Autonomous caesium fountains for applications in distributed time scales, science and industry

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Caesium fountain primary frequency standards provide a direct realization of the SI second and are the most accurate microwave clocks. They form a key part of the best time scales, are used for steering the frequency of Coordinated Universal Time (UTC), and act as a frequency reference for science applications. Historically Cs fountains have been operated by national metrology institutes, which possess the specialist capabilities and laboratories to build and operate them. Using these frequency standards in a wider range of applications requires systems that can operate continuously in non-laboratory environments without frequent intervention from specialist operators.

An example of such an application is the National Timing Centre (NTC) programme in the UK, where NPL is leading the development of a nationally distributed time and frequency infrastructure[1]. This will involve the installation of time scale hardware, including Cs fountains, at various partner sites around the UK. To meet the NTC's performance targets these fountains must achieve very high uptime and operate autonomously for many months at a time.

NPL has previously built highly engineered versions of its proven Cs fountain design for supply to partners under commercial contracts[2]. In this paper we describe the latest generation of these systems, which have reduced size, environmental sensitivity, and downtime, all without sacrificing performance. One such system has already been supplied to the ALPHA consortium based at CERN, who are using it as a frequency reference for precision antimatter metrology in an environment where it is exposed to significant thermal and magnetic field fluctuations.

Fig. 1: One of the new generation of NPL Cs fountains, showing the physics package and two racks that make up the system.

In this paper we describe the latest fountain design, and the features that enable it to operate with >99% uptime over several months. We show that these systems are capable of frequency measurement instability at the level of 3E-14 at one second, and accuracy better than 2E-16. Finally, we report on the development of a prototype miniaturised fountain that aims to further meet the needs of end users with minimal compromising on performance[3].

[1] Jones et al., A new resilient time and frequency infrastructure for UTC(NPL), submitted to J. Phys.: Conf. Ser.

[2] Hendricks et al., Cs fountain clocks for commercial realizations, IEEE T-UFFC, 66, 624 (2019)

[3] Szymaniec et al., Robust design and performance of NPL Cs fountain clocks, submitted to J. Phys.: Conf. Ser.