Quantum spin stabilized magnetic levitation

Thursday 30.03, 14:00 - 14:25

C. C. Rusconi
IQOQI / University of Innsbruck

We theoretically study the levitation of a single magnetic domain nanosphere in an external static magnetic field. We show that apart from the stability provided by the mechanical rotation of the nanomagnet (as in the classical Levitron), the quantum spin origin of its magnetization provides two additional mechanisms to stably levitate the system. Despite of the Earnshaw theorem, such stable phases are present even in the absence of mechanical rotation. For large magnetic fields, the Larmor precession of the quantum magnetic moment stabilizes the system in full analogy with magnetic trapping of a neutral atom. For low magnetic fields, the magnetic anisotropy stabilizes the system via the Einstein-de Haas effect. These results are obtained with a linear stability analysis of a single magnetic domain rigid nanosphere with uniaxial anisotropy in a Ioffe-Pritchard magnetic field.

Rotational optomechanics with levitated nanorods

Thursday 30.03, 14:25 - 14:50

S. Kuhn
University of Vienna

Optical control over nano-mechanical structures has become a valuable tool for tests of fundamental physics and force sensing applications. In order to achieve optimal performance of such devices, their dissipation to the environment needs to be minimized. Levitating nanoparticles in external fields is a possible solution which opened up the growing field of levitated optomechanics. Here we extend this work to the rotational degrees of freedom of optically levitated silicon nanorods[1]. We track and manipulate their linear and rotational motion by exploiting the polarization of two counter-propagating, focussed laser beams. This allows us to gain full control over the ro-translational dynamics of the rod. We will discuss the prospects of our levitated system for sensing applications [2] as well as for realising rotational optomechanics and cavity cooling [3,4] which may be an important step towards high-mass matter-wave interference experiments with nanoparticles.

[1] To appear in Optica, 4(3) (2017)
[2] arXiv:1702.07565 (2017)
[3] Nano Lett., 15(8), 5604–5608 (2015)
[4] Phys. Rev. A, 94, 033818 (2016)

Time crystals

Thursday 30.03, 15:50 - 16:45

J. Zakrzewski
Jagiellonian University Krakow

A review of time crystals idea will be presented. Starting from the original work of Wilczek that was criticised by Bruno and others, the recent developments on "Floquet" time crystals that are due to spontaneous breaking of discrete time translation symmetry are discussed. The existence of those have been verified experimentally in groups of C. Monroe and M. Lukin. It will be shown that Wilczek's idea for spontaneous breaking of continuous time translation symmetry (without external driving) may be modified into a plausible proposition. Other basic models of condensed matter physics translated from the space to the time domain will also be introduced.

Subwavelength emitters are not where we see them

Thursday 30.03, 16:45 - 17:20

G. Araneda & S. Walser
University Innsbruck, ATI/TU Vienna

Optical microscopy is widely used for imaging in, e.g., biology and physics. Recently, the advent of high- and super-resolution microscopy techniques has improved the achievable resolution by orders of magnitude, far beyond the standard resolution limit lambda/NA. In this talk we demonstrate a physical effect that has so far been neglected, and that can lead to a shift in the apparent position of an emitter. This shift, which can be of the same order of magnitude as the imaging wavelength, arises from the vector nature of the light. We demonstrate this effect by imaging a nanoparticle which scatters light with different elliptical polarizations, and observe an image displacement that depends on the ellipticity, with shifts up to 0.8 lambda. Furthermore, we show this effect in the image of the most fundamental emitter, a single atom, by collecting photons emitted on two different dipolar transitions.

New Developments in Mid-IR Frequency Comb Spectroscopy

Friday 31.03, 9:00 - 9:55

O. Heckl
University Vienna

Optical frequency comb spectroscopy has blossomed into a versatile tool for the broad-bandwidth and high-spectral-resolution study of molecules in the visible and near-infrared. Cavity-Enhanced Direct Frequency Comb Spectroscopy (CE-DFCS) enables measurements with a simultaneous bandwidth of up to hundreds of nm at a frequency resolution comparable to stable CW light sources.

During this talk, I will present recent developments of mid-IR frequency comb sources and the application of frequency combs sources for mid-IR spectroscopy. Topics include work on direct frequency comb measurements of *OD + CO → DOCO* kinetics and continuous probing of cold complex molecules with infrared frequency comb spectroscopy.

