Symposium on Ion-based Quantum Optics

Lundbeck Foundation Theoretical Center for Quantum System Research

Thursday, October 9, 2008

in
The Physics Auditorium

Programme

13:15-14:00	**Prof. Jürgen Eschner** ICFO – The Institute of Photonic Sciences, Barcelona, Spain	Single-atom – single-photon interaction
14:00-14:45	**Prof. Stefan Kröll**, Department of Physics, Lund University, Sweden	Ensemble-based quantum memories for single photon wave-packets
14:45-15:15	Coffee	
15:15-16:00 Also AMO-Seminar	**Prof. Giovanna Morigi**, Department of Physics, Universitat Autonoma de Barcelona, Spain	Ion crystals in traps: An unusual form of condensed matter
16:00-16:45	**Prof. Wolfgang Lange**, Department of Physics and Astronomy, University of Sussex, United Kingdom	Ion-Qubits and Photonic Wires

The talks are open for all interested!

Klaus Mølmer
Michael Drewsen

Abstracts

Speaker:

Prof. Jürgen Eschner, ICFO – The Institute of Photonic Sciences, Barcelona, Spain

Title:

Single-atom – single-photon interaction

Abstract:

The controlled interaction between single atoms and single photons is the basis for quantum interfaces that coherently connect qubit storage and qubit transmission. I will review a series of experiments where aspects of such interaction have been studied with single trapped ions and single photons, either from the ion's own resonance fluorescence or from a heralded single-photon source. The results range from the observation of line shifts and mechanical effects of single back-reflected fluorescence photons, over indistinguishability of photons from independent atoms, to the study of heralded single-photon absorption. A possible future perspective of the latter is the realisation of photon-to-atom entanglement transfer.

Speaker:

Prof. Stefan Kröll, Department of Physics, Lund University, Sweden

Title:

Ensemble-based quantum memories for single photon wave-packets

Abstract:

Wave-packets may be viewed as being created by a summation of monochromatic waves where the relative phases of these monochromatic waves have been chosen such that they form the particular wave-packet. If a wave-packet can be stored such that we have the ability to manipulate the phases of the individually monochromatic components, we can, for example, control the shape and direction of the wave packet when it is read out. We will discuss an approach for storing single photon wave-packets of the type used for quantum key distribution in rare-earth-ion doped crystals. Theoretically the efficiency of this memory is 100%. The best value obtained experimentally today (limited by technical difficulties) is 40%. The storage technique also gives control of the individual phases of the different frequency components of the wave-packet and the added features this may bring will be discussed.

Speaker:

Prof. Giovanna Morigi, Department of Physics, Universitat Autonoma de Barcelona, Spain

Title:

Ion crystals in traps: An unusual form of condensed matter

Abstract:

Laser cooled ions in anisotropic harmonic potentials can form ion chains of various sizes. In this setup the density of ions is not uniform and the eigenmodes are not phononic-like waves. We study chains of N >>1 ions and evaluate analytically the long wavelength modes and the density of states in the short wavelength limit. These results reproduce with good approximation the dynamics of chains consisting of dozens of ions. Moreover, they allow us to determine the critical transverse frequency required for the stability of the linear structure. At this critical valuet the chain exhibits a sudden transition to a zigzag configuration. In the thermodynamic limit this is a phase transition of second order, whose order parameter is the crystal displacement from the chain axis. In this limit we study analytically the transition using Landau theory. Our theory allows us to determine analytically the system behaviour at the transition point.
Finally, we show that the statistical properties of the system can be measured by means of a standard interferometric procedure performed on the spin of one ion in the chain. The ion spin, constituted by two internal levels of the ion, couples to the crystal modes via spatial displacement induced by photon absorption. The loss of contrast in the interferometric signal allows one to measure the auto-correlation function of the crystal observables. Close to the critical point, where the chain undergoes a second-order phase transition to the zigzag structure, the signal gives the behaviour of the correlation function at the critical point.

Speaker:

Prof. Wolfgang Lange, Department of Physics and Astronomy, University of Sussex, United Kingdom

Title:

Ion-Qubits and Photonic Wires

Abstract:

Ions confined in a radio-frequency trap are presently the most advanced system for quantum information processing. Quantum bits are stored and manipulated in internal electronic states of the ions. One limitation is that the quantum information is available only locally. A significant gain is expected from connecting multiple processing nodes through quantum channels, capable of distributing quantum states over long distances. The obvious choice for these quantum wires are photons, which are already used as qubit-carriers in quantum communication. The principal challenge is to establish a coherent interface

between photons and ions to reliably map quantum information between two systems which interact only weakly in free space.

Strong coupling of single photons to ions has been achieved in cavity-QED, placing the ions in a high-finesse cavity. In this way, unprecedented control over the production of single photons was demonstrated. An important application of ion-trap cavity-QED is the distribution of entanglement among ions in remote traps. I will discuss probabilistic and deterministic schemes which are being implemented in our labs using calcium ions and single infrared photons.