Determination of the fine structure constant with atom interferometry and Bloch oscillations

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The fine structure constant α sets the scale of the electromagnetic interaction so it can be determined in different domains of physics. As α is dimensionless, it does not depend on any unit system. Hence this allows the comparison of various accurate determinations which constitutes an interesting test of the consistency of physics. The most precise determination of α comes from the measurement of the electron magnetic moment anomaly a_e, but this determination is strongly dependent on QED calculations. There are many reasons to realize an other determination of α. (i) The CODATA value is determined mainly by only one value of α, this is a true weakness. (ii) The comparison of $\alpha(a_e)$ with another measurement which is weakly dependent on QED provides an accurate test of QED. (iii) Assuming QED is exact, a determination of α with the same uncertainty as $\alpha(a_e)$ gives an upper limit upon a possible internal electron structure.

We report a new measurement of the atomic recoil using atom interferometry and Bloch oscillations (BO) in a vertical accelerated optical lattice. Such a measurement yields to a determination of h/m (m is the mass of the atom) which can be used to obtain a value of the fine structure constant following the equation:

$$\alpha^2 = \frac{2R_\infty}{c}\frac{m}{m_e}\frac{h}{m} \quad (1)$$

where the Rydberg constant R_∞ and the mass ratio m/m_e are precisely known.

The principle of the experiment is to coherently transfer as many recoils as possible to the atoms (i.e. to accelerate them) and to measure the final velocity distribution. In our experiment, the atoms are efficiently accelerated by means of N Bloch oscillations. The velocity selection and velocity measurement are done with Raman transitions.

In this talk, we will present two measurements of α: a non interferometric one using two π Raman pulses[1], and an interferometric measurement with the $[\pi/2 - \pi/2]$-BO-$[\pi/2 - \pi/2]$ pulses arrangement. This last method leads to a determination of the fine structure constant α with a relative uncertainty of 5 ppb.

[1]P. Cladé, E. de Mirandes, M. Cadoret, S. Guellati-Khélifa, C. Schwob, F. Nez, L. Julien and F. Biraben, Phys. Rev. Lett. **96**, (2006) 033001; Phys. Rev. **A 102**, (2006) 052109.