A large-momentum-transfer atomic mass measurement scheme in intermediate-scale atom interferometers for determining the fine-structure constant

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Interferometry of atomic de Broglie waves is a powerful technique for precision measurement. With the 2019 redefinition of the SI base units, atom interferometry experiments can measure the mass of an atom in kilograms to parts in 10^{10} [1]. Such a measurement is used to calculate the fine-structure constant and, at present, limits the precision of the result. Intermediate-scale atom interferometers (of order 10m) are under development as prototypes for very-long-baseline experiments (of order 100m-1km) aimed at gravitational-wave detection. We have devised a scheme to perform high-precision atomic mass measurements via the photon-recoil phase in these intermediate-scale atom interferometers [2]. Large momentum transfer (LMT) at different points in a standard Ramsey-Bordé sequence is used to optimise the recoil phase, which can scale quadratically with LMT order. We find that existing LMT techniques in a 10-metre instrument using the clock transition in Sr or Yb to implement our scheme are more than sufficient to improve the precision of the fine-structure constant by an order of magnitude, subject to improved relative mass measurements from Penning traps. This is important for improving the most precise test of the Standard Model of particle physics via the anomalous magnetic moment of the electron [3].

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