Light shift mitigation in a rubidium two-photon optical frequency standard using a 1556.2 nm wavelength beam

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The rubidium two-photon atomic clock offers a remarkable balance of compactness, reliability and frequency stability by combining hot atomic vapor cell technology with Doppler-free interrogation of an optical transition. However, the AC Stark or light shift effect often limits the long-term stability since interrogation laser power instabilities directly translate into clock frequency stabilities.

While the most straightforward attempt to increase frequency stability is to reduce laser power drifts and fluctuations, a handful of approaches have emerged which target mitigation of the light shift as such. Namely, two-color excitation as well as error signal processing schemes based either on power modulation or on dual interrogation have been explored.

Here, we report on the experimental demonstration of light shift mitigation in a rubidium two-photon frequency standard through the addition of a 1556.2 nm wavelength beam. The latter is colinear with the 778.1 nm wavelength interrogation beam but is not involved in the excitation of the 5S-5D two-photon transition. Since those two wavelengths exhibit opposite sign light shift coefficients, their combination allows to cancel the net light shift effect.

In our system, both beams are derived from the same oscillator, namely by frequency-doubling a portion of light emitted from a 1556.2 nm external cavity laser. Many recent realizations of two-photon frequency standards and clocks rely on a 1556.2 nm laser source together with second harmonic generation (SHG). Opting for that wavelength thus keeps the system's complexity increase at a minimum. Furthermore, potential frequency drifts resulting in light shift coefficient changes are avoided since the 1556.2 nm wavelength is linked via SHG to the frequency-locked 778.1 nm.

Our measurements of the light shift coefficients of both wavelengths agree well with theoretical predictions[1]. By adjusting the beam intensities to the appropriate ratio, we cancel the light shift (see Figure 1). This is tested by deliberately introducing large power steps that would otherwise result in frequency shifts of several hundreds of Hz. However, with the appropriate power ratio, the measured frequency changes are drastically reduced. In particular, we achieve a reduction of frequency sensitivity to overall power changes larger than 10 dB. The presented results prepare the ground for long-term stability improvements with the goal of reaching fractional frequency instability below 10^{-15}.

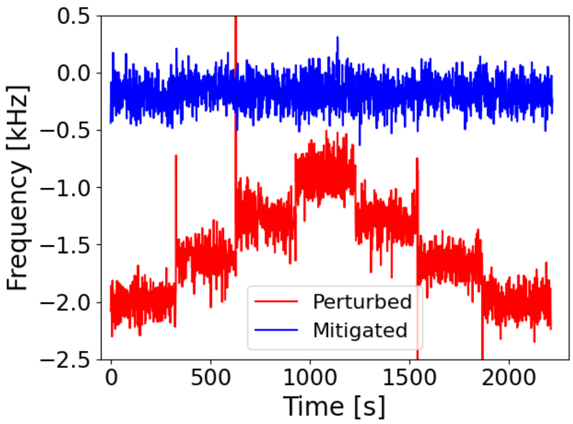

Figure 1: Measured optical frequency (arbitrary offset) when the total optical power is varied stepwise: (red) without and (blue) with 1556.2 nm wavelength mitigation laser.

[1]K. W. Martin et al., 'Frequency shifts due to Stark effects on a rubidium two-photon transition', Phys. Rev. A, vol. 100, no. 2, p. 023417, 2019.