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HIGH-PRECISION MEASUREMENTS WITH MATTER WAVE INTERFEROMETRY IN MICROGRAVITY - SCIENCE AND TECHNOLOGY

Abstract

Inertial sensors based on interferometry with ultra cold matter waves are a valuable tool for several physics missions. The spectrum of applications covers broad areas from metrology, through gravimetry and geodesy up to addressing fundamental questions in physics, as for instance testing the Einstein equivalence principle (EEP) in the quantum domain. The performance is mainly limited by the unperturbed evolution time of the wave packets in the interferometer. Here, microgravity conditions offer extremely long interrogation times and allow for ultra low temperatures of the quantum object, which substantially increase the sensitivity to levels not obtainable on Earth.

The successful observation of Bose-Einstein condensation in microgravity at the drop tower in Bremen (ZARM) was an important result towards realizing coherent sources for atom interferometers under extreme conditions [1]. We have now implemented an interferometer based on the coherent manipulation of a BEC with stimulated Bragg diffraction as a spitting and recombination process. In recent drop campaigns we have analyzed long-time coherence properties of the macroscopically separated wave packets in a Mach-Zehnder configuration by applying an advanced delta kick cooling method.

In addition we are working on the second generation apparatus for dual species atom interferometry with Rubidium and Potassium as degenerate Bose-Fermi mixtures in order to carry out experiments on tests of the EEP. A major experimental challenge is to design a catapult capable experimental setup, which has to withstand 30g accelerations in an operating state during the catapult launch.

Subsequently a sounding rocket mission is planned for fall 2013. In contrast to the drop capsule based apparatuses, this means even higher requirements in terms of mechanical and thermal robustness, miniaturization and redundancy. Ambitious challenges, especially in the construction of the laser systems are posed by the extreme and tough environment, putting stringent requirements on the performance of the laser sources. For that purpose, diode-laser based systems and compact subcomponents have been developed, which successfully passed mechanical stability (50g) and vibration (8gRMS) tests, which simulate mechanical loads of a sounding rocket launch.

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[1] T. van Zoest et al., Science 328 (2010)