Atom interferometry with hot and cold atoms: our projects in Toulouse

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We are presently building two experimental setups in Toulouse to study atom interferometry and nanolithography using radiative forces. One setup works with lithium atoms and the other one with cesium atoms. We will describe the present status of our projects.

Interferometry with hot lithium atoms:

We have made the choice of using hot lithium atoms (i.e. a thermal supersonic beam of lithium seeded in argon, with a velocity close to 1000 m/s) to build an atom interferometer. This interferometer is a 3-grating Mach-Zehnder interferometer, similar in its design to the one of Pritchard and coworkers working with sodium [1]. The choice of lithium is very favorable because of its lighter mass and of the possibility of using diode lasers and amplifiers. The gratings are laser standing waves in the Bragg diffraction regime. Bragg diffraction was used by Lee and coworkers in their atom interferometer operating with metastable neon atoms [2]. The main point in using this diffraction regime for an interferometer is that one can optimize the diffraction efficiency simply by tuning the laser power, thus creating either a mirror or a beam splitter. Our experimental setup is presently under test. We will also discuss some of the possible applications of this apparatus. Our initial interest is the measurement of the index of refraction and birefringence of gases for atomic waves, as measured by Pritchard and coworkers for sodium waves. Several other experiments are possible (Sagnac effect and measurement of absolute rotations, measurement of the static polarizability of lithium,...), as already done by other groups with their interferometers. Additionally, we have recently studied the possibility of using atom interferometry to test neutrality of atoms. In addition to conceptual advantages, our calculations show the extreme sensitivity of this technique, which should surpass the present experimental limits of sensitivity provided that we use a slow atomic beam.

Nanostructures:

We are presently building a bright, intense Cs beam to write directly photoelectron-emitting nanostructures on Sb and GaAs substrates. Light masks from optical standing waves spatially segregate beams of atoms into regularly spaced arrays whose feature size is on the order of tens of nanometers and whose characteristic repeat distance is a fraction of the wavelength of the standing wave. Atomic-beam, direct-write deposit of lines, dots and hexagons have been demonstrated for sodium, chromium and aluminium by research groups in the US and in Europe [3]. Our contribution will be to write active arrays of Cs/Sb and Cs/GaAs nanophotocathode lines and dots that will self-image by photoelectron emission. We will observe the dynamical behaviour of these structures in real time by using photoelectron emission spectroscopy (PEEM).

In parallel we are investigating the use of high-index dielectric and metal nanostructures to confine evanescent wave light fields into subwavelength spatial regions on a substrate [4]. The idea here is to generate optical gradient forces near the substrate surface that will be greatly amplified over the forces derived from conventional standing waves. These amplified gradients in turn will be used to modulate cold atom beam deflection with the goal of writing arbitrary figures onto a surface without being limited to interferometric figures. Furthermore, periodic optical potentials generated from high-index nanostructure arrays with feature size of the order of the deBroglie wavelength of the cold atoms and repeat distances of the order of 100 nanometers can be used to diffract coherently matter waves at wide angle. We are investigating the possibility of using such periodic optical potentials to construct a wide-angle reflection interferometer for a flux of cold Cs atoms. Such an instrument opens the door to advances in precision inertial measurements and matter-wave holography. We are presently carrying out calculations of the optical fields and simulations of atom trajectories to determine the most promising design.

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[2] D. Giltner, R. McGowan and S. A. Lee, Phys. Rev. A **52**, 3966 (1995).
[3] W. R. Anderson, C. C. Bradley, J. J. McClelland and R. J. Celotta, Phys. Rev. A **59**, 2476 (1999) and references cited therein.
[4] C. Girard, C. Joachim and S. Gauthier, "The physics of the near field", Rep. Prog. Phys. (scheduled for June 2000).