Laser frequency stabilization using light-shift in vapor-cell clocks

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We introduce the Light-Shift Laser-Lock (LSLL) technique, a novel method for laser-pumped atomic clocks to stabilize the pumping-laser frequency to the same atomic sample used in the clock operation. The method exploits the light shift induced on the clock transition as a frequency discriminator, eliminating the need for an external reference [1].

One of the key features of the LSLL technique is real-time digital processing of the atomic signal necessary to extract clock and laser-frequency information from the atomic signal. We tested the method using a pulsed-optically-pumped (POP) Rb clock developed at INRIM [2]. The results have shown that the LSLL technique operates robustly, having a capture range of gigahertz without significantly compromising clock stability [2]. In our tests, the clock exhibited a white frequency noise of $3.2\times10^{-13}\ \tau^{-1/2}$ for averaging time up to 4000 s, reaching a floor below 1×10^{-14} up to 100 000 s (drift removed) [3]. These performance levels meet the requirements of next-generation Global Navigation Satellite Systems on-board clocks, and offer the added benefit of a reduced number of laser-system components, as well as increased reliability and robustness.

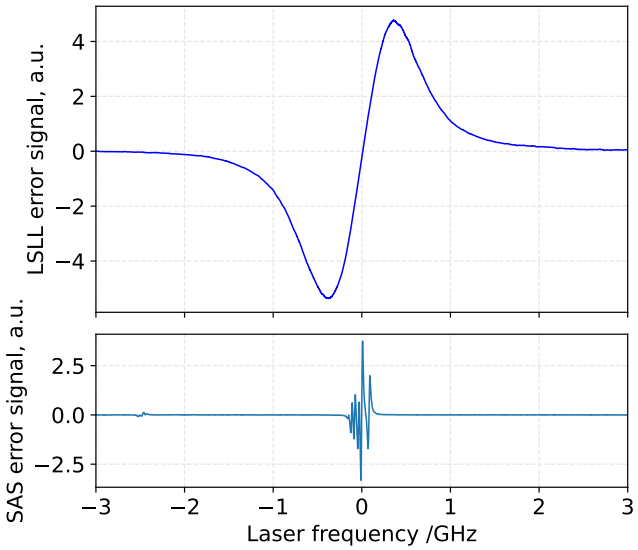

Figure 1. Upper Plot: Error signal generated with the LSLL technique on the clock vapor cell (25 Torr of buffer gas); Lower plot: spectroscopy signal obtained in a conventional saturated absorption setup (SAS) on an external cell filled with Rb (no buffer gas), for comparison.

[1] B.S. Mathur, H. Tang, and W. Happer. "Light shifts in the alkali atoms", Physical Review vol. 171, p. 11, 1968.
[2] M. Gozzelino et al., "Realization of a pulsed optically pumped Rb clock with a frequency stability below 10-15", Scientific Reports, vol 13, p. 12974, 2023.
[3] C.E. Calosso et al., arXiv:2404.14105