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Development of an ultrastable laser at 1550 nm

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Development of an ultrastable laser at 1550 nm

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Abstract. This work deals with the development of a 1550 nm diode laser stabilized against a high finesse cavity (>250,000). It reports the components, apparatus and some preliminary results for the system under construction.

1. Introduction

Lasers are applied in a wide range of sectors, from industry to high precision physics. In order to be used in some physics experiments, like high resolution spectroscopy, there is a need for very accurate and stable systems. In this sense is fundamental to reduce the linewidth of the laser system, to be able to resolve certain atomic transitions. Our Group has been developing a system of this kind, with linewidth enough to deal with atomic reference standards that we have in other experiments [1].

One of the main aspects concerning the quality of a laser is its linewidth. For a free-running laser, this characteristic can be on the order of megahertz. There are several techniques to reduce the linewidth, for example, the use of an extended cavity for a diode laser (ECDL) [2] or servo the laser to a high finesse Fabry-Perot cavity (PDH technique) [3]. The use of external Fabry-Perot cavities to reference laser systems is one of the most common techniques for stabilizing ultra stable lasers [4].

On the other hand, special attention should be devoted when preparing the mechanical structure to isolate the cavity, since the deformations in the cavity degrade the stabilization system [5], and a temperature control in the mK range is crucial, in order to maintain the cavity around the most stable region of operation. Also, the quality of the controllers has a fundamental whole in the laser stabilization, where a reflection from the optical cavity is used to lock on the desired frequency. The aim of this work is to develop a system able to stabilize a diode laser at 1550 nm in a sub-hertz level linewidth. Figure 1 summarizes the system.

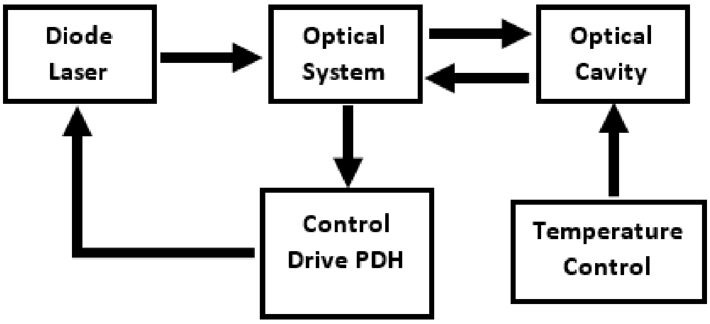

Figure 1. General scheme of the parts for the ultrastable laser system at 1550 nm.

2. System description

Following are presented the components for the laser stabilization system.

2.1. Diode Laser

The system has a diode laser of 1550 nm with linewidth in free-running regime of 1 kHz (RIO Orion Laser). The laser parameter settings (temperature and current) are set through a SPI / USB interface with the computer. In addition the laser has a modulation input used as corrective feedback.

2.2. Optical System

In order to stabilize the laser in the sub-hertz level is essential to use an optical cavity for reference. The cavity used has a finesse 250,000 and length of 10 cm.

The big issue for the laser stabilization is the injection of laser light into the optical cavity and the optical system should be done to achieve the best possible impedance and mode matching for the cavity.

2.3. Vacuum chamber

In order to provide a shielding for temperature stabilization, a vacuum chamber is used to protect the optical cavity. The chamber used is also involved with an acrylic blanket to increase their isolation with the variation of ambient temperature. In addition there are four Peltier elements coupled to the chamber for temperature control, figure 2 shows the vacuum chamber used in this project.

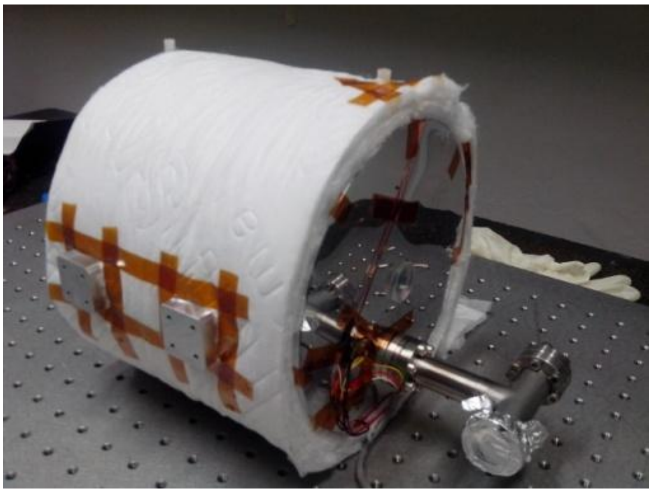

Figure 2. Vacuum chamber involved with the acrylic blanket for thermal insulation.

