Special Feature Article for Time Day (June 10)

Is your clock accurate?

— Universal Coordinated Time and Primary Frequency Standards —

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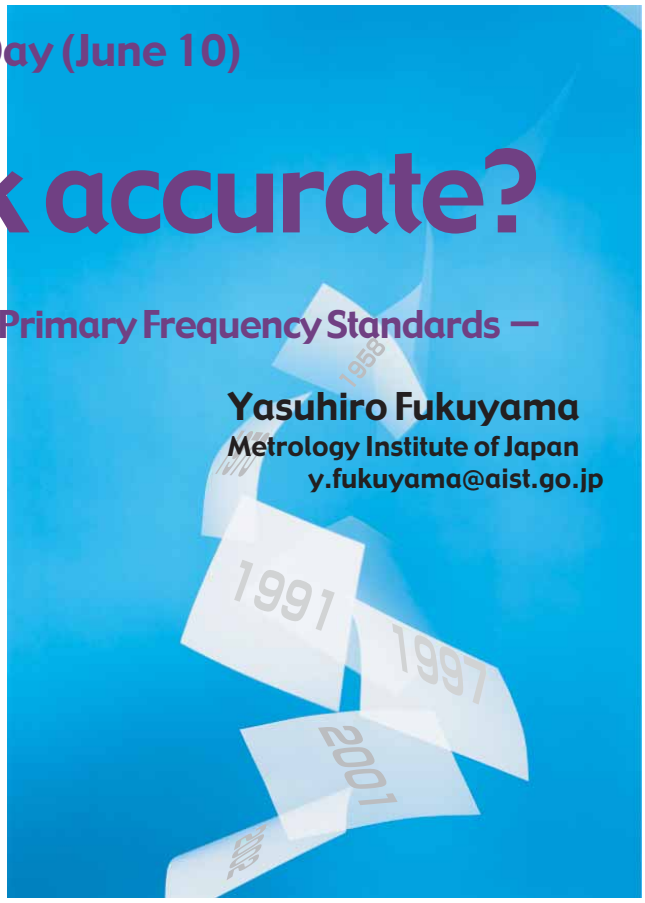

Accurate clock

"Is your clock accurate?"

This may not be as strange as it sounds. If we ask whether the time shown on your clock is accurate, then perhaps you could answer straight away. However, this question is actually asking whether the clock, once adjusted, ticks accurately for ever. To answer this question, you should have an understanding of at least two characteristics of the clock to prove this kind of "accuracy". Basically, you must be sure that the frequency of the oscillations -"ticking movement"- is constant and the frequency is faithful to a certain standard.

June 10 is designated as "Time Day" in Japan. Taking this opportunity, now we are taking a look at both ancient and contemporary efforts to "create an accurate clock" in Japan.

Time Day and Water Clock - Attempt to create an accurate clock in ancient Japan

According to *Chronicles of Japan*, on April 25th (June 10th under the current solar calendar) of 671A.D. a water clock called "Rokoku" was used for the first time in Japan to announce the time at the palace. "Time Day" was created based on this episode.

The water clock used at the palace regulated time at certain frequencies which were determined by water flow-in at a constant rate. And the intervals were calibrated to a standard, i.e. scale marks interlocking with the solar movement. In other words, the said two key factors to make an accurate clock were already pursued in Japan over 1300 years ago.

Establishment of Universal Coordination Time (UTC) - Contemporary approach to an accurate clock

Regarding the endeavors of the modern age. Currently, the time scale employed as an international standard is UTC, Universal Coordination Time. It is rather perplexing but this time scale has no function to indicate the current time nor to send out an electric signal. All we can define is the difference between the UTC at a past moment and the clock in hand. Even so, UTC possesses its own raison d' etre because it is the most "accurate time scale" in the world.

In fact, the complicated procedures to define UTC are intended to meet the two requirements of an "accurate clock" as previously mentioned.

