Status Report to the 19th meeting of the CCTF on Time and Frequency Activities at KRISS

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1. Atomic Fountain Standard

KRISS is developing an atomic fountain frequency standard. The newly designed atomic fountain clock at KRISS is a Rb/Cs double fountain which is similar to the fountain at LNE-SYRTE [1]. We will try to trap two species of atoms simultaneously with cooling laser beams of (111)-geometry in the fountain. However, as the laser system only for cesium was presently prepared, we have been experimenting with it as only a Cs fountain. A laser system for rubidium is under construction. We observed Ramsey fringes with an interrogation Cs cavity installed for preliminary test. The measured central Ramsey fringe has a linewidth of 1 Hz and a S/N of about 600. Now we are designing a microwave cavity with low DCP error [2], and c-field coil, and magnetic shields. After completing accuracy evaluation of the atomic fountain, we hope it will contribute to the generation of TAI and be used as a reference standard for frequency comparison of an Yb optical lattice clock under development at KRISS.

2. Optical Frequency Standard

For the Yb optical lattice clock, we developed a clock laser at 578 nm by using sum frequency generation (SFG). We used a 1030-nm fiber laser with a 20 kHz linewidth and a 1319-nm Nd:YAG laser with a 1 kHz. A WG-PPLN was pumped simultaneously by the co-propagating 1030-nm laser of 10 mW and the 1319-nm laser of 20 mW producing a collimated output beam of 2 mW at 578 nm. The Pound-Drever-Hall technique was used to stabilize the clock laser frequency to a resonance of the super-cavity with a finesse of 350,000. To evaluate the frequency stability of the clock laser, we constructed an independent second clock laser system, which was based on the second harmonic generation (SHG) of an 1156 nm laser with the same ULE batch as in the clock laser system using SFG. The short-term linewidth was measured by heterodyne beat note between the two clock lasers. The full width at half maximum (FWHM) of the beat note was about 80 Hz (sweep time: 43 ms) but varied mostly between 70 ~ 170 Hz in each frequency sweep due to frequency jitters. This mid-term frequency jitter was as large as 700 Hz in a measurement time of 10 s. The relatively large short-term linewidth and frequency jitter in our system was attributed to several causes. First of all, the cavity was not supported at the vibration-immune points, and the residual vibration level was relatively high even after an active vibration isolation platform was used, since the cavity setup was located on the second floor of the building. In addition, the control loop bandwidth (30 kHz) was insufficient to completely remove the clock laser frequency noise. Also, there was long-term frequency drift of the clock laser due to the room temperature variation, since the stabilized temperature was away from the temperature for the zero in the coefficient of thermal expansion (CTE) of the cavity. The cavity setup is currently on the way of moving down to the basement floor and will be optimized for supporting points and the temperature.

We measured the absolute frequency of the optical clock transition $^1S_0$ (F = 1/2) – $^3P_0$ (F = 1/2) of ^{171}Yb atoms confined in a one-dimensional optical lattice. The frequency was measured against Terrestrial Time (TT; the SI second on the geoid) by using an optical frequency comb of which the frequency was phase-locked to an H-maser as a flywheel oscillator traceable to TT. 592 measurements were taken on three separate days over a 45 day period (241 measurements on MJD 55803, 187 measurements on MJD 55805, and 164 measurements on MJD 55848) and the results are shown in Fig. 1. Uncertainty budget for three different measurements is shown in Table 1. From the weighted mean of the three measurements, the absolute frequency of the clock transition was determined to be 518 295 836 590 863.6 (8.1) Hz. The magic wavelength was also measured as 394 798.48 (79) GHz. The results are in good agreement with two previous measurements of other institutes within the specified uncertainty of the work [3, 4]. Details will be published elsewhere.

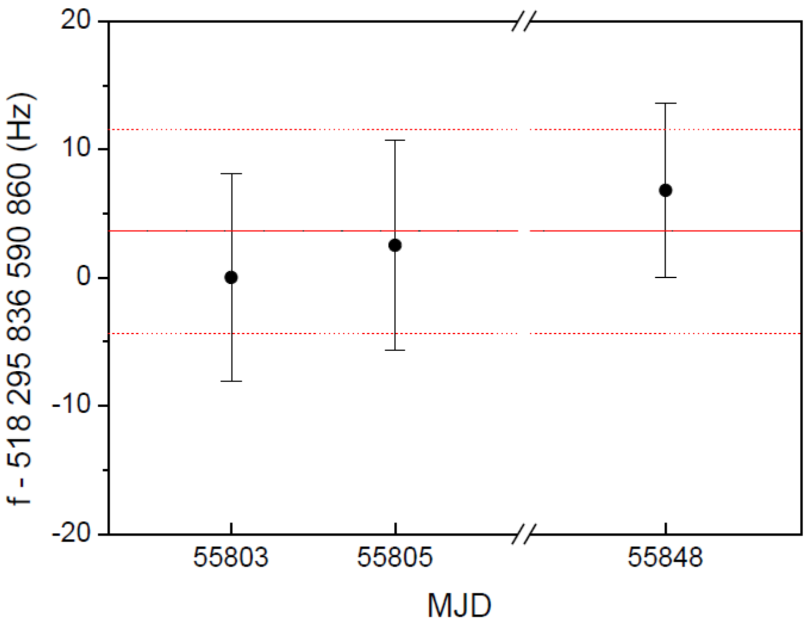

Fig. 1. The three absolute frequency measurement results performed for the Yb clock transition with corrections already included. The determined absolute frequency and uncertainty from the weighted mean of the results are indicated by the red solid line and dotted line, respectively.

