PERFORMANCE OF THE LIGO PRE-STABILIZED LASER SYSTEM

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The pre-stabilized laser system (PSL) provides frequency- and intensity-stabilized laser light to the LIGO interferometers. The first pre-stabilized laser system was installed at the LIGO Hanford Observatory (LHO) in December, 1998 and has subsequently operated continuously for more than 18,000 hours. Based on this experience, several upgrades to the optical elements and feedback control loops have been implemented. All elements except the relative power stabilization control loop are operational. The system now maintains lock of its control loops for weeks or even months at a time. A second PSL is operating at the LIGO Livingston Observatory (LLO) and a third is presently being installed for the second interferometer at the LHO.

The LIGO PSLs utilize optically-pumped Nd:YAG lasers and several feedback control loops to provide intensity- and frequency-stabilized light to the LIGO interferometers. The heart of a PSL is a 10-W, all-solid-state Nd:YAG laser (Model 126-MOPA, developed under contract with Lightwave Electronics in Mountain View, CA) operating at 1064 nm with approximately 95% of the output in a TEM_{00} mode. [1] The PSL feedback control loops serve three principal functions: a) reduction of power fluctuations in the gravitational wave (GW) detection band of frequencies, from 10 Hz to 10 kHz, b) reduction of power fluctuations at the modulation frequency used for GW detection, about 25 MHz, and c) reduction of frequency fluctuations in the GW detection band.

To reduce relative power fluctuations in the GW frequency band to the 10^{-8} level, the PSL will utilize a photodetector located downstream of the long (15 m), triangular modecleaner. Development of a suitable actuator has delayed implementation of the power stabilization feedback control loop. Recently, a novel *current shunt* actuator that controls a fraction of the pump diode current was developed. [2] The frequency response of this actuator appears to be satisfactory for stabilization to the required levels.

The PSL utilizes a triangular Fabry-Perot cavity, a pre-modecleaner (PMC), to reduce relative power fluctuations at the 25 MHz modulation frequency utilized for GW detection to a fraction of the shot noise limit for 600 mW of laser light. The PMC operates in the low-finesse (~200), p-polarization mode. The length of the PMC is controlled by a feedback loop to maintain resonance with the laser light. One of the cavity mirrors is bonded to a piezo-electric transducer (PZT) that provides the actuator for the loop. Passive filtering above the PMC half-bandwidth of approximately 1.8 MHz attenuates the relative power fluctuations. Preliminary measurements indicate that the PMC filtering is a factor of 2 to 3 lower than the required level. New PMC cavities with higher finesse (lower half-bandwidth) are being fabricated.

The LIGO frequency noise reduction strategy utilizes three nested feedback control loops with progressively quieter sensors – a fixed-spacer, 20-cm-long, lin-

ear reference cavity, the 15(or 12)-m-long suspended, triangular modecleaner, and the 2- or 4-km-long suspended interferometer arm cavities. The three loops are designed to reduce frequency fluctuations at 100 Hz to 10^{-2}, 10^{-4}, and 10^{-7} Hz/$\sqrt{Hz}$, respectively. The actuators for the PSL frequency stabilization loop are: control of the master oscillator (MO) crystal temperature, a PZT mounted to the MO crystal, and an electro-optic modulator located between the MO and the PA. An acousto-optic modulator located in the reference cavity beam path provides a variable frequency shift that enables the PSL loop to function as a frequency actuator for the other two nested servo loops. Closed-loop control of the reference cavity temperature provides and actuator for earth tides compensation. The PSL frequency noise level, measured with the modecleaner cavity, is shown in Figure 1.

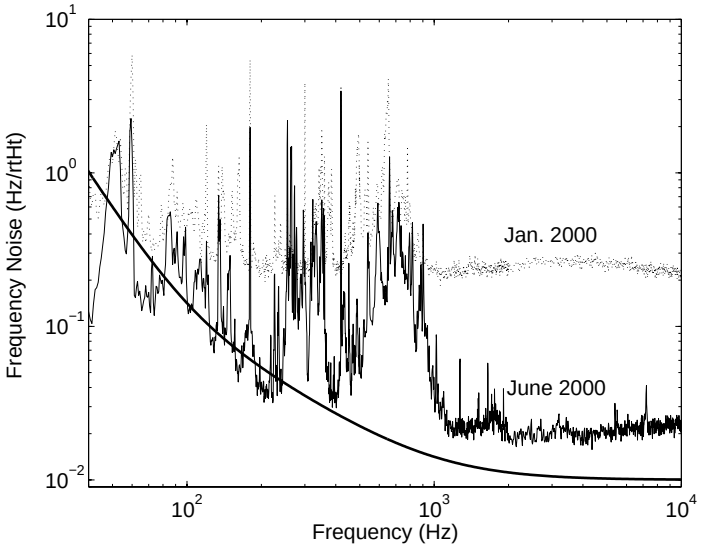

Figure 1. PSL frequency noise measured with the 15-m-long modecleaner. The heavy solid line is the frequency noise requirement.

Acknowledgments

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References

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2. R. Abbott and P. King, to be published in *Rev. Sci. Instr.* **72**, (2001).