ICAP 2012

Corrections to the book of abstracts

Palaiseau, 23-27 July 2012

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Hot topics

Frequency metrology in quantum degenerate helium

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We have measured the absolute frequency of the 1557-nm doubly forbidden transition between the two metastable states of helium, $2\ ^3S_1$ (lifetime 8000 s) and $2\ ^1S_0$ (lifetime 20 ms), with 1 kHz precision [1]. With an Einstein coefficient of 10^{-7} s^{-1} this is one of weakest optical transitions ever measured. The measurement was performed in a Bose-Einstein condensate of $^4He^*$ as well as in a Degenerate Fermi Gas of $^3He^*$, trapped in a crossed dipole trap. From the isotope shift we deduced the nuclear charge radius difference between the α-particle and the helion. Our value differs by 4σ with a very recent result obtained on the $2\ ^3S \rightarrow 2\ ^3P$ transition [2].

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Mo-075 (instead of Th-073) Bose gases

Instability in the Riemann problem of the two-fluid hydrodynamic equations for Bose-Einstein condensate

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We consider the time dependent two-fluid hydrodynamic equations with one spatial coordinate x for the degenerate ideal Bose gas. The equation of state is $p = BS^{5/3}$, where p is the pressure, S is the entropy per unit volume ($B = const$). We obtain two splitting pair of equations. The second set is

$$\partial v_S/\partial t + v_S \partial v_S/\partial x = 0$$

$$\partial R/\partial t + R\partial v_S/\partial x + v_S \partial R/\partial x = 0$$

where v_S is the superfluid velocity, $R = \rho - AS$, ρ is the density ($A = const$). The Riemann problems with the initial values $\rho(0,x) = \rho_0$, $S(0,x) = S_0$ ($\rho_0, S_0 - const$) and $v_S(0,x) = v_1(x < 0)$, $v_S(0,x) = v_2(x > 0)$,$v_1 > v_2$ lead to an unstable solution where the density becomes unbounded by analogy to [1, 2, 3]. Although equation of two-component hydrodynamic is not applicable to ideal degenerated Bose gas, obtained solutions may be treated as limit ones for non-ideal gas.

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Mo-109bis Bose gases

Contact Measurements on Atomic BEC

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For ultracold fermions, a powerful set of universal relations, centered on a quantity called the contact, connects the strength of short-range two-body correlations to the thermodynamics of a many-body system with zero-range interactions [1]. When extended to bosons, the contact can be used to study issues such as three-body interactions and decreased stability of BECs that arise as repulsive interactions are increased [2]. We present measurements of the contact for an ^{85}Rb atomic Bose-Einstein condensate (BEC) near a Feshbach resonance using RF spectroscopy. At large interaction strengths we were able to set a limiting value for the three-body contribution to the contact.

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Complete Reconstruction of the Sidebands Modes of Intense Optical Fields

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Homodyne detection has been in the heart of many measurements of continuous variables in quantum optics. While this technique can be used to obtain a complete reconstruction of the state at a given frequency, there is the challenge of overcoming classical noises at low frequencies. This is the reason why entanglement or squeezing measurements uses the demodulation with an electronic reference at radio frenquency. The resulting measurement corresponds to the beatnote of the optical sidebands with the central carrier and is a mixture of the information present in both sidebands. Although widely used by the community, this measurement is not complete, unless symmetries between the sidebands modes are assumed. A way to completely recover the quantum state of the sidebands involves measuring the light reflected by an empty optical cavity. In this case, the phase of each sideband mode and of the carrier are shifted independently, enabling access to the modes of the sidebands. We applied this technique to reconstruct the state coming from an optical parametric oscillator (OPO) operating above threshold. We perform the measurement of the pair of sidebands of each mode (pump, signal and idler), recovering the covariance matrix of the sideband modes at the detected frequency.

Interaction between cold atoms and carbon nano tubes

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We perform a theoretical study of cold atoms interacting with static and vibrating carbon nanotubes. We construct the full finite temperature Casimir-Polder interaction and explore the scattering of atoms on the tube. We find that elastic quantum reflection can typically be ignored for thermal atom clouds but is important if a Bose-Einstein condensate is used. Atom loss from the condensate is shown to be highly non-trivial, but provided atomic interaction effects and quantum pressure are included in the description , our simulations describe experiments [1] well. Finally, we study a vibrating nanotube in a condensate and show that vibration frequencies typical to nanoscaled objects do not significantly reduce the condensate's coherence, but certain low frequency oscillations dramatically heat the cloud.

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Progress towards MOTs of Yb and CaF, loaded from a slow buffer-gas beam

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The high brightness, low forward velocity, and versatility of slow buffer-gas beams could allow direct loading of MOTs. Using a structured nozzle, we have developed a very slow cryogenic beam source of atoms and molecules, with velocities in the range for MOT capture [1]. We have demonstrated this beam source for atomic Yb, creating a beam of adjustable pulse length (up to 15 ms) and consisting of approximately 10^9 ground state atoms moving with a narrow forward velocity distribution peaked at 70 m/s, with a width of $\sim$ 35 m/s , as measured at 0.4 m from the source (10^{13} atoms/sr/pulse). We will describe progress toward directly loading a MOT of Yb atoms on the ${}^1S_0 \rightarrow {}^1P_1$ line. We also propose a scheme for the laser cooling and confinement of CaF molecules, following a similar approach used in the cooling of SrF [2].

