Twin-lattice interferometry with thousands of photon recoils

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We investigate a novel interferometer scheme for infrasound gravitational wave detection with atoms. This geometry is based on recent developments in symmetric beam splitters with scalable momentum transfer, relaunching techniques for suspending the atoms against gravity, and delta-kick collimation techniques to generate very slowly expanding atomic ensembles. Today's generation of atomic inertial sensors typically operates with laser cooled atoms released or launched from an optical molasses. The finite temperature and size of these sources limit the efficiency of employed beam splitters and the analysis of systematic uncertainties. These limits can be overcome using high-flux ultracold sources such as a delta-kick collimated Bose-Einstein condensate (BEC) with an extremely narrow velocity distribution [1,2].

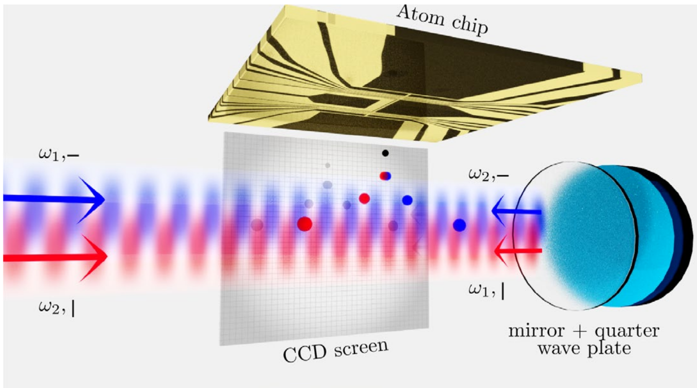

Figure 1. Scheme of the twin lattice generated by a light field of two frequency components retro-reflected of a mirror surface to drive symmetric double Bragg diffraction and Bloch oscillations.

Using condensed atoms from these sources in atom interferometry opens the possibility to implement new methods of coherent manipulation at high fidelity. With the help of Bloch oscillations in an optical lattice combined with a double Bragg diffraction pulse [3,4] we developed a novel coherent relaunch technique in a twin-lattice, a lattice of two frequencies retroreflected at a mirror (fig. 1). This technique allowed for the implementation of a relaunch technique where the atomic ensemble is coherently relaunched on a parabolic trajectory in a single laser beam [5]. Based on symmetric and scalable momentum transfer in the twin-lattice, interferometry with a momentum separation of up to 408 photon momenta is demonstrated, which is to our best knowledge the largest separation in an interferometer reported to date. Achieving these large momentum splittings is one of the cornerstones to reach the necessary sensitivities for gravitational wave detection.

[1] Hauke Müntinga et al., *Interferometry with Bose Einstein Condensates in Microgravity*, Phys. Rev. Lett. **110**, 093602, (2013).
[2] Jan Rudolph et al., *A high-flux BEC source for mobile atom interferometers*, New J. Phys. **17**, 079601, (2015).
[3] Enno Giese et al., *Double Bragg diffraction: A tool for atom optics*, Phys. Rev. A **88**, 053608, (2013).
[4] Holger Ahlers et al., *Double Bragg Interferometry*, Phys. Rev. Lett. **116**, 173601, (2016).
[5] Sven Abend et al., *Atom-Chip Fountain Gravimeter*, Phys. Rev. Lett. **117**, 203003, (2016).