Modern methods in the transportable Yb ultracold atoms optical clocks development

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Transportable optical clocks (TOC) development is an important step to redefine the second through a quantum transition in the optical range[1]. TOCs can be used as an intermediate unit between the remote optical clocks. The main technical difficulty in developing TOCs is to keep size, weight and power consumption (SWaP) for the physical package at the low level achieving system frequency uncertainty $<1\cdot10^{-17}$.

In our work we study ^{171}Yb optical clock optimization ways. To achieve low-SWaP TOC with frequency uncertainty $<1\cdot10^{-17}$ we locate the magnetic coils at the minimal distance to the ultracold atoms and control the BBR shift uncertainty by set of platinum sensors. The preliminary study shows that at our configuration the robust first stage magneto-optical trap (MOT) is achieved down to magnetic field gradient of 26 Gs/cm which corresponds 9 W of power consumption. A special black coating inside of the science chamber eliminates radiation reflections and increases the optical clock transition spectroscopy signal-to-noise ratio and at the-end should improve the optical clocks frequency stability.

We abandon the Zeeman slow beam and magnetic section and the speed of loading atoms into the first-stage MOT decrease we compensated by the cooling beams alignment and radius size optimization. In this configuration we obtained $\sim3\cdot10^{6}$ ^{171}Yb atoms[2] in the first-stage MOT, which is sufficient for further cooling and capture Yb atoms into the optical lattice.

The diode-based laser system is used to form optical lattice. An intra-chamber cavity increases the radiation intensity by factor of ~20 and the confining potential depth. To stabilize the lattice laser frequency to the "magic" wavelength value, a compact frequency stabilization system (CFSU) with 20,000 finesse ULE cavities is used. The stabilized laser frequency is shifted by less than 100 kHz when the CFSU is tilted by 20° along any axis. This leads to a "clock" frequency shift $\sim7\cdot10^{-18}$ with beam waist 90 μm and lattice laser optical power 1.5 W.

A microcontroller-based compact control system (MCCS) is under final stage development. The MCCS already successfully tested on stationary ^{87}Sr optical clocks. For example, the measured second-stage MOT temperature is 12 μK under MCCS hardware and software control, which is typical for this setup.

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[2] A. P. Vyalykh et al. "Atomic chip and diffraction grating for laser cooling of Yb atoms", to be published, JETP letters 2024