Noise quantitation of a home-made, rack-mounted ultra-stable laser

Weinan Zhao, Hanxu Wu, Yang Fu, Xinyi Chen, Honglei Yang*,

Shengkang Zhang*, and Jun Ge

Science and Technology on Metrology and Calibration Laboratory, Beijing Institute of Radio Metrology and Measurement, Beijing, China 100854

* yhlpc@163.com, zhangsk@126.com

Abstract: With extremely high frequency stability and time coherence, ultra-stable laser plays essential roles in the fields of time-frequency transfer, optical atomic clocks, ultra-low phase noise microwave signal generation, gravitational wave detection and fundamental physics experiments.

In this paper, we present a rack-mounted ultra-stable laser with all fiber-coupled devices before incidenting into the optical reference cavity. The cavity is designed to be a rigidly fixed cube with 5 cm length and cutted vertices. In order to obtain comprehensive knowledge about an ultra-stable laser system to a target performance, we investigated the contribution of the system noises.

The results are depicted in Fig. 1 in the form of frequency noise spectra and Allan deviations. The frequency stabilization of the laser system is below 3.0×10^{-15} at the average time between 1 s and 10 s, which is approaching the thermal noise limit of 1.4×10^{-15}. The performance is limited by vibrations, power fluctuations and the aging of the cavity at the average time above 10 s. In this system, the vibration and intra-cavity power fluctuations can be optimized if the system performance is to be further improved, and the contribution of the other noises could be neglected. Noise quantitation providing a comprehensive noise picture is useful for the development of such a system.

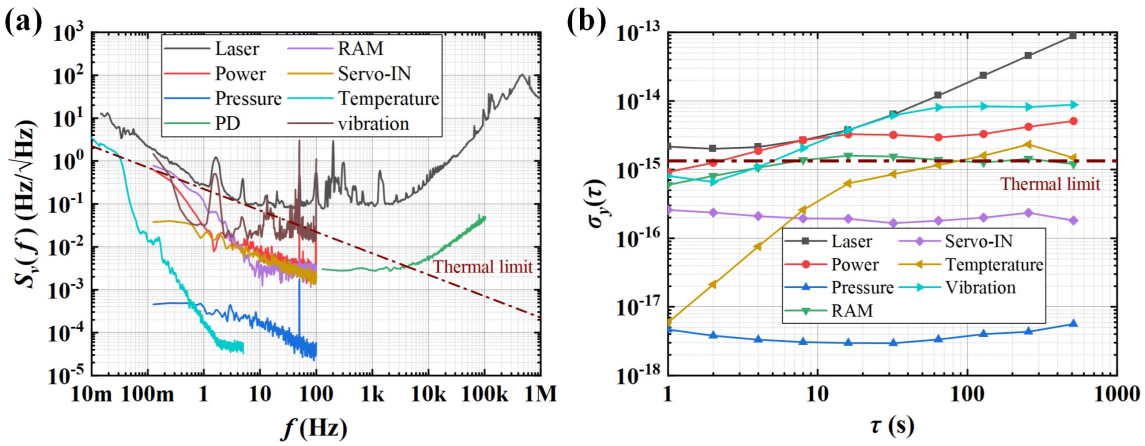

Fig. 1 (a) Frequency noise spectra. (b) Allan deviations. RAM: Residual amplitude modulation, PD: photodetecor.

References

[1] S. Herbers, S. Häfner, S. Dörscher, et al. "Transportable clock laser system with an instability of 1.6×10^{-16}", Opt. Lett.. vol. 47, p. 5441-5444, 2022.

[2] M. Giynta, J. Yu, M. Lessing, et al. "Compact and ultrastable photonic microwave oscillator", Opt. Lett., vol. 45, p. 1140-1143, 2020.

[3] J. Liu, T. Liu, L. Chen, et al. "A compact sub-hertz linewidth Fabry Perot cavity frequency stabilized laser for space application" Optics and Laser Technology, vol.136, p. 106777, 2021.