A HBAR-oscillator-based 4.596 GHz frequency source: design, characterization and application to a Cs microcell atomic clock

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The most common technological approach for the development of a local oscillator in miniature atomic clocks (MACs) application consists of a frequency synthesizer using a LC voltage-controlled oscillator (VCO) phase-locked to a 10 MHz quartz oscillator through a fractional-N phase-locked loop (PLL) [1,2]. However, in such systems, the frequency multiplication degrades the phase noise and can consume up to 50% of the MAC total power budget [1]. In that domain, a promising alternative solution is the development of microwave MEMS oscillators based on bulk acoustic wave (BAW) resonators, exhibiting small size, low power consumption and high Q-f products.

This work reports on the design and characterization of a high-overtone bulk acoustic wave resonator (HBAR)-oscillator-based 4.596 GHz frequency source. A 2.298 GHz signal, generated by an oscillator constructed around a thermally-controlled two-port AlN-sapphire HBAR resonator with a Q-factor of 24000 at 68°C, is frequency multiplied by 2 to 4.596 GHz, half of the Cs atom clock frequency. The temperature coefficient of frequency (TCF) of the HBAR is measured to be -23 ppm/°C at 2.298 GHz. The measured phase noise of the 4.596 GHz source is -105 $dBrad^2/Hz$ at 1 kHz offset and -150 $dBrad^2/Hz$ at 100 kHz offset. These phase noise performances are significantly better than those achieved with usual technologies [1,2].

The 4.596 GHz output signal is used as a local oscillator (LO) in a laboratory-prototype Cs microcell-based coherent population trapping (CPT) atomic clock [3]. The HBAR-based source signal is frequency-stabilized onto the atomic transition frequency in two steps: a coarse frequency tuning by adjusting the HBAR resonator temperature and a fine tuning by using a voltage-controlled phase shifter (VCPS) implemented in the 2.298 GHz HBAR-oscillator loop, preventing the need for a high-power-consuming direct digital synthesis (DDS).

The short-term fractional frequency stability of the free-running oscillator is 1.8 10^{-9} at one second integration time. In locked regime, the latter is improved in a preliminary proof-of-concept experiment at the level of 6.6 10^{-11} $\tau^{-1/2}$ up to a few seconds and found to be limited by the signal-to-noise ratio of the detected CPT resonance. The potential of this technology to be embedded in viable miniature atomic clocks will be discussed.

References

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