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Ultracold atoms - Methods, problems and perspectives

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By using quasi-resonant exchanges of energy, linear and angular momentum between atoms and photons, it is possible to polarize atoms, to displace their energy levels and to control their position and their velocity. A few physical mechanisms allowing one to trap atoms and to cool them in the microkelvin, and even in the nanokelvin range, are briefly reviewed. Special attention is given to subrecoil cooling where the momentum spread of the atoms is reduced to values smaller than the momentum of the photons used to cool the atoms. It is pointed out that all subrecoil cooling schemes are based on an anomalous random walk of the atom in momentum space, which does not obey the central limit theorem and which introduces a fundamental non ergodicity in the cooling process. Lévy statistics are very useful for analyzing the long time limit of the momentum distribution. Recent experiments using ultracold atoms with very long spatial coherence lengths are also presented.

The second part of the lecture is devoted to a review of a few applications of ultracold atoms. These applications take advantage of the long interaction times and large atomic de Broglie wavelengths which can now be achieved with laser cooling and trapping techniques. A few recent experiments are described, including atomic clocks using fountains of Cesium atoms, Young fringes obtained with metastable neon atoms and Bose-Einstein condensation with ultracold atomic gases.

References to recent review papers

[1] - C. S. Adams and E. Riis, Prog. Quant. Electr. 21, 1 (1997).

[2] - Nobel Lectures of S. Chu, C. Cohen-Tannoudji and W. Phillips, in Rev. Mod. Phys. 70, 685-741 (1998)

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