Coherent control of trapped Rydberg ions

Friday 31.03, 9:55 - 10:20

M. Hennrich
University Stockholm

Trapped Rydberg ions are a novel quantum system [1]. By combining the high degree of control of trapped ion systems with the long-range dipole-dipole interactions of Rydberg atoms [2], fast entanglement gates may be realized in large ion crystals [3]. Quantum information processing in this system is envisaged to use low-lying electronic states for storage of qubits and strongly interacting Rydberg states for entanglement operations. This requires the Rydberg excitation to be coherently controlled.

In our experiment [4] we have observed the first coherent Rydberg excitations of an ion via a two-photon excitation to Rydberg S states. Coherent effects observed include Rabi oscillations, EIT and STIRAP. We also report the realization of microwave-dressed Rydberg ions driving the transition between Rydberg S and P states. This marks an important step towards realizing entanglement operations between Rydberg ions, which are envisaged to strongly interact with each other via the large oscillating dipole moments of microwave-dressed Rydberg states.

[1] M. Müller, et al., New J. Phys. 10, 093009 (2008).
[2] D. Jaksch, et al., Phys. Rev. Lett. 85, 2208 (2000).
[3] F. Schmidt-Kaler, et al., New J. Phys. 13, 075014, (2011).
[4] G. Higgins, et al., arXiv:1611.02184v1, (2016).

Subradiance via entanglement in atoms with several independent decay channels

Friday 31.03, 10:20 - 10:45

L. Ostermann
University Innsbruck

Spontaneous emission of atoms in free space is modified by the presence of other atoms in close vicinity inducing collective super- and sub-radiance. For two nearby atoms with a single decay channel the entangled antisymmetric superposition state of the two single excited states will not decay spontaneously. No such excited two-atom dark state exists, if the excited state has two independent optical decay channels of different frequencies or polarizations. However, we show that for an excited atomic state with *N-1* independent spontaneous decay channels one can find a highly entangled *N*-particle dark state, which completely decouples from the vacuum radiation field. It does not decay spontaneously, nor will it absorb resonant laser light. Mathematically, we see that this state is the only such state orthogonal to the subspace spanned by the atomic ground states. Moreover, by means of generic numerical examples we demonstrate that the subradiant behavior largely survives at finite atomic distances including dipole-dipole interactions.

Majorana quasi-particles protected by $\mathbb{Z}_2$ angular momentum conservation

Friday 31.03, 11:15 - 12:10

R. Fazio
ICTP Trieste

Angular momentum conservation can stabilise a symmetry-protected quasi-topological phase of matter supporting Majorana quasi-particles as edge modes in one-dimensional cold atom gases. We investigated a number-conserving four-species Hubbard model in the presence of spin-orbit coupling. The latter reduces the global spin symmetry to an angular momentum parity symmetry, which provides an extremely robust protection mechanism that does not rely on any coupling to additional reservoirs. The emergence of Majorana edge modes is elucidated using field theory techniques, and corroborated with density-matrix-renormalization-group simulations. We believe that our results pave the way toward the observation of Majorana edge modes with alkaline-earth-like fermions in optical lattices, where all basic ingredients for our recipe - spin-orbit coupling and strong inter-orbital interactions - have been experimentally realized over the last two years.

F. Iemini, L. Mazza, L. Fallani, P. Zoller, R. Fazio, and M. Dalmonte, arXiv:1702:04733

The entropic approach to classical, quantum, and postquantum causal structures.

Friday 31.03, 12:10 - 12:35

C. Budroni
IQOQI Vienna

Inferring causal relations among variables on the basis of the observed data is of fundamental importance in physics and in all natural sciences. A familiar example of a causal inference method is provided by a Bell inequality: if violated, it can disprove certain assumptions of causal relations among (classical) variables. The same idea can be applied to more complex causal structures, involving classical, quantum, and postquantum variables.

We give a basic introduction on classical causal inference and briefly review some recent results on classical, quantum, and postquantum causal inference. In particular, we will focus on the entropic approach, where constraints are derived in terms of the entropy of the observed data, instead of the probability.

Characterizing the response of mouse's eye to single photons

Friday 31.03, 12:35 - 13:00

A. Tavala
University Vienna

We report the experiment in which we treat the mouse retina as a single photon detector and probe it. After a brief introduction to the retina, we describe the single photon source and the optical interface which stimulate the ex-vivo retina. Finally, we explain the method for measuring the output of the neurons and present the preliminary results.