Q 6: Ultracold atoms and molecules

Time: Monday 11:00–12:30 Location: A 310

Group Report Q 6.1 Mon 11:00 A 310

Electric quantum walks — •Andrea Alberti, Maximilian Genske, Andreas Steffen, Noomen Belmechri, Wolfgang Alt, and Dieter Meschede — Institut für Angewandte Physik, Universität Bonn - Wegelerstr. 8, 53115 Bonn

Quantum walks represent the quantum motion of a particle on a lattice with a strictly local dynamics, and they constitute the quantum counterpart of classic random walks. Their dynamics is determined by periodically reiterating a set of discrete quantum operations. Single atoms in a spin-dependent optical lattice provide, e.g., spin-dependent displacements, spin rotations, and collisional phase shifts, which can be employed to experimentally implement quantum walks and to simulate the quantum evolution of complex physical systems.

We will report on the experimental realization of an electric quantum walk, which mimics the quantum transport of charged particles in a period potential in the presence of an external electric field. The continuous-time quantum dynamics of these systems – well known for leading to the Bloch oscillation phenomenon – is here stroboscopically approximated by a periodic sequence of basic discrete operations.

We are able to reproduce the mechanism of Bloch oscillations and to investigate the Landau-Zener tunneling between the two energy bands that govern the transport dynamics of quantum walks. We detected quantum resonances every time the Bloch period is chosen commensurate with duration of one step, forcing the walker to spread out ballistically. Off-resonance, we present a clear experimental signature that the walker remains localized instead.

Q 6.2 Mon 11:30 A 310

Ground state cooling of a single atom at the center of an optical cavity — •Andreas Reiserer, Christian Nölleke, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Straße 1, 85748 Garching

The study of the dynamics and precise manipulation of physical systems at the quantum level requires full control over all relevant degrees of freedom. In this respect, single atoms in optical dipole traps are a well advanced system. In order to couple these atoms to single photons, optical cavities have proven very successful. However, for complete control of this coupling, the atoms have to be cooled to the ground state of the trapping potential.

In our experiment, a single neutral atom is deterministically localized at the center of an optical resonator of high finesse. Using a three-dimensional optical lattice with high intensities, we observe trap frequencies of several hundred kHz. This allows us to cool the atom to the three-dimensional ground state via Raman sideband cooling. Thus, our system is the first to achieve simultaneous experimental control over the motional, internal and radiative properties of a single atom.

Q 6.3 Mon 11:45 A 310

Feedback on a single atom using heterodyne detection — Christian Sames, Haytham Chibani, Christoph Hamsen, Anna Caroline Eckl, Paul Altin, •Tatjana Wilk, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, D-85748 Garching

An optical cavity can be used as a kind of intensifier to study radiation features of an atom, which are hard to detect in free space, like squeezing [1]. Such experiments make use of strong coupling between atom and cavity mode. Experimentally, strong coupling requires the atom to be well localized in the cavity mode. This can be achieved using feedback on the atomic motion: since the atom-cavity coupling depends on the atomic position within the mode, the field of a probe beam transmitted through the cavity varies strongly when the atom moves. The intensity of an intracavity dipole trap can then be switched in synchronism with the atomic motion, leading to cooling and localization. In contrast to previous feedback experiments done with photon counting [2,3], feedback with heterodyne detection gives continuous information of the field leaking out of the cavity. In this talk we will present recent measurements that were enabled by this new feedback strategy. [1] A. Ourjoumtsev et al., Nature 474, 623 (2011). [2] A. Kubanek et al., Nature 462, 898 (2009). [3] M. Koch et al., Phys. Rev. Lett. 105, 173003 (2010).

Q 6.4 Mon 12:00 A 310

A raman laser system for adiabatic photo association of NaK molecules — •Diana Amaro, Nikolaus Buchheim, Zhenkai Lu, Tobias Schneider, Immanuel Bloch, and Christoph Gohle — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching

Ultra cold quantum gases with large dipolar interaction or large polarizability that are recently becoming available promise exciting new possibilities. Self assembled lattices of polarized particles supporting phonon modes will provide opportunities to simulate an even broader range of solid state physics phenomena [1]. New classes of many body phases (like super solids and stripe phases) are on the horizon and ferroelectric phases of highly polarizable systems are expected [2].

One such system is the NaK bialkali with a ground state dipole moment of 2.8 Debeye. In order to create these molecules at sufficiently high phase space density, an adiabatic route from a near degenerate mixture of sodium and potassium to the molecular electronic, rotational and vibrational ground state bridging 150THz is required. We have built a highly stable raman laser system by stabilizing two diode lasers to a ultra stable fabry perot transfer cavity.

[1] Pupillo, G., Micheli, A., Büchler, H. P., & Zoller, P. (2008). Condensed Matter Physics with Cold Polar Molecules. arXiv:0805.1896.

[2] Iskin, M., & Sá de Melo, C. (2007). Ultracold Heteronuclear Molecules and Ferroelectric Superfluids. Physical Review Letters, 99(11), 110402.

Q 6.5 Mon 12:15 A 310

Vacuum-Induced Coherence in Ultracold Molecules — •Sumanta Das[1,2], Arpita Rakshit[1], and Bimalendu Deb[1] — [1]Department of Material Sciences, IACS, Kolkata 700032, India — [2]Max Planck Institute for Nuclear Physics, Saupfercheckweg 1, 69117 Heidelberg, Germany

We show that coherence between two excited rovibrational states belonging to the same molecular electronic configuration arises quite naturally due to their interaction with the electromagnetic vacuum [1]. For initial preparation of a molecule in the desired rovibrational states, we propose to employ the method of ultracold photoassociation. Spontaneous decay of the excited molecule then gives rise to vacuum-induced coherence between the excited ro-vibrational states. We demonstrate theoretically an interesting interplay of effects due to vacuum-induced coherence and photoassociation. We apply our theory to photoassociation of bosonic ytterbium (^{174}Yb) atoms, which appear to be a promising system for exploring such interplay [2, 3]. The effects discussed here can be important for controlling decoherence and dissipation in molecular systems.

[1] S. Das, A. Rakshit and B. Deb, Phys. Rev. A **85**, 011401(R) (2012).
[2] S. Tojo *et al.*, Phys. Rev. Lett. **96**, 153201 (2006).
[3] M. Borkowski *et al.*, Phys. Rev. A **80**, 012715 (2009).