# Exploiting highly accurate frequency ratio measurements over coherent fiber links for exploring fundamental physics problems

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Frequency ratio measurements are key to improving the accuracy of optical frequency spectroscopy of nearly forbidden atomic transitions. These are transitions with sub-Hz linewidths ($Q \sim 10^{16}$) and the accuracy and uncertainty of these frequency measurements can be independently verified by comparison to each other. Frequency ratios can also be used to search for variations in fundamental constants, specifically the fine structure constant, $\alpha$, and the proton/electron ratio [1]. Additionally, highly accurate frequency sources are beginning to be utilised in geodesy, where currently achievable spectroscopy of an atomic optical transition frequency down to a fractional uncertainty of $10^{-17}$ can be used to determine the height of the atomic frequency source above the geoid down to a resolution of 10 cm [2].

Atomic transitions are sensitive to environmental factors. Due to this sensitivity, it follows that utilising the least sensitive atomic species would be ideal. Hg was partially chosen as an atomic species for use in a clock at SYRTE due to its low sensitivity to blackbody radiation induced Stark shift and DC Stark shift. However, it is predicted that the role of non-linear lattice light shift is quite significant [3]. Strong control or good characterisation of external B- and E- fields are required to minimise the effects of Zeeman and Stark shifting when measuring a transition frequency. The SYRTE Hg clock is in a unique position of being able to access Sr clock frequency in-house, and Sr and Yb+ [5, 6] frequencies at PTB via utilising a phase compensated optical fiber network [5]. We will present improvements to the characterisation of systematic sources of inaccuracy and instability of the Hg optical lattice clock at SYRTE, including characterisation of lattice light shift by exploiting the Sr and Yb+ frequencies as accurate references. The Hg/Yb+ ratio is expected to be highly sensitive to variations in $\alpha$, further incentivising the choice. Ultimately we reach a measurement of the $^{199}$Hg $^1S_0 \rightarrow {}^3P_0$ transition to a fractional uncertainty of the order of $10^{-17}$. To support this, we will describe an improved uncertainty budget.

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