LaLI-POP Progress: A Bridge Technology Between Lamp-Pumped and Laser-Pumped Clocks

Micheal Huang and James Camparo

Physical Sciences Laboratories/The Aerospace Corp., El Segundo, CA/USA

Email: james.c.camparo@aero.org

Arguably, the Rb atomic frequency standard (RAFS) is the workhorse of precise timekeeping in space. However, today's RAFS has two deficiencies: its short-term stability is limited by weak optical pumping and its long-term stability can be limited by light-shift induced frequency jumps. In both cases the problem traces to the RAFS's rf-discharge lamp. Though lamp replacement by a pulsed diode laser eliminates the problems, use of lasers in RAFS presents space-systems engineers with a dilemma: trading improved clock performance against *potentially* shortened lifetime.

Here, we discuss progress developing the Lamp and Laser Integrated Pulsed Optically Pumped clock (LaLI-POP), which is a "bridge technology" that can solve the system engineer's dilemma. At one level, LaLI-POP is similar to a lamp-pumped RAFS: a discharge lamp operates cw with cw-microwaves driving the atom's hyperfine transition. The lamp, however, is operated at low brightness (*i.e.*, small light shift), since it only monitors the atoms' microwave absorption. A pulsed diode laser optically pumps the atoms, and the clock signal is generated using a gated photodetector when the laser is off. For the systems engineer the advantage of LaLI-POP lies in its dual modes of operation: in LaLI-POP mode the pulsed laser pumping yields large signal-to-noise ratios and small light shifts (due to gated detection), in case of laser failure the clock can revert to standard RAFS mode by simply increasing the lamp brightness and disabling gated detection.

In this presentation, we provide a progress report on our laboratory's development of a phase-1 LaLI-POP testbed. To avoid filter-cell design complications in phase-1, we employ a natural isotope-ratio Rb rf-discharge lamp. Due to a coincidence of nature, the $|e\rangle \rightarrow {}^{85}\mathrm{Rb}\ 5^2S_{1/2}(F_g=3)$ lamp line overlaps the ${}^{87}\mathrm{Rb}\ 5^2S_{1/2}(F_g=2) \rightarrow |e\rangle$ absorption line. The cylindrical clock cell (L = 3.0 cm and D = 2.5 cm) contains ^{87}Rb and 10 Torr of N_2. A VCSEL diode laser provides optical pumping, and microwaves are delivered via a microwave horn. Our phase-1 testbed does not employ photodetector gating nor laser pulsing. Our present purpose is focused solely on understanding the quality of LaLI-POP's clock signal.

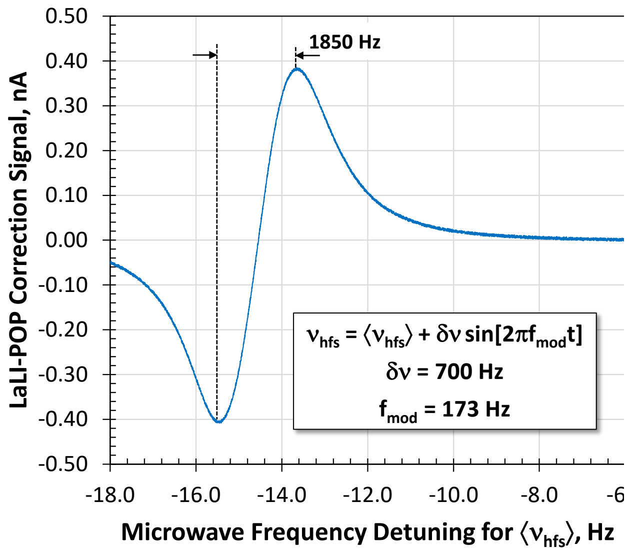

Fig. 1: Open-loop LaLI-POP correction signal. The S/N = 1.5×10^4 in a 1 Hz bandwidth.

Figure 1 shows the open-loop correction signal for our phase-1 testbed. The signal-to-noise ratio is estimated as 1.5×10^4 in a 1 Hz bandwidth, and the full-width half-maximum is 2700 Hz. This implies an estimated Allan deviation of $5\times10^{-12}/\tau^{1/2}$. In addition to a fuller discussion of the Fig. 1 results, the presentation will discuss the contrast of LaLI-POP signals and the LaLI-POP signal linewidth.