Study on Stabilizing the Laser Frequency in 10^{-14} Level by Optimizing Modulation Transfer Spectroscopy on the ^{87}Rb D_2 Line

SangLok Lee[1,2], **Geol Moon**[2], **Sang Eon Park**[1], **Hyun-Gue Hong**[1], **Jae Hoon Lee**[1], **Sangwon Seo**[1], **Taeg Young Kwon**[1], **Sang-Bum Lee**[1]

1. Korea Research Institute of Standards and Science, Daejeon 34113, Republic of Korea
2. Department of Physics, Chonnam National University, Gwangju, 61186, Republic of Korea

email: sl6621@kriss.re.kr

Stabilizing the laser frequency using the D_2 line of alkali atoms is essential for the implementing high-performance cold atom interferometer. In this study, we present a high-performance laser frequency stabilization method that utilizes modulation transfer spectroscopy (MTS) on the rubidium 87 D_2 transition line [1, 2]. By optimizing the diameter and intensity settings of the probe and pump beams for the spectroscopy, we achieve a substantial improvement in frequency stability. The frequency instability is evaluated with beating signal of two frequency-locked external cavity diode lasers (ECDL), and reached a short-term stability of $4.5\times10^{-14}/\sqrt{\tau}$ and did not exceed 2×10^{-12} until 10^5 s. To the best of our knowledge, this is the best performance reported with the rubidium 87 D_2 transition [1, 2]. However, offset fluctuations induced by residual amplitude modulation (RAM) limit the long-term stability, which is expected to be further improved by reducing the temperature fluctuation. Nevertheless, the current long-term stability is already good enough considering state-of-the-art gravimeters with instability of 5×10^{-11} at 10^5 s [3].

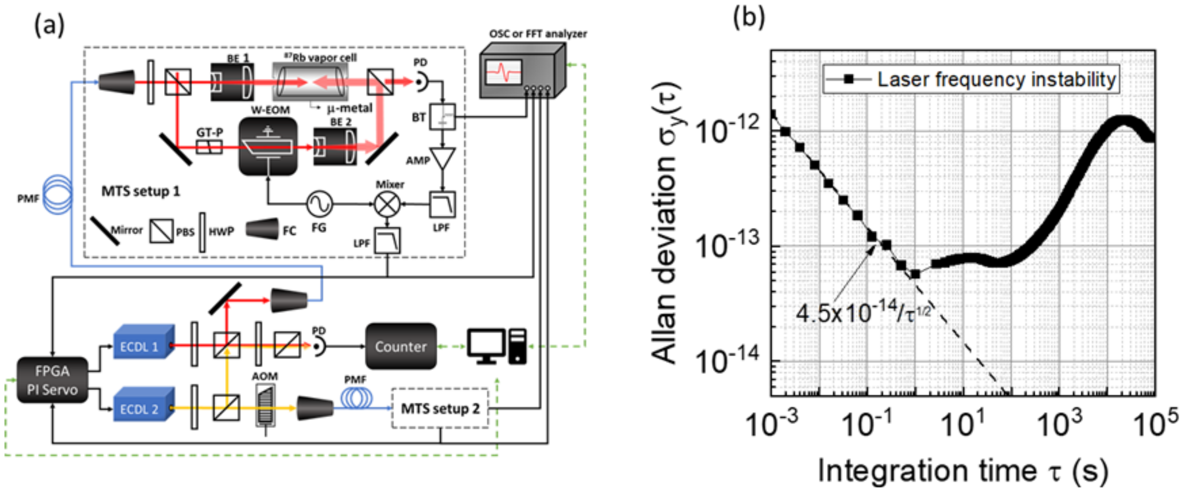

Fig. 1 (a) MTS setup. ^{87}Rb vapor cell; ^{87}Rb enriched wedged vapor cell, FC; fiber collimator, HWP; half-wave plate, BT; Bias-tee, M; mirror, PBS; polarizing beam-splitter, GT-P; Glan-Thompson polarizer, EOM; electro-optic modulator, PD; photodiode, AMP; amplifier, LPF; low-pass filter, Mixer; phase detector, FG; function generator, OSC: Oscilloscope, BE 1&2; beam expander (custom-made). (b) Allan deviation showing laser frequency instability obtained from the beating frequency of two locked external cavity diode lasers.

References

[1] S. Lee, S.-B. Lee, S. E. Park, H.-G. Hong, M.-S. Heo, S. Seo, J. Jeong, T. Y. Kwon, and G. Moon, "Compact modulation transfer spectroscopy module for highly stable laser frequency," Opt. Lasers Eng. 146, 106698 (2021).

[2] S. Lee, G. Moon, S. E. Park, H.-G. Hong, J. H. Lee, S. Seo, J. Jeong, T. Y. Kwon, and S.-B. Lee, "Laser frequency stabilization in the 10-14 range via optimized modulation transfer spectroscopy on the 87Rb D2 line," Opt. Lett. 48, 1020-1023 (2023).

[3] C. Freier, M. Hauth, V. Schkolnik, B. Leykauf, M. Schilling, H. Wziontek, H.-G. Scherneck, J. Müller, and A. Peters, J. Physics: Conf. Ser. 723, 012050 (2016).