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MATTER-WAVE INTERFEROMETRY IN MICROGRAVITY

Abstract

Ever since the first creation of a Bose-Einstein condensate (BEC) in 1995 [1] the idea of using an ultracold gas as the source of an atom interferometer (AI) has been discussed. It is especially appealing to use such a device in space-born experiments to measure gravitational effects with unprecedented precision. Several proposals to perform tests of the Weak Equivalence Principle (WEP), the equality of inertial and gravitational mass are considered. We have taken first steps towards a space-borne AI by creating a quantum degenerate atomic ensemble of 10^4 ^{87}Rb atoms in microgravity at the Drop Tower of the ZARM in Bremen [2]. We were able to observe the free expansion of the cloud over a timescale of two seconds. Moreover, we implemented an atom interferometer based on the coherent manipulation of a BEC in microgravity using Bragg diffraction on a standing light wave. In recent measurement campaigns we have characterized the coherence of the ensemble over large time spans and were able to slow the expansion of the ensemble further using the technique of delta-kick cooling [3]. Currently, we are working on the second generation of microgravity experiments, which features atomic ensembles of more than 10^5 atoms. Thanks to the enhanced density of the source, we will be able to extend the observable time by further using the catapult mode of the Drop Tower. In the near future, this experiment will also be able to perform WEP tests with two atomic species, ^{87}Rb and ^{40}K, simultaneously in microgravity. The last part of this talk will be dedicated to describe our efforts in creating the first BEC-based atom interferometer in space on board a sounding rocket mission. The experiment is based on our experiments in the drop tower and is adapted to withstand the harsh conditions of a rocket launch. A successful launch will be a major step towards the realization of atom interferometers on satellite or space station missions.

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[1] M.H. Anderson et al.,Science 269 (1995) ; K.B. Davis et al., PRL75 (1995)
[2] T. van Zoest et al.,Science 328 (2010)
[3] Müntinga et al., arXiv:1301.5883, accepted in PRL.