# Status of the Low-AC-Power Cryogenic Sapphire Oscillators

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The cryogenic sapphire oscillator (CSO) is a highly specialized oscillator delivering a microwave signal exhibiting extremely low instability. The Allan deviation $\sigma_y(\tau)$ is of parts in $10^{-15}$ at 1 s, with a flicker floor of parts in $10^{-16}$, and some drift beyond a few hours. After the early American and Australian experiments in liquid-He bath [1,2], we demonstrated the use of a closed-cycle refrigerator at no cost in terms of stability. Prototypes #0 to #3 required 6-7 kW 3-phase AC power. The first codenamed ELISA [3], was delivered to the ESA station in Malargüe, Argentina, and #1-#3 were built for Oscillator IMP, our platform of metrology. The second generation, called ULISS 2G, came in 2015 starting from prototype #4. We used a new refrigerator requiring only 3 kW single phase AC, which can be powered from a regular 230 V, 16 A outlet.

After the results shown at the 8th Frequency Standard and Metrology Symposium [4], we spent a significant effort in understanding and engineering the oscillator. We gathered data about resonators of different manufacturers, including the spread of $Q$ and temperature turning point, related to the frequency stability; and about the long-term operation, faults, interruptions, etc. Unlike optical FP etalons, no lock fault has been detected in the CSO. Recent results are available in [5].

The current version of the CSO can run continuously, requiring only one in-field maintenance (1 H manpower of a trained engineer) every 2nd year. Drift, in most cases $< 10^{-14}$/day, proved to be extremely regular, and easy to model and remove.

The CSO is now a semicommercial product available to qualified users from Franche Comté Innov, a nonprofit Company owned by the University of Franche Comté, in turn a French Gov institution.

Finally, the CSO outperforms the optical FP in terms of reliability and drift, and exhibits the most desirable characteristics for use as the flywheel of atomic frequency standards. It deserves consideration for a maser-free time scale.

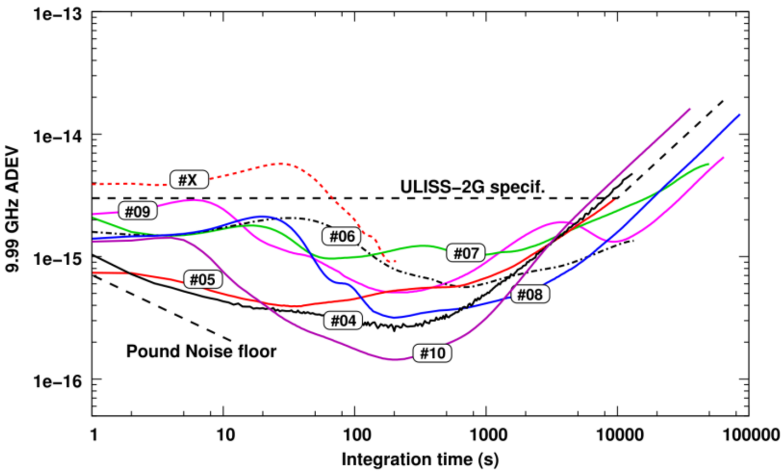


Fig.1. Allan deviation of the low-power (3 kW, single-phase AC) CSOs implemented and tested in Besancon. The sapphire resonator of #X is out of specs. Drift is not removed.
From arXiv:2210.05545 [physics.ins-det].

## References

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