Report to the 15th Session of the Consultative Committee for Time and Frequency (CCTF)

Korea Research Institute of Standards and Science

1. Atomic Frequency Standards Under Development

1.1 Caesium atomic fountain

A caesium atomic fountain frequency standard has been developed at KRISS since 1998. Until now, a vacuum system and an optical system have been constructed, and a new theory has been developed to explain the cooling mechanism in the MOT [1-9]. The total height of the system is 2.2 m including a 0.72-m long aluminum chamber. For the optical system, two slave-lasers are injection-locked to a master-laser, and four laser beams from the lasers with acousto-optic modulators are introduced to the MOT along x, y, +z, and –z directions. Trapping, launching, optical-pumping, and detecting of atoms are automatically controlled by personal computers. Seven Rabi microwave transition signals were observed by detecting the fluorescence light from the atoms fallen after they were launched to the height of about 1 m from the MOT. However, Ramsey interference fringe was not observed yet because the microwave cavity in our system had two degenerate modes of TE_{011} and TM_{111} due to inappropriate microwave coupling between semi-rigid cable and the cavity. The width of the Rabi-pedestal was measured as 50 Hz.

1.2 Slow atomic beam frequency standard

Continuous beam of caesium atoms having the longitudinal velocity of about 30 m/s with the rms velocity width of 0.85 m/s was produced from a thermal atomic beam by laser-cooling technique, and was used for the atomic- beam frequency standard [10,11]. The Ramsey fringe with about 60 Hz linewidth was observed with a 21-cm long Ramsey cavity. Fig.1 shows the observed Ramsey fringe compared with that of the KRISS-1 frequency standard. The linewidth was reduced by four times as compared with that of the KRISS-1. Microwave frequency locking to the center of the Ramsey fringe is scheduled to be carried out with a new laser system [12] composed of injection-locked diode lasers.

1.3 The KRISS-1 frequency standard

Accuracy evaluation

The accuracy evaluation of the KRISS-1 has been performed [13-16]. The overall uncertainty (1σ) was estimated as 6×10^{-13}, most of which was caused by microwave leakage from the atomic beam holes of the Ramsey cavity. A new cavity has been recently replaced after the characteristics of the microwave leakage were precisely measured. The accuracy evaluation will be performed soon again. Being taken into account the angular anisotropy of the spontaneous photon emission, a more accurate theory to estimate the light shift in an optically pumped atomic beam frequency standard has been developed. The light shift for the KRISS-1 was estimated as -2.4×10^{-15} [17].

Improvement of the S/N ratio

We have found that the transverse cooling of the atomic beam using two-dimensional optical molasses is able not only to collimate the atoms but also to reduce the longitudinal velocity of the atoms [18]. Applying this method to the atomic beam of the KRISS-1, we could enhance the amplitude of the Ramsey fringe as well as reduce its linewidth. The cooling laser beam was used to illuminate the atomic beam just before the exit of a caesium oven. The asymmetric signal amplitude in neighboring transitions around the clock transition was controlled by adjusting the magnetic field around the optical molasses with Helmholtz coils. As shown in Fig. 2, the linewidth of the Ramsey fringe was reduced from 260 Hz to 200 Hz, and the S/N ratio was improved by a factor of 8. We expect that the frequency stability of the KRISS-1 will be finally improved by an order of magnitude with this method.

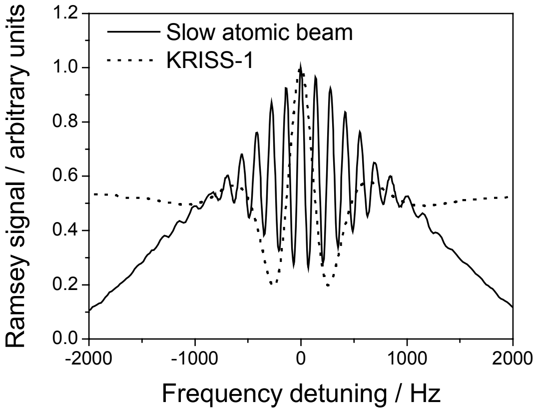

Fig. 1. Ramsey fringes observed from the slow atomic beam standard and the KRISS-1 frequency standard.

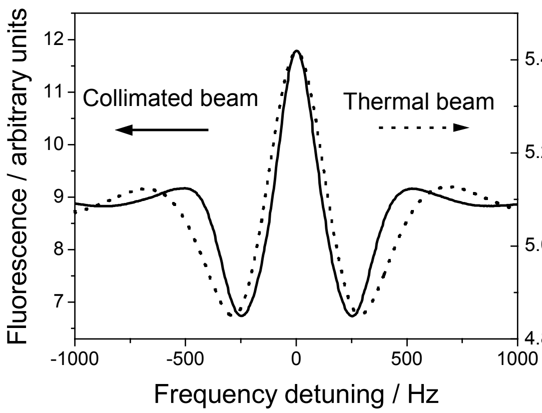

Fig. 2. Ramsey fringes observed using the collimated beam and the thermal beam in the KRISS-1.

2. Time and Frequency Comparisons

For the routine international time comparison of UTC(KRIS), we operate two TTR-6 GPS receivers for the GPS common-view time transfer using the BIPM tracking schedule [19]. UTC(KRIS) has been generated by a HP clock (5071A with a normal tube) and a micro phase stepper. Recently, a set of GPS/GLONASS receiver (3S Navigation) was equipped. Two-way satellite time transfer via JCSAT-1B with Communication Research Laboratory (CRL) is scheduled to start in coming September. A part of CRL's equipment has been already established at KRISS for the comparison.

3. Dissemination of Time and Frequency

The Time Server is under operation for the time synchronization of PC clocks via Internet using Simple Network Time Protocol (SNTP). The accuracy of this service is less than 0.5 s after automatic compensation of time delay on the network. The number of connections to the server is about 500,000 a day. A 5-MHz broadcasting station (call sign: HLA) is maintained for dissemination of standard time and frequency in Korea. More than 100 organizations are using this signal for the reference.

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