Contribution ID: **27** Type: **Poster**

Towards a network of 43Ca+ optical clocks for entanglement-enhanced metrology

Monday 8 July 2024 16:40 (2 minutes)

Over the past few decades, advancements in optical atomic clocks have made it possible to measure time and frequency with unprecedented stability and systematic uncertainty [1,2]. Precision frequency comparisons between macroscopically separated clocks have applications in geodesy [3], probing variations in fundamental constants, and in dark matter searches [4].

Until now, most previous frequency comparisons between different clocks have been done on independent systems, which are limited by the standard quantum limit (SQL). In contrast, a set of entangled atomic clocks can surpass the SQL to reach the Heisenberg limit – the ultimate precision limit in quantum theory – wherein a system of N entangled clocks sees an improvement of $\sqrt{N}$ in its stability.

We previously demonstrated this enhancement in a network of two ^{88}Sr^{+} clocks [5] on the 674 nm $5S_{1/2} \leftrightarrow 4D_{5/2}$ quadrupole transition using Ramsey spectroscopy, reaching a fractional frequency uncertainty of 10^{-15}, mainly limited by the short probe duration of 20 ms due magnetic field fluctuations. To reach lower uncertainties, we are setting up the next generation of the experiment wherein we map the remote Sr-Sr entanglement onto two ^{43}Ca^{+} ions. The 729 nm ^{43}Ca^{+}
$lvert 4S_{1/2}, F=4, m_F=4\rangle \leftrightarrow$
$lvert 3D_{5/2}, F=4, m_F=3\rangle$ optical clock transition is field-insensitive at 4.96 G, enabling probe durations of over 500 ms, which is comparable to the start-of-the-art clocks [1]. This improves the fractional frequency uncertainty on each measurement and thus yields a lower overall instabililty.

We will present progress towards these clock experiments, including the setup of a 729 nm laser system locked to a high finesse cavity, as well as fibre noise cancellation on 20 m of fibre length.

References

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Session Classification: Poster session

Track Classification: Atomic Clocks