

FREQUENCY STABILITY OF 1×10^{-13} IN A COMPENSATED SAPPHIRE OSCILLATOR OPERATING ABOVE 77 K*

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Summary

We report on tests of a compensated sapphire oscillator which shows frequency-stable operation at temperatures above 77 K[1]. The frequency stability for this oscillator shows an apparent flicker floor of 8×10^{-14} for measuring times between 5 and 30 seconds, and stability is better than 1.5×10^{-13} between 1 second and 100 seconds. These values are approximately the same as for the very best available quartz oscillators. Up to now, high stability in sapphire oscillators has only been obtained with liquid helium cooling.

Performance of newly developed atomic and ionic frequency standards is presently limited by available local oscillators. These passive standards, which include mercury ion traps and cesium fountains, rely on an ancillary oscillator which is periodically corrected by comparison to atomic frequencies. In order to reach their potential, local oscillator stability of a few times 10^{-14} would be required. The compensated sapphire approach promises to meet this requirement in a compact and inexpensive cryogenic package.

A mechanical compensation mechanism, driven by the difference between thermal expansion coefficients of copper and sapphire, adjusts a gap between two sapphire parts and cancels the effect of temperature-induced variation in sapphire's dielectric constant. The WG_{811} mode at 7.23 GHz was excited, and showed a frequency turn-over temperature of 87 K in agreement with finite element calculations.

The presently observed $Q \approx 2 \times 10^6$ is very much lower than the intrinsic value of ≈ 30 million for sapphire at 77K, and is also below the value of 20 million we observed for other, uncompensated, modes in the same resonator. A redesign is presently underway to reduce surface contamination of the tuning gap, where resonant electric fields are large. We project a stability of 5×10^{-14} or better with the improved design. A noise-limited frequency stability of $1-2 \times 10^{-14}$ is calculated for a resonator with $Q = 10^7$.

References:

[1] G. J. Dick, D. G. Santiago, and R. T. Wang, "Temperature-Compensated Sapphire Resonator for Ultra-Stable Oscillator Capability at Temperatures Above 77 K," *IEEE Trans. UFFC*, **42** pp. 812-819, Sept. 1995.

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