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An Actuated Retro-reflection Chamber for Long-Baseline Atom Interferometry

Long-baseline atom interferometers based on the ultranarrow optical clock transition of strontium are currently being developed for fundamental physics by several consortia, including the US-UK collaboration MAGIS-100 and AION in the UK. These novel quantum sensors operate at the intersection of atom interferometry and optical clocks and aim to build and operate a 100-metre baseline atom interferometer, an order of magnitude advance on the current state-of-the-art. MAGIS-100, currently under construction at Fermilab, will create macroscopic quantum superpositions on unprecedented scales, enabling searches for ultralight dark matter, tests of quantum gravity, and prototype for the detection of mid-band gravitational waves –a regime between the sensitivities of LIGO and LISA.

Such long-baseline atom interferometers require retro-reflection platforms which can control the direction of the interferometry beam to extreme precision. Here, the design and characterization of an ultra-high vacuum retro-reflecting mirror system for the active compensation of the Coriolis effect and the implementation of phase-shear readout, designed for MAGIS-100 and AION, is reported. A measurement of the pointing jitter noise of the mirror and, using a transfer function of sequential square pulses for atom-laser interactions, the projected atomic phase shift due to this systematic are presented. The measurements show that the system has an rms angular jitter of 33 nrad and a noise floor of 0.1 nrad/√Hz at 500 Hz. For an atomic fountain experiment with a large-momentum transfer of order 100-hk this corresponds interferometer noise close to the expected 1 mrad shot noise limit. Prospects for improving the system further towards km-scale and future space-based devices are discussed.

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