Cesium and Rubidium fountains at NTSC

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The National Time Service Center, Chinese Academy of Sciences (NTSC), generates and maintains the UTC (NTSC), which connects BeiDou Navigation Satellite System Time (BDT) to UTC, and broadcasts the time signal to users through BPM, BPC and BPL systems, networks and telephones, etc. Cesium atomic fountain primary frequency standards(PFS) and Rubidium fountain clocks are building to produce more accurate and stable local atomic time UTC(NTSC).

NTSC-CsF2 is operating to calibrate hydrogen maser as PFS. A cold atom beam source produced by 2D MOT is used to increase the loading rate. Microwave leakage is confirmed below 130dB before and after assembling the physical package in the free drift zone and around the detection zone. The type A and combined type B uncertainties of NTSC-CsF2 is exhibited at 3×10^{-16} and 4.2×10^{-16} in 30 days period . Frequency comparison between NTSC-CsF2 and the SI second show the rate difference of $3.9(4.5) \times 10^{-16}$ over six months through GNSS link with reduced chi-square of $\chi 2 = 1.1$. This indicates NTSC-CsF2 is consistent with that of the other fountains within the uncertainty.

NTSC-CsF3 is under building to operate at cryogenic temperature near 85 K. The microwave cavity[1] have been tested to install in physical package. A zero-evaporation liquid nitrogen Dewar device maintains a continuous cryogenic environment for free drift zone. Preliminary operation indicates blackbody radiation frequency shift is 9.05×10^{-17}, and the uncertainty is 2.68×10^{-18}.

Rubidium fountain clock NTSC-RbF1 is developed as a continuous clock (^{87}RFCC) like commercial cesium clocks. A frequency doubled C-band telecom fiber laser is lock to the ^{87}Rb D2 line by modulation transfer spectroscopy in pulse mode. In this way, the frequency is decreased to 150MHz red detuned during post-cooling stage and remain locking during other stage. The fountain generates 5 MHz or 1 PPS signal by the phase and frequency offset generator with maser input which exhibited a frequency stability of $1.91\times10^{-13}\tau^{-1/2}$, reaching 4.7×10^{-16} at 200000 s [2]. Since May 2022, the NTSC-RbF1 has demonstrated frequency drift of E-18/d level and they have regularly received weight in the TAI timescale.

NTSC-RbF2 has similar structure except the laser setup, which is made of all fiber component including fiber laser, AOM, shutter and splitter. An ultra stable oscillator HSO14 is lock to Ramsey fringe directly, which is shown frequency stability $3\times10^{-13}\tau^{-1/2}$(1-10000s). A cyro sapphire oscillator is an alternative to improve the stability down to $5\times10^{-14}\tau^{-1/2}$.

Reference

1. Fan Yang, Xinliang Wang, Sichen Fan, Yang Bai, Junru Shi, Dandan Liu, Hui Zhang, Yong Guan, Qiang Hao, Jun Ruan, and Shougang Zhang, Development and tuning of the microwave resonant cavity of a cryogenic cesium atomic fountain clock, Review of Scientific Instruments 93, 044708 (2022)
2. Hui Zhang, Jun Ruan, Dandan Liu, Fan Yang, Sichen Fan, Yang Bai, Yong Guan, Xinliang Wang, Junru Shi and Shougang Zhang. Development and Preliminary Operation of ^{87}Rb Continuously Running Atomic Fountain Clock at NTSC, in IEEE Transactions on Instrumentation and Measurement, vol. 71, pp. 1-12, 2022, Art no. 1008312