Report to the CCL/CCTF joint group meeting from Japan

--- MNIJ/AIST ---

Question 1.1: No

Question 1.2: No

Question 1.3: No

Question 2.1: No

Question 2.2: Yes

We report the improved frequency measurement of the Sr lattice clock at the University of Tokyo. As the result of a joint research project between the University of Tokyo and the NMIJ/AIST, we have improved our frequency measurement by introducing both an H-maser and a Global Positioning System (GPS) carrier phase link. This system is used to measure the frequency of the clock transition of ^{87}Sr in an optical lattice. The absolute frequency of the $^1S_0$ – $^3P_0$ clock transition of the Sr lattice clock is determined to be 429,228,004,229,876(4) Hz.

Question 2.3: Yes

We report the activities of three optical frequency standards in Japan.

1) Sr optical lattice clock (location: the University of Tokyo)

The absolute frequency of the transition for the Sr lattice clock was first determined to be 429,228,004,229,952(15) Hz using a Cs clock referenced to the SI second [1, 2]. Later the JILA group has measured the frequency to be 429,228,004,229,869(19) Hz [3]. The measurement results of the two groups had a poor agreement at a level of three times of the combined uncertainties.

Recently, we have performed an improved frequency measurement based on an H-maser linked to UTC(NMIJ) using GPS carrier phase signals. The UTC(NMIJ) is in turn linked to international atomic time (TAI). The Allan standard deviation is obtained for the Sr lattice clock and is found to reach 2×10-15 at an averaging time of 1300 s. The newly obtained absolute frequency of the Sr lattice clock is 429,228,004,229,876 Hz, with an uncertainty of 4 Hz. This frequency value differs from that of our previous measurement by five times the combined uncertainty but fall within the uncertainty of the JILA value. We reported the preliminary results of our improved frequency measurement at the CLEO/QELS 2006 conference [4]. Later we learned that the SYRTE group has also posted their measured frequency value of the Sr lattice clock as 429,228,004,229,879(5) Hz on the arXiv [5] during the period of the CLEO/QELS conference. The weighted average of the frequencies measured by

three groups gives an averaged frequency of 429,228,004,229,877.0 Hz, which is within the error bars of the three groups. The standard deviation of the mean for this average is 3.2 Hz (fractionally 7.5×10^{-15}). Good agreement is obtained between the measurement results of the three groups. We will send a publication reference related to our improved measurement to the CCL/CCTF JWG when it is ready.

References:

[1] M. Takamoto, F.-L. Hong, R. Higashi, and H. Katori, "An optical lattice clock," Nature 435, 321 (2005).

[2] F.-L. Hong, M. Takamoto, R. Higashi, Y. Fukuyama, J. Jiang, and H. Katori, "Frequency measurement of a Sr lattice clock using an SI-second-referenced optical frequency comb linked by a global positioning system (GPS)," Opt. Express 13, 5253 (2005).

[3] A. D. Ludlow, M. M. Boyd, T. Zelevinsky, S. M. Foreman, S. Blatt, M. Notcutt, T. Ido, and J. Ye, "Systematic study of the 87Sr clock transition in an optical lattice," Phys. Rev. Lett. 96, 033003 (2006).

[4] H. Katori, M. Takamoto, R. Higashi, and F.-L. Hong, "Optical Lattice Clock: Towards Frequency Measurement at 10-18 level (invited)," presented at the Quantum Electronics and Laser Science Conference 2006, Long Beach, CA, 21-26 May 2006.

[5] R. Le Targat, X. Baillard, M. Fouche, A. Brusch, O. Tcherbakoff, G. D. Rovera, and P. Lemonde, "An accurate optical lattice clock with 87Sr atoms,"arXiv:physics/0605200.

2) Yb optical lattice clock (location: the NMIJ/AIST)

We have been building up an Yb optical lattice clock at the NMIJ/AIST in cooperation with the University of Tokyo. We have finished the vacuum system including the source oven, the Zeeman slower, and the magnet-optical trap (MOT) chamber. We have also constructed the LD based 399 nm laser system for the Zeeman slower and the MOT. We have succeeded in making the violet MOT. We prepared the fiber laser based 556 nm SHG system for the spin-forbidden MOT, and the 578 nm SFG laser system for the $^1S_0$-$^3P_0$ clock transition.

3) Calcium ion trap (location: NICT)

A single Calcium ion optical frequency standard has been developed in National Institute of Information and Communications Technology (NICT). S-D electric quadrupole quantum jump signals of the single 40Ca+ ion were observed in a miniature trap. The central frequency of the S-D transition was measured on the order of a few MHz.