical detection of single trapped atoms with less than one spontaneous emission — Jürgen Volz, Roger Gehr, Guilhem Dubois, Jérôme Estève, and •Jakob Reichel — Laboratoire Kastler Brossel, ENS/CNRS/UPMC, Paris

Coherence times of several seconds have been demonstrated for neutral atomic ensembles trapped on atom chips. Combining this feature with efficient single-atom preparation and detection methods may enable quantum engineering in a style similar to ion traps, while maintaining the attractive simplicity of an atom chip experiment.

We have developed such techniques using a fiber Fabry-Perot (FFP) cavity on the chip, which works in the strong coupling regime of cavity quantum electrodynamics. Starting from a small BEC trapped inside the cavity mode, it enables us to prepare a single atom in a well-known hyperfine and Zeeman state, and to detect this atom with a back action of less than one spontaneous emission.

Invited Talk SYSA 1.3 Th 11:30 A 320
Substantial interaction between a singe atom and a focused light beam — •Gleb Maslennikov[1], Syed Abdullah Aljunid[1], Brenda Chng[1], Florian Huber[2], Meng Khoon Tey[3], Timothy Liew[4], Valerio Scarani[1], and Christian Kurtsiefer[1] — [1]Centre for Quantum Technologies / Physics Dept., Nat. Univ. Singapore — [2]Harvard University — [3]IQOQI Innsbruck — [4]EPFL Neuchatel

We investigate both theoretically and experimentally the near-resonant interaction between a single atom in an optical dipole trap and a focused coherent light beam. We have demonstrated that even for a moderate focusing strength, a single atom localized at the focus of a simple aspheric lens can scatter a significant fraction of light [1,2], impose a phase shift [3], and partially reflect a probe beam. With our current experimental system, we observe an extinction of 10%, a phase shift of about 1° and a reflectivity of 0.17%. For an optimal focusing geometry, we expect an extinction up to 92% and a phase shift of 30°.

The strength of the observed effect suggests that an fficient interface between atoms and photons for quantum information purposes can be established – either without cavities, or by enhancing the electrical field in in a low-finesse cavity simply by strong focusing. We report on our experimental progress towards this goal.

[1] M. K. Tey, et al., Nature Physics **4**, 924 (2008)
[2] M. K. Tey et. al., New J. Phys. **11**, 043011 (2009)
[3] S.A. Aljunid et al., Phys. Rev. Lett. **103**, 153601 (2009)

Invited Talk SYSA 1.4 Th 12:00 A 320
Exploring Quantum Physics with Single Neutral Atoms — •Artur Widera — Institut für Angewandte Physik, Universität Bonn, Germany

Advances in preparation, manipulation and detection of single neutral atoms have paved the way to experimentally address fundamental questions of quantum mechanics. I will report on two approaches to realize different paradigms of quantum physics. First, trapping atoms in a state-dependent optical lattice allows us to entangle the atomic spin with both the position and the motional state of the atom. This has enabled the implementation, for instance, of the quantum walk with single atoms, the coherent walk of a quantum particle on a line. Second, we can deterministically insert a single atom into a high-finesse optical resonator and employ the coherent interaction with single photons to non-destructively study the spin dynamics of the atom. This method might prove useful in the creation and detection of non-classical atomic states.

SYSA 2: Single Atoms II

Time: Thursday 14:00–15:00 Location: A 320

Invited Talk SYSA 2.1 Th 14:00 A 320
Detecting single ultra cold atoms — •Jörg Schmiedmayer — Atominstitut, TU-Wien, Stadionallee 2, 1020 Vienna, Austria

Two different settings detecting single atoms by fluorescence are presented.

The first is a detector for trapped atoms [1], fully integrated on an atom chip, consisting of a tapered lensed single-mode fiber for precise delivery of excitation light and a multi mode fiber to collect the fluorescence, both mounted SU-8 holding structures on an atom chip. Single Rb atoms propagating freely in a magnetic guide are detected with an efficiency of 66% with a signal to noise ratio in excess of 100.

The second is a single atom camera that allows imaging of ultra cold quantum gases in expansion [2]. Atoms fall through a sheet of resonant excitation light and the emitted fluorescence photons are imaged onto an amplified CCD camera using a high numerical aperture optical system. We demonstrate single-atom detection for dilute atomic clouds with high efficiency where at the same time dense Bose-Einstein condensates can be imaged without saturation or distortion.

These detectors can be used to probe atom-atom correlations in ultra cold degenerate quantum many body systems.

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[1] M. Wilzbach, et al. Opt.Lett. 34, 259 (2009).
[2] R. Bücker, et al. NJP, 11, 103039 (2009).

Invited Talk SYSA 2.2 Th 14:30 A 320
Entanglement of two individual neutral atoms using Rydberg blockade — •Tatjana Wilk, Alpha Gaëtan, Charles Evellin, Janik Wolters, Yevhen Miroshnychenko, Philippe Grangier, and Antoine Browaeys — Institut d'Optique, Campus Polytechnique - RD128, 91127 Palaiseau cedex, France

The interaction between atoms in Rydberg states is enhanced by many orders of magnitude compared to ground state atoms. This effect can be used to turn on and off the interaction between single atoms at distances on the order of micrometers. In particular the simultaneous excitation of more than one atom to a Rydberg state is strongly suppressed. A decade ago this so-called Rydberg blockade effect was proposed for the implementation of fast quantum gates for neutral atoms and for the creation of entanglement between them [1]. Only recently two experiments have demonstrated the realization of such schemes [2]. Here, we report on our work of the generation of entanglement between two individual ^{87}Rb atoms in hyperfine ground states $|F{=}1, m_F{=}1\rangle$ and $|F{=}2, m_F{=}2\rangle$ which are held in two optical tweezers separated by 4 μm. The entangled state is generated in about 200 ns using pulsed two-photon excitation. We quantify the entanglement by applying global Raman rotations on both atoms. [1] D. Jaksch et al., *Phys. Rev. Lett.* **85**, 2208 (2000). M.D. Lukin et al., *Phys. Rev. Lett.* **87**, 037901 (2001). [2] L. Isenhower et al., *arXiv:* 0907.5552 (2009). T. Wilk et al., *arXiv:* 0908.0454 (2009).