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Threshold resonances in ultracold chemical reactions

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We extend our previous work on ultracold reactive scattering of D + H_2 [1] to study the role of resonances on cross sections and rate coefficients, by scaling the mass of the system. We analyze the effects of near threshold resonances on the low energy behavior of cross sections for reactive scattering systems with reaction a barrier (*e.g.* Cl + H_2, D + H_2). We find an anomalous behavior when a resonance pole is very close to the threshold of the entrance channel. For inelastic processes, including reactive ones, the anomalous energy dependence of the cross sections is given by $\sigma \sim E^{-3/2}$. However, at vanishingly low energies, the standard Wigner's threshold behavior ($\sigma \sim E^{-1/2}$) is eventually recovered, but limited to a much narrower range of energies. When the cross sections are averaged to obtain rate coefficients, the anomalous behavior persists; indeed, we find an intermediate regime of ultralow temperatures, where the inelastic rate coefficients behave as $K \sim 1/T$, before recovering the Wigner regime's constant rate.

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Laser cooling of Iron atoms

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We report on the first laser cooling of Iron atoms. Our laser cooling setup makes use of 2 UV laser radiation sent colinearly in a 0.8 m Zeeman slower. One laser is meant for optical pumping of the Iron atoms from the ground state to the lowest energy metastable state. The second laser cools down the atoms using a quasi-perfect closed transition from the optical pumped metastable state. The velocity distribution at the exit of the Zeeman slower is obtained from a probe laser crossing the atom beam at an angle of 50 degrees. The fluorescence light is detected using a photomultiplier tube coupled with a boxcar analyzer. The Iron atom beam is produced with a commercial effusion cell working at around 1950 K. Our laser radiations are stabilized using standard saturated-absorption signals in both an Iron hollow cathode absorption cell and an Iodine cell. We will present our experimental setup, as well as the first evidences of cooled down Iron atoms at the exit of the Zeeman slower.

Magic Wavelength for A Few States of Interest of ^{87}Sr

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A few experiments were planned to be done using the tripod scheme of ^{87}Sr atoms in the states $5s^2\ ^1S_0 F = 9/2 m_F = 5/2, 7/2, 9/2$ and $5s5p\ ^3P_1 F = 7/2 m_F = 7/2$. In order to estimate the optimal optical dipole trap laser frequency, the lightshift of these states was calculated using time-dependent perturbation method so as to find the “magic wavelength” [1] For comparison and checking of the above result, the same calculation was also performed using a different formulation developed by V. Ovsiannikov et al. [2]. A slight difference in the “magic wavelength” was found between the two methods.

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Coherent backscattering of a dilute Bose-Einstein condensate

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We study both experimentally and numerically the quasi-bidimensional transport of a ^{87}Rb Bose-Einstein condensate launched with a wave vector k_0 inside an optical disordered potential generated by a laser speckle pattern. A time-of-flight analysis reveals a pronounced enhanced density peak in the backscattering direction $-k_0$. Numerical simulations indicate that in addition to the coherent backscattering (CBS) effect, a "backscattering echo" effect is present due to the high position-momentum correlations of the initial wave packet. A radial integration of the atomic distributions after a finite time of flight allows to recover the CBS peak[1].

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A diffusion Monte Carlo study of spin polarized fermionic systems

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We perform a quantum Monte Carlo simulation (based on Generalized Feynman-Kac path integral method) for the two component unitary Fermi gas confined in a three dimensional harmonic potential. The calculation of the energies of a spin polarized Fermi gas at unitarity has been motivated by the experimental effort at MIT and RICE University on the fate of a BCS state for a spin imbalanced Fermi system. Even though both groups found phase separation and no sign of FFLO, they differed for the other outcomes. For example the critical polarization is vastly different for them. MIT group found a third partially polarized phase in addition to a superfluid phase and a normal phase which is absent in the case of Rice experiment. In our work the ground state energy has been calculated for a small system of atoms interacting with an attractive potential. At this point our energies are in excellent agreement with the previous calculations. We believe that our path integral method will also help in exploring the bulk behavior of such fermionic system as a function of number of atoms and provide a benchmark for other theoretical methods.

Single atom lensing

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Singly trapped ions can be utilised to explore the intriguing world of quantum optics. In particular, fundamental optical devices such as a mirror [1] or a lens can be demonstrated by atom-light interactions. We have observed the first lensing of light by a single atom. We employ a three dimensional RF Paul trap to laser cool a $^{174}\mathrm{Yb}^{+}$ ion near the Doppler limit on the $\lambda = 369\,\mathrm{nm}$ transition. The ion is imaged at wavelength scale resolution [2] with a large aperture phase Fresnel lens (NA=0.64). The shadow of the ion is recorded and changes to the wavefront of the illumination light field are measured from background-subtracted images. The refractive index of the single atom was changed as the laser detuning of the cooling transition was varied and images were taken at different defocusings. The wavefront was observed to converge for negative laser detunings (positive focal lengths), diverge for positive detunings (negative focal lengths), and agrees with an analytic microscope model of a dipole radiator. We find the effective focal length to be on the order of several lambda near resonance.

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Attosecond measurements of photoemission time delays

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The development of ultrashort light pulses in the attosecond range allows scientists to tackle temporal aspects of electron transitions in atoms, molecules and more complex systems. In this work, we present experimental measurements and theoretical calculations of photoemission time delays difference between the 3s and 3p shells in Argon as well as between Argon and other valence shells from noble gases (Krypton, Neon, Xenon). The experimental measurements are performed by interferometry (RABITT technique) using attosecond pulse trains and the infrared laser used for their generation. The measured delays span between 10 and 100 attosecond depending on the gas and the electron energy. The theoretical approach includes intershell correlation effects between the valence (shell) and the inner shells within the framework of the random phase approximation with exchange (RPAE).

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