Session 9

Lectures:

Adiabatic theorem for open systems :
alignment/entanglement of molecules by lasers

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Surprising, two qualitatively different forms of the induced dipole Hamiltonian appear in the theoretical literature on alignment of molecules by laser.

We prove that there is no contribution of the permanent dipole moment to the Born-Oppenheimer time-dependent Hamiltonian and therefore even heterenuclear diatoms are aligned/entangled by lasers.

High order harmonic generation spectra (HGS) measurements will enable us to follow the transition from entangled to oriented molecule, indicated by the transition from odd HGS only to a mixed odd and even HGS.

Semiconductor quantum dots as entangled light sources

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Entangled photon pairs are emitted from the biexciton decay cascade of single quantum dots when spectral filtering is applied. We show this by experimentally measuring the density matrix of the polarization state of the photon pair emitted from a continuously pumped quantum dot. By applying in addition a temporal window, the quantum dot becomes an entangled light source.

NONLINEAR OPTICS WITH FEW PHOTONS ?

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I will survey two promising approaches to the realization of nonlinear optical communications and / or data processing with large bandwidth and high signal - to - noise ratio that are sustainable with ultra weak (few photon) signals . These approaches pioneered by us are based on self -induced transparency or slow - light effects in periodic structures with resonantly - enhanced nonlinearities.

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Curiosity killed the cat:
The generation and death of coherence and entanglement in trapped-ion systems

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In this talk we will review methods for the generation of coherent superpositions and entanglement in trapped-ion systems. We will primarily focus on the generation of Schrödinger's cat-like states. We will discuss two types of cat-states. One type composed out of a superposition of two coherent states of motion of a single, harmonically trapped, ion which are entangled its' spin. The other type is a multi-ion state which is a superposition of states where all of the ions' spins are pointing in the same direction. Cat states are exceptionally fragile and highly susceptible to decoherence. We will discuss decoherence and disentanglement of cat states, and will primarily focus on decoherence which occurs due to spontaneous scattering of photons.

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QUANTUM CHAOS, RESONANCES AND ATOM OPTICS: FROM EXPERIMENT TO NUMBER THEORY

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Quantum Mechanics is essential for the description of the dynamics of laser cooled atoms. The most well known phenomenon that was observed so far in this field is Bose-Einstein Condensation (BEC), but also other impressive effects were found, such as Anderson localization in momentum space (suppression of heating by interference) and Quantum Accelerator Modes (laser induced coherent enhancement or suppression of acceleration). With the help of lasers various potentials for these atoms can be applied in an extremely controlled way. In particular it enables the realization of systems relevant for the field of Quantum Chaos. In this field, the quantum dynamics of systems that are chaotic in the classical limit is explored. The dynamics of such systems looks random in spite of the fact that it is generated by simple deterministic models. The Kicked Rotor is the standard model for the exploration of such systems with time dependent Hamiltonians. It was first realized for laser cooled atoms by Mark Raizen and coworkers at Austin, Texas. Since then various aspects of Quantum Chaos were studied for such systems. Resonances are among the most typical manifestations of quantum mechanical behavior and are very sensitive to values of parameters (for example in standard atomic spectroscopy).

In 1999 resonances, that are stable with respect to variation of parameters, were discovered experimentally by the Oxford group for the dynamics of laser cooled Cesium atoms when driven in he direction of gravity. A theoretical explanation of this surprising observation, based on a novel pseudo-classical limit, will be presented. The relation between quantum and classical resonances will be discussed. Theoretical predictions that were verified experimentally by several groups will be presented. In particular it is found that the experimental results depend on the number theoretical properties of the values of parameters. The theory makes use of invariance properties of the system that are similar to the ones of solids, of scaling theory as well as of the theory of dynamical systems.

EIT LINE-WIDTH: HOW LOW CAN YOU GO?

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Electromagnetically induced transparency (EIT) is a unique light-matter interaction that exhibits extremely narrow-band spectroscopic features along with low absorption. EIT occurs when an atomic ensemble is driven to a coherent superposition of its ground state sub-levels by two phase-coherent radiation fields. Recent interest in this phenomenon is driven by its possible applications in quantum information (slow light, storage of light), atomic clocks and precise magnetometers. In all the applications mentioned above the EIT line-width is a key parameter.

We discuss the physical mechanisms that determine the EIT line-width in vapor medium. These include: quantum decoherence, spatial diffusion of the atomic population, Doppler broadening, Dicke narrowing, multi-level atomic structure and more. We present experimental demonstrations of some of these mechanisms, and explore several possibilities to achieve narrow EIT lines by appropriate design.

CONFINEMENT EFFECTS ON THE STIMULATED DISSOCIATION OF MOLECULAR BOSE-EINSTEIN CONDENSATES

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We show that a molecular BEC in a trap is stabilized against stimulated dissociation if the trap size is smaller than the resonance healing length $\varsigma = \hbar(2mg)^{-1/2}n^{-1/4}$. The condensate shape determines the critical atom-molecule coupling frequency. We discuss an experiment for triggering dissociation by a sudden change of coupling or trap parameters. This effect demonstrates one of the unique collective features of 'superchemistry' in that the yield of a chemical reaction depends critically on the size and shape of the reaction vessel.