Optical clocks for the redefinition of the second

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Summary:

This is an experimental project, working with the UK's best atomic clocks at the National Physical Laboratory (NPL). The aim is to develop optical clocks that can achieve fractional frequency uncertainties as low as 1 part in 10^{18} and compare these clocks with others across Europe via optical fibre links, and across the globe via the Atomic Clock Ensemble in Space. These international comparisons are an essential step before an expected redefinition of the second based on an optical atomic frequency.

Experimental techniques will involve working with trapped atoms or ions, ultra-stable lasers, quantum state manipulation, and the evaluation of frequency shifts experienced by the atoms within their environment.

More details:

At NPL, we are developing optical clocks with atoms trapped in optical lattices and also using ions held in rf traps. In both cases, the clocks are based on measuring the frequency of an optical transition between two internal energy levels within the atoms. With careful evaluation of the possible sources of frequency shift, an accurate realisation of the unperturbed atomic frequency can be obtained, and oscillations at this frequency constitute the 'tick' of the clock.

Optical clocks have already demonstrated that they can realise frequencies with fractional uncertainties at least an order of magnitude better than the caesium primary standards. An optical redefinition of the second is therefore anticipated, but first it must be shown that the frequencies derived from optical clocks in different institutions (and countries) all agree. These comparisons must be carried out at the highest levels of accuracy, and the performance of individual optical clocks should be pushed to their limits.

The ability to measure frequencies with such high accuracy also opens up possibilities to test fundamental physics at unprecedented levels. Measurements within our group over the last few years have revealed new constraints on levels of violation of Lorentz invariance and also time-variation of fundamental constants, demonstrating the broad range of applications for optical clocks.

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