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Determination of the fine structure constant from atom interferometry[1]

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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 $h/m_{\rm Rb}$ ($m_{\rm Rb}$ is the mass of Rubidium atom) which can be used to obtain a value of the fine structure constant following the equation:

$$\alpha^2 = \frac{2R_\infty}{c}\frac{m_{\rm Rb}}{m_{\rm e}}\frac{h}{m_{\rm Rb}} \tag{1}$$

where the Rydberg constant R_∞ and the mass ratio $m_{\rm Rb}/m_{\rm e}$ are precisely known. The key idea to precisely determine the recoil velocity, is to transfer to the atoms as many recoils as possible and to measure their velocity variation. For this purpose we use an atomic interferometer consisting in two pairs of $\pi/2$ pulses combined with Bloch oscillations. The first pair selects an atomic sub recoil velocity Ramsey pattern from an ultra cold Rb atoms sample. We then accelerate the atoms and give to the selected atoms up to 1000 recoils by means of Bloch oscillations. The final velocity distribution is measured by scanning the frequency of the second pair of $\pi/2$ pulses. Following this scheme, we have performed in 2010 a measurement of α with an uncertainty of 6.6×10^{-10}. Our final result is:

$$1/\alpha = 137.035\ 999\ 037(91). \tag{2}$$

Using this determination, we obtain a theoretical value of the electron anomaly $a_{\rm e} = 0.001\ 159\ 652\ 181\ 13(84)$ which is in agreement with the experimental measurement of Gabrielse ($a_{\rm e} = 0.001\ 159\ 652\ 180\ 73(28)$). The comparison of these values provides the most stringent test of the QED. Moreover, the precision is large enough to verify for the first time the muonic and hadronic contributions to this anomaly.

[1]Work completed by Rym Bouchendira, Pierre Cladé, Saïda Guellati-Khélifa, François Nez and François Biraben.