Laser Stabilization System for Space Applications Based on Hydroxide-catalysis Bonding

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The development of an ultra-stable Nd:YAG laser system for space missions based on the Pound-Drever-Hall (PDH) method[1] is presented in this paper. In order to fulfill the measurement requirement in space, not only the cavity but the whole PDH optical system has to be space-qualified. Thus, we apply the hydroxide-catalysis bonding technique[2] to establish a monolithic ultra-stable bench, consisting of the cavity and the mode-matching coupling optics. The bench is made of ultra-low expansion (ULE) materials, and the positions and parameters of every component are well analyzed and designed to ensure that the high stability of cavity and the mode-matching efficiency of TEM_{00} mode can be achieved. Fig. 1(a) shows the photos of the optical bench made by using the hydroxide-catalysis bonding.

For the PDH system we apply all fiber optics as shown in Fig. 1(b). The laser is coupled into a PM fiber and phase-modulated by an electro-optic modulation (EOM). After being power attenuated and isolated, the modulated laser is sent to the bench via a fiber collimator and the reflected light is coupled back to the fiber and guided to the photodiode via a fiber circulator for error signal detection. A digital controller based on FPGA is used to lock the laser frequency onto the resonant frequency of the cavity. We have obtained a control bandwidth of more than 30 kHz, while the frequency noise spectrum of free-running laser is within 10 kHz.

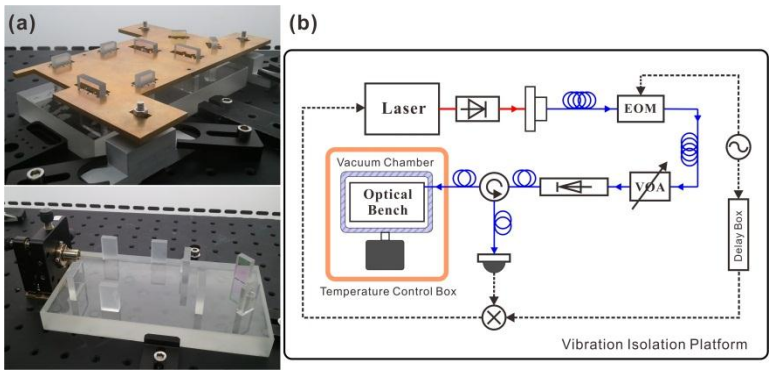

Fig. 1: (a) Optical bench with cavity and mode-matching optics established by hydroxide-catalysis bonding; (b) PDH laser stabilization system with all fiber optics and monolithic optical bench installed in vacuum chamber and thermal controlled box.

The ultra-stable bench is installed in a vacuum chamber with the pressure less than 10^{-8} mbar. The temperature outside the vacuum chamber is stabilized at the zero-crossing coefficient of thermal expansion (CTE) temperature of ULE by active thermal control.

For demonstration testing on ground, the influence of the seismic noise must be reduced to a negligible level. Thus, the mounting of the ultra-stable bench is analyzed and optimized by the finite-element analysis (FEA) simulations to minimize the vibration sensitivity of cavity, and the whole system is installed on a commercial active-vibration-isolation (AVI) platform. The latest results will be presented in the conference.

[1] R. W. P. Drever et al., Appl. Phys. B, vol. 31, p. 97-105, 1983.

[2] E. J. Elliffe et al., Class. Quantum Grav., vol. 22, p. S257-S267, 2005.