# Improvement in accuracy of absolute frequency measurements of the Ti:Sa/$I_2$ standard at 732 nm for high precision spectroscopy of muonium.

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High resolution laser spectroscopy on the 1S-2S transition in muonium has required a frequency standard in the vicinity of 732 nm (1/6 of the transition energy). Such a standard based on a Ti:sapphire laser locked to a hyperfine component of the R26(5-13) transition in $I_2$ was developed at the Novosibirsk Institute of Laser Physics [1]. This standard was used for the calibration of the laser spectrometer in the experiments on laser spectroscopy of muonium performed in the Rutherford Appleton Laboratory (England) [2]. Preliminary absolute frequency measurements of the standard have been performed with an accuracy of $10^{-9}$ by using two reference standards [1]. The first standard is a $CO_2$ laser stabilized on peak of the $CO_2$ 9R(10) Doppler absorption line by using a fluorescent cell. The second standard is a diode laser stabilized on the d hyperfine component of the $D_1$ $^{87}$Rb line. The sum of frequencies of these standards differs from the measured frequency by approximately several GHz. Now, we increased the accuracy of the $CO_2$ standard by locking it to the Lamb dip of the absorption line, and repeated our measurements. The accuracy of these measurements is in the order of $2\cdot10^{-10}$. For further improvement of the measurement accuracy, a new synthesis scheme is being created. This scheme is based on the use of the fourth harmonic of a He-Ne/$CH_4$ standard as a reference standard. To bridge the large frequency gap between the fourth harmonic near 848 nm and at the 732 nm $I_2$ line, we employ a method for visible frequency division [3] and a mode-locked Ti:sapphire laser as a precise active frequency comb generator. Two diode lasers are used in the synthesis scheme. The first laser is locked to the fourth harmonic of the He-Ne/$CH_4$ standard, and the selected mode of the femtosecond Ti:sapphire laser is locked to this diode laser at 848 nm. The midpoint between the frequency $\nu_0$ at 732 nm being measured and the diode laser frequency $\nu_1$ at 848 nm is the second diode laser frequency $\nu_2$ at 786 nm ($2\nu_2 = \nu_0 + \nu_1$). This laser is phase locked to the sum frequencies of the lasers at 732 and 848 nm by using a beat signal between its second harmonic and a sum frequency. In order to obtain the correct frequency $\nu_2$, the intermode frequency $\nu$im of the mode-locked Ti:sapphire laser and the beat frequency $\nu_b$ between $\nu_2$ and the nearest mode of the Ti:sapphire laser have to be measured, and the exact number of modes N between the two laser diodes at 848 and 786 nm has to be determined. Then $\nu_2 = \nu_1 + N\nu_{im} \pm \nu_b$, and the frequency of the iodine reference line at 732 nm may be determined as: $\nu_0 = \nu_1 + 2N\nu_{im} \pm 2\nu_b$ The new synthesis scheme can achieve an accuracy of frequency measurements better than $10^{-12}$.

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[3] H.R. Telle, D. Meschede, T.W. Hansch, Realizing a new concept for visible frequency division: phase locking harmonic and sum frequency, *Opt. Lett.* **15** 532 (1990).