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An optical second with strontium optical lattice clocks

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1 Introduction

Optical lattice clocks have now become the best frequency standards, by combining a high quality factor and a large number of interrogated ultra-cold atoms, tightly confined in an optical lattice. Their fast progress makes a re-definition of the SI second using these clocks a possibility within the next decade, as well as numerous applications in fundamental physics and Earth science.

2 Applications of optical lattice clocks to the SI second

Two optical lattice clocks using Sr atoms have been implemented at LNE-SYRTE. They feature a fractional frequency instability of 10^{-15} at 1 s, and a systematic uncertainty of 4×10^{-17}. These optical clocks have been developed with the objective to demonstrate that a complete architecture based on optical clocks can be realized, by implementing three operational components:

- A set of local clock comparisons firmly establishing the accuracy of these clocks. For this, a repeated agreement in the 10^{-17} uncertainty range has been demonstrated between the two Sr clocks. Local frequency comparisons with Cs and Rb microwave clocks, as well as with a Hg optical lattice clock, both in the low 10^{16} accuracy are shown to be reproducible, and are confirmed by independent international measurements.
- All optical international clock comparisons using phase-compensated optical fiber links. These comparisons show the reproducibility of optical lattice clocks, and that their signals can be compared beyond the current accuracy of the SI second. In addition, they enable new tests of fundamental physics by searching temporal signatures in the frequency difference between remote clocks.
- The quasi-continuous operation of two optical clocks during repeated period of several weeks. During these measurement campaigns, the comparison between the Sr clocks and an H-maser linked to TAI led to a first calibration of TAI with optical clocks.

3 Novel detection scheme for an improved stability

The instability of optical clocks is currently limited by the frequency noise of the interrogation laser. We propose the experimental demonstration of a novel detection scheme for optical lattice clocks, based on the cavity-enhanced measurement of the dispersion properties of the atoms. This detection scheme has a sensitivity of a few atoms, and can be used to reduce the loading time in optical lattice clocks in order to reduce the sampling effect, and thus to improve the frequency stability. In addition, this detection scheme promises to reach the quantum regime in which quantum correlations between atoms can be exploited to overcome the quantum projection noise.

References

[1] J. Lodewyck *et al.*, "Optical to microwave clock frequency ratios with a nearly continuous strontium optical lattice clock," *Metrologia*, **53**, 2013, pp. 1123, doi:10.1088/0026-1394/53/4/1123.

[2] C. Lisdat *et al.*, "A clock network for geodesy and fundamental science," *Nature Communications*, **7**, 2016, 12443, doi:10.1038/ncomms12443.

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