Firstly, the frequency of oscillations must be maintained constant. This is achieved by taking the average of measurements at reference atomic clocks all over the world. More specifically, the differences between UTC and measurements submitted by any timing center in the world by satellite are calculated at BIPM (the Bureau International des Poids et Mesures) for analysis. Based on this analysis, BIPM computes EAL (free atomic time), which is the most dependable time scale to keep the second constant.

Secondly, there is a "standard". Time shifting, once based on length of a day is now defined using quantum resonance of a cesium atom as a yardstick. In order to comply with this standard, it is necessary to use a special atomic clock called "primary frequency standards". This reference clock is designed and developed at timing

standard centers with the utmost care to determine a second precisely. The result of frequency corrections to EAL based on calibration by primary frequency standards is TAI (International Atomic Time) which achieves consistence of the definition of a second.

TAI is adjusted by adding leap seconds to produce the universal time scale, UTC.

Cesium Atomic Fountain Primary Frequency Standard

AIST, as a national metrology institute, is contributing to the establishment of UTC in the following two ways. Firstly, we maintain and control multiple atomic clocks at all times to provide BIPM with data to define EAL. Moreover, we develop our own primary frequency standards with a view to the establishment of TAI.

Unfortunately, there are few institutions to provide constantly their clock measurements from primary frequency standards for TAI. Therefore the current UTC lacks an important factor to maintain accurate time scale.

AIST is presently pursuing a research project to build atomic fountain frequency standards, next generation frequency standards. Measurement data which serves as a reference for TAI establishment will be acquired shortly. It is expected that with this atomic clock, there is a potential for a tenfold increase over the accuracy of the conventional method, to reach order-of-magnitude improvements equivalent to accuracy of 10^{-15}. Accuracy has been a long held challenge in our history of clockmaking since June 10th 1331. In 2002, we will mark a next step toward the lure of hyper-accurate time.

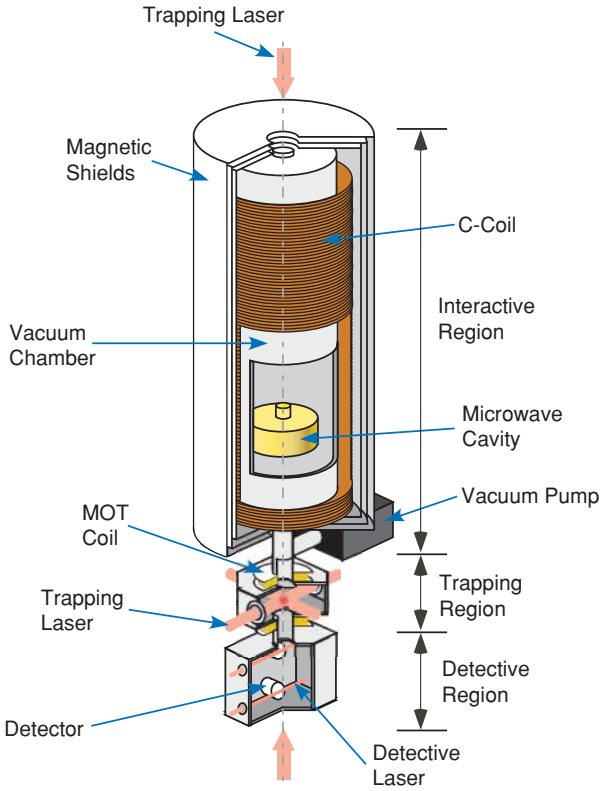

Fig. Cesium Atomic Fountain Primary Frequency Standard

Tanabata (The Star Festival)

Tanabata is the Weaver Star Festival, which occurs on July 7. The Chinese legend, which has it that Altair(the Cowherd Star) and Vega(the Weaver Star) were split apart by the two banks of the River of Heaven(the Milky Way) and come together once a year on this night, has aligned with Japanese belief. Originally a festival carried out among the Court nobility, it has since the Edo Period(1603-1867) become established among the people at large.

On the night of the 6th, people write their wishes or poems on strips of poetry paper in various color. And hung them on leafy bamboo; then on the night of the 7th, they are put out in the garden. These are attractive enough to be called summer Christmas trees.

Photo : K.Nakajima