2.4. Mechanical Insulation System

The vacuum chamber, diode laser and the optical system are being mounted on a breadboard attached to a high isolation passive platform (Minus K). This platform performs isolation through a negative constant spring system, which provides excellent isolation down to 0.5 Hz. In addition the entire system is placed in an acoustic box to prevent coupling of noise. Figure 3 illustrates the pre mounted system.

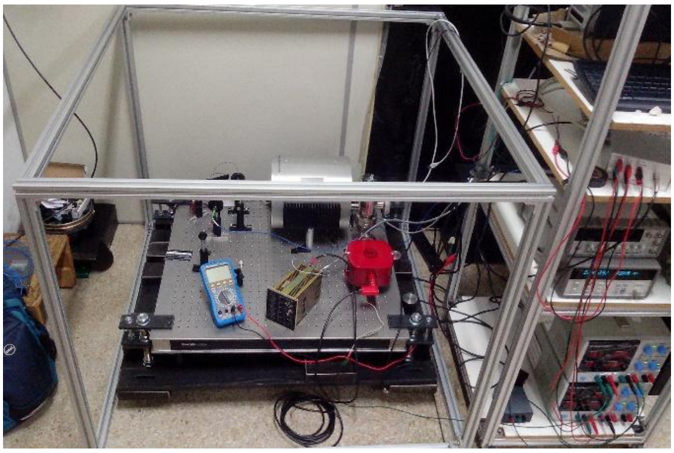

Figure 3. Preliminarily assembled system.

It is noteworthy that the platform used has an acceptable weight range of 164 - 239 kg i.e. the optical table over the vacuum chamber is not sufficient to achieve the minimum weight limit, therefore, steel bars were added to the system to work in nominal mass of the platform. This provides a good margin for additional components and, at the same time, keeps the mass center of the system very low.

2.5. Laser locking system

To lock the laser, we will use the Pound-Drever-Hall technique, shown schematically in figure 4.

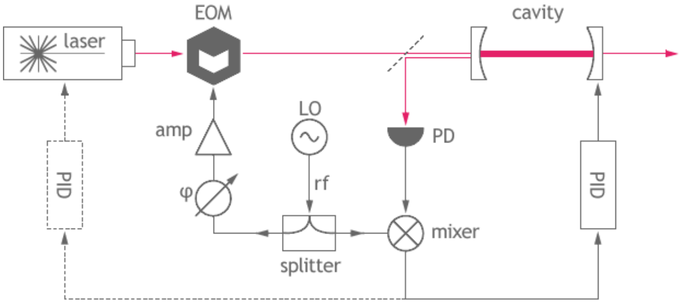

Figure 4. Pound Drever Hall technique [6].

Basically, this technique is achieved through modulation and demodulation of a signal in the megahertz order in the laser light. A radio frequency signal is injected through an electro-optic modulator, which induces sidebands to the laser light. The light of the optical cavity resonance and the sidebands are collected by a photo-detector and demodulated with a mixer.

2.6. Temperature control of the vacuum chamber

To implement the temperature control is essential to know the thermal behavior of the vacuum chamber. So it is necessary to take into account the plant parameters. The technique used is the relay method, which induces a relay-type non-linearity in the plant, founded by descriptive function [7], the output is basically a sinusoidal signal, with time and amplitude depending on the input signal (relay signal). Figure 5 shows a control loop using this technique and figure 6 illustrates the relay signal and the plant response.

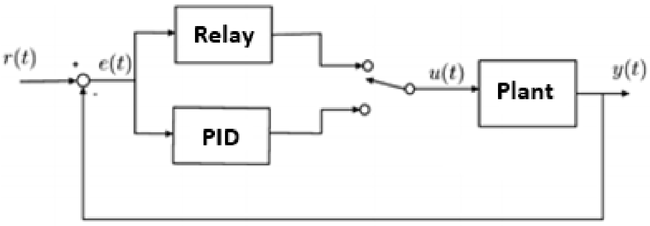

