Transportable optical lattice clock with uncertainty below 5×10^{-18}

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After laboratory optical clocks have reached fractional frequency uncertainties in the 10^{-18} regime, it is an ongoing task to miniaturize these complex devices and to make them transportable. This effort is primarily motivated by promising prospects in geodesy. Together with accurate frequency transfer techniques, e.g. via phase-stabilized fiber links, these clocks can measure gravitational potential differences in the 0.1 m^2/s^2 regime (corresponding to *cm* height differences on Earth's surface)[1]. Thus, they could help to establish an accurate height reference system. Additionally, transportable clocks are indispensable devices for inter-institute clock comparisons in absence of long-distance fiber links, paving the way towards the redefinition of the SI-second.

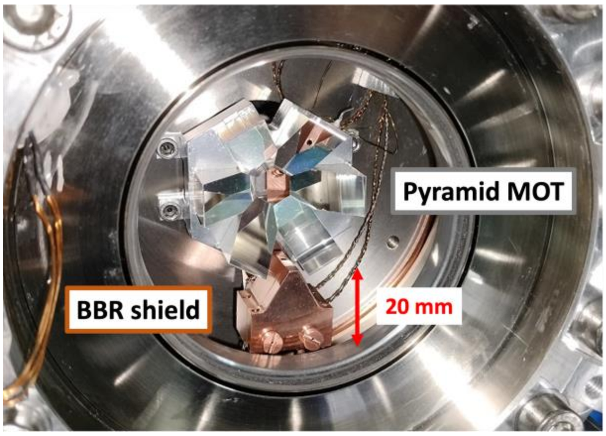

Fig. 1: The pyramid MOT mirrors and the BBR shield.

Here we present the development and evaluation of our second-generation transportable clock. For robust cooling and trapping of ^{87}Sr atoms, a single-beam pyramid magneto-optical trap (MOT) is used (Fig. 1). The laser-cooled cloud of atoms is transferred into an optical lattice generated by two counter-propagating laser beams. Frequency chirps on one of the beams are used to move the atoms into a blackbody radiation (BBR) shield[2] for clock interrogation and back to the trapping region for state readout. The shield, operating at ~223 K, allows us to achieve a fractional BBR shift uncertainty below 1×10^{-18}. Other features of the system include a ≥15 s vacuum-limited lifetime for a reduced background gas collision shift and a mu-metal shield for a stable magnetic field environment. To achieve a higher clock stability, the setup is equipped with a frequency-doubled, transportable clock laser based on a 20 cm long, ultra-stable resonator with crystalline AlGaAs mirror coatings[3]. The laser system enables the clock to have an instability below $5 \times 10^{-16}\ \tau(s)^{-1/2}$. With the above-mentioned upgrades and by a careful characterization of various perturbations, we reach a total systematic uncertainty below 5×10^{-18}.

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