Macroscopic scale matter wave interferometers for exploring quantum physics

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Abstract

Seminal experiments with electrons, neutrons, atoms and now with molecules have shown that matter wave interferometers provide remarkable tools for exploring quantum physics, until then limited to thought-experiments. In Toulouse, we demonstrated atom interferometry experiments operating with a large spatial separation between the interferometer's arms. This specificity allows to shape electromagnetic and gravitational potentials, opening the way to new measurements in fundamental physics.

In a first period (1998-2014), we developed a lithium atom interferometer using a supersonic beam of lithium and Bragg diffraction on a laser standing wave at a 671 nm wavelength. We mostly used diffraction of order 1. In this Mach-Zehnder interferometer, the maximum separation of the two atomic paths was near 100 micrometers, sufficient to introduce a septum (a thin sheet of aluminized mylar or an aluminum foil) between the two atomic paths. We were thus able to apply different electric fields on the two paths or to put a small gas pressure on one atomic path. These possibilities were used for a series of experiments with metrological interest such as the measurement of the lithium electric polarizability, the index of refraction of argon, krypton and xenon for a lithium atomic wave, the atom-surface interaction. This interferometer was also used for exploring quantum curiosities such as the He-McKellar-Wilkens and Aharonov-Casher geometrical phases, or the phase modulation of lithium atomic waves.

Since 2016, we are developing a new atom interferometer using rubidium Bose-Einstein condensates manipulated with a vertical optical lattice. A very appealing solution to enlarge the arms separation is the so-called Large Momentum Transfer (LMT)-interferometer, in which the interferometer's arms separation is increased by the transfer of a large number of photons momentum () during the beam-splitting process. Various configurations for an LMT-interferometer have been demonstrated. We will present a promising technic based on a sequence of optical lattice

pulses in the quasi-Bragg diffraction regime. In particular, we will show interferometric measurements with a total momentum transfer of 200 , improving upon the previous record of 112 . This work has applications in high-precision sensing. In addition, such interferometers with macroscopic spatial separations pave the way for the new LMT-interferometers proposed in various tests of fundamental physics for example in dark matter searches, atom neutrality tests, gravitation tests.