Advanced concepts in atomic clocks and atom interferomertry

A. Bertoldi, E. Cantin, R. Kohlhaas, D. Pandey, B. Barrett, L. Antoni-Micollier, P.-A. Gominet, B. Battelier, A. Landragin, and P. Bouyer

LP2N, Laboratoire de Photonique Numérique et Nanosciences, Institut d'Optique Graduate School IOA, Rue François Mitterrand, 33400, Talence, France
SYstèmes de Référence Temps-Espace, Observatoire de Paris, CNRS, UPMC et LNE, 61, avenue de l'Observatoire, F-75014 PARIS
France

The remarkable success of atom coherent manipulation techniques has motivated competitive reearch and development in precision metrology. Matter-wave inertial sensors and atom clocks based on these techniques are all at the forefront of their respective measurement classe. Atomic clocks have reached stabilities at the 10-18 level thanks to a tremendous progress in the development of ultra-stable optical local oscillators (LOs). Atom inertial sensors provide nowadays about the best accelerometers and gravimeters and allow, for instance, to make precise tests of the weak equivalence principle (WEP). We present here two recent advances in theses fields.

We first present a new method to remove the limitation in clock stability that can be set by the decoherence source represented by noise of the local oscillator. For that, we use coherence preserving measurements of the atom-LO phase, and achieve longer effective interrogation times. We implemented a non-destructive frequency modulation detection for the measurement of the number difference on the 87Rb clock transition. With this probe we could observe the real time evolution of a collective spin and correct it using feedback [1].

Secondly, we present the recent progress in compact and transportable atom interferometer designed to using two atomic species: ^{39}K and ^{87}Rb to veriy that two massive bodies will undergo the same gravitational acceleration regardless of their mass or composition. An atom-interferometric test of the WEP involves precisely measuring the relative acceleration of two different atoms. Since potassium and rubidium differ greatly in mass, but have similar internal structure, they are ideal choices for this type of test. Recently, we demonstrated the first airborne matter-wave interferometer, which operated in the micro-gravity environment created during the parabolic flights of the Novespace Zero-g aircraft [2]. The 20 seconds of 0*g* produced during each parabola allows us to extend the interrogation time and therefore the sensitivity of our interferometer. Here, we review our recent experimental results, including some of the first interferometric measurements with ^{39}K [3].

[1] T. Vanderbruggen, R. Kohlhaas, A. Bertoldi, S. Bernon, A. Aspect, A. Landragin, and P. Bouyer, Phys. Rev. Lett. 110, 210503 (2013)

[2] R. Geiger, V. Menoret, G. Stern, N. Zahzam, P. Cheinet, B. Battelier, A. Villing, F. Moron, M. Lours, Y. Bidel, A. Bresson, A. Landragin, P. Bouyer, Nature comm. **2**, 474 (2011).

[3] B. Barrett, P.-A. Gominet, E. Cantin, L. Antoni-Micollier, A. Bertoldi, B. Battelier, P. Bouyer, J. Lautier, and A. Landragin, to be published in Proceedings of the International School of Physics "Enrico Fermi" on Atom Interferometry (2014).