Development of Stationary Strontium Optical Lattice Clock at University of Birmingham

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We present our work towards realising a stationary strontium optical lattice clock [1]. Originally constructed to benchmark the transportable strontium optical lattice clock being built in our lab, it is now being developed into a fully-fledged frequency standard. When operational, the clock will serve as an ultra-low phase noise oscillator for our quantum-enabled radar testbed [2]. As of writing, we have successfully confined strontium (Sr) atoms into an optical lattice with a lifetime of 4.45 s and are gearing towards Rabi spectroscopy of the 698nm $^1\boldsymbol{S}_0 - {}^3\boldsymbol{P}_0$ clock transition. The ultra-stable laser used for clock spectroscopy is stabilised to a 10cm ULE cavity, which has a measured modified Allan deviation, mod $\sigma_y = \sim 2.5 \times 10^{-15}$ at averaging times between 1 to 8 seconds and a linewidth of 1 Hz.

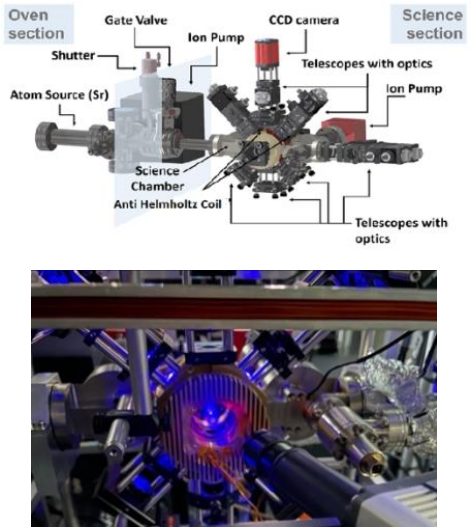

Fig.1: (Top) Schematic of the physics package. (Bottom) First stage cooling within the physics package. Here, we employ a standard six-beam MOT to cool the Sr atoms down to ~2 mK via first-stage cooling at 461 nm. To cool the atoms further, we employ a second stage cooling at 689 nm, which has a much narrower natural linewidth of 7.5 kHz. Cooling the atoms down to ~2 μK, which are then loaded into a 1D optical lattice (detailed more in Fig.2).

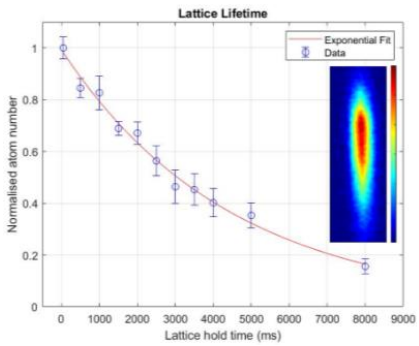

Fig.2: Here we load atoms in 1-D optical lattice for ^{88}Sr with a trap depth of 78 µK for a 30 µm lattice beam waist. The optimized lifetime of atoms trapped in the optical lattice is ~ 4.45 s.

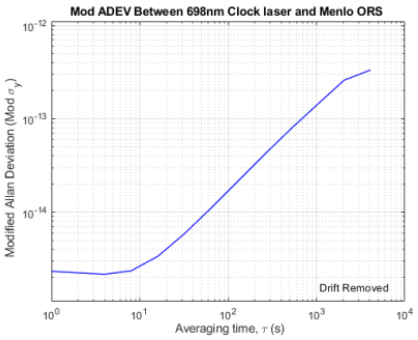

Fig.3: Modified Allan deviation of the clock laser vs Menlo-NPL cubic cavity with 0.5 Hz/s drift removed and τ = 1 s.

[1] M. Gellesch *et al.*, "An Optical Lattice Clock Testbed System for the iqClock Project Demonstrator," *2020 Joint Conference of the IEEE International Frequency Control Symposium and International Symposium on Applications of Ferroelectrics (IFCS-ISAF)*, 2020, pp. 1-2, doi: 10.1109/IFCS-ISAF41089.2020.9234854.

[2] *Griffiths, D. et al. (2023) 'Fully Digital, urban networked staring radar: Simulation and experimentation', IET Radar, Sonar & Navigation [Preprint]. doi:10.1049/rsn2.12499.*