Table1. Uncertainty budget for the absolute frequency measurement of the ^{171}Yb optical lattice clock for three different measurement days – MJD 55803, 55805, and 55848.

Effect	MJD 55803		MJD 55805		MJD 55848	
	Shift (Hz)	Uncertainty (Hz)	Shift (Hz)	Uncertainty (Hz)	Shift (Hz)	Uncertainty (Hz)
Linear lattice ac Stark shift	1.4	7.3	1.4	7.3	1.1	5.8
Hyperpolarizability	0	0.4	0	0.4	0	0.4
Second order Zeeman	-1.3	0.2	-1.3	0.2	-1.3	0.2
Gravitational shift	5.2	0.1	5.2	0.1	5.2	0.1
Blackbody radiation shift	-1.6	0.2	-1.6	0.3	-1.5	0.2
Collisional shift	0.6	2.7	0.6	2.7	0.6	2.7
Yb	**4.3**	**7.8**	**4.3**	**7.8**	**4.0**	**6.4**
Yb-Maser (statistical)	-	1.8	-	2.2	-	1.7
Yb-Maser(deadtime)[a)]	-	0.9	-	1.0	-	1.5
Maser-TAI(5 day)[b)]	10.6	0.7	10.9	0.7	7.1	0.7
TAI-TT[b)]	2.7	0.2	2.6	0.2	2.4	0.2
Total	**17.6**	**8.1**	**17.8**	**8.2**	**16.2**	**6.8**

a) Uncertainty due to the difference between the measurement time and frequency calculation period of 5 days in Circular-T.

b) Calculated from Circular-T No. 284, 285, and 286 respectively.

3. Time and Frequency Comparisons

In order to contribute to the generation of TAI and keep UTC(KRIS) traceable to UTC, KRISS is operating GNSS and TWSTFT time transfer systems. Time transfers using P3 code, precise point positioning, and C/A code of GNSS are being carried out with two Ashtech Z12T receivers, a Septentrio PolaRX2eTR, and a multi-channel GPS receiver (Topcon Euro-80) (Fig 2). Recently, two sets of Septentrio PolaRX3eTR were introduced for time transfer using GLONASS as well as GPS. The GIPSY-OASIS II Ver.6.1 is installed for PPP computations.

For TWSTFT links, two sets of TWSTFT system are ready. One of them is for Asia-link via the GE-23 satellite and the other for Europe-link via the AM2 satellite. At present, the both links are on standby due to radio licenses issue. We expect that KRISS will get the radio licenses from the Korea Communications Commission this year.

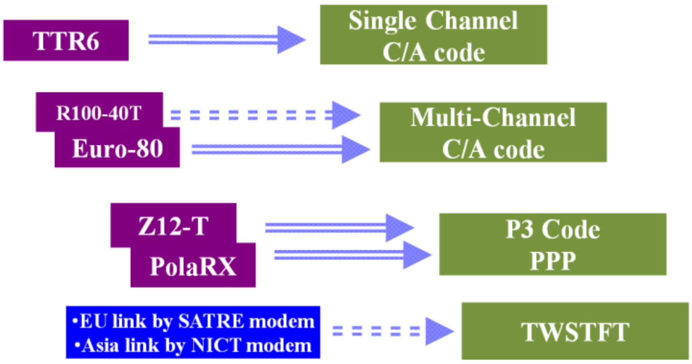

Fig. 2. Time Transfers at KRISS.

4. Dissemination of Time and Frequency

KRISS maintains 5 cesium clocks (HP5071A) and 4 hydrogen masers (a Symmetricom and three KVARZ) for the generation of UTC(KRIS). One of the hydrogen masers (Sigmatau) stopped operation as its life ended. A newly hydro maser (Symmetricom) was introduced to replace the old one in 2011. Currently, time comparison data of 5 Cs clocks and 3 hydrogen masers are reported to the BIPM. The clock comparison data of the new hydrogen maser will be sent to the BIPM very soon.

For time dissemination, we are operating two NTP time server allowing users to synchronize their computer clocks via the internet.

A 5 MHz broadcasting station (call sign: HLA) is being operated for the dissemination of the Korea Standard Time (KST) and Korea Standard Frequency (KSF). The whole broadcasting system including transmitters, time-code generators, and Cs atomic clocks is replaced with new one to provide more stable and reliable signals. For the improvement of short-wave reception, we introduced the FSK modulation with IRIG-B format in addition to the AM modulation with IRIG-H to broadcast the time code information.

References

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