# High performance iodine-stabilized laser

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This study focuses on the development and optimization of a frequency-stabilized laser system based on molecular iodine, aiming to meet the demands of high-precision measurements. We develop a high-performance molecular iodine optical frequency reference based on the modulation transfer spectroscopy (MTS) which is referenced to the R(56)32−0: $a_1$ transition of molecular iodine.

The stability of the laser is limited by the beam pointing noise, the electronic servo noise, and the residual amplitude modulation noise. To improve the beam pointing stability, the system is constructed by gluing most components of the optical system on an ultra-low expansion glass base. We use a pre-amplifier to suppress the electronic servo noise, and use a wedged electro-optic phase modulator to suppress the residual amplitude modulation noise.

The signal to noise ratio of the iodine frequency-stabilized system is 420 with 10 kHz resolution bandwidth. The Allan deviation is calculated from the beat signal, and is shown in Fig. 1(b). The frequency instability of the iodine frequency-stabilized laser is evaluated by beating with an ultra-stable cryogenic sapphire cavity laser which has a fractional frequency instability of $2.0\times10^{-16}$. The fractional frequency instability of the system is evaluated to be $3.3\times10^{-15}$ at 2 s and 4 s averaging time, and is lower than $6\times10^{-15}$ at averaging times from 1 s to 10000 s.

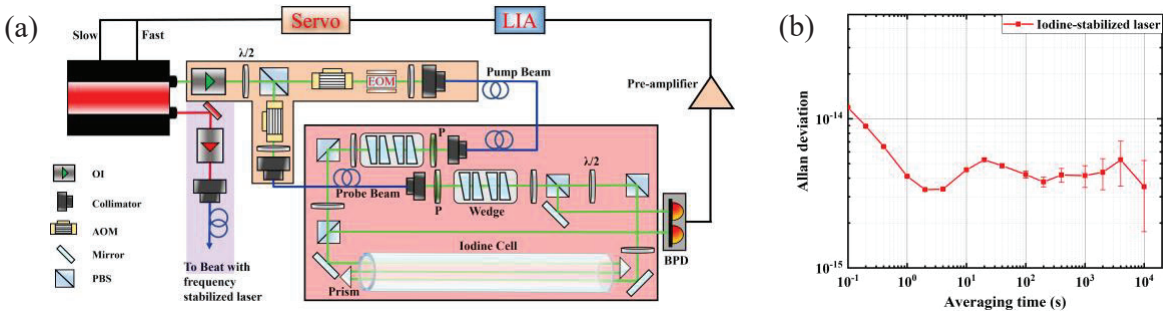


Fig. 1. (a) Experimental setup for the iodine frequency-stabilization laser. (b) Frequency instability of the locked laser system.

[1] Z. Zhang, et al, "An ultra-stable laser based on molecular iodine with a short-term instability of $3.3\times10^{-15}$ for space-based gravity missions," Class. Quantum Grav. 40, 225001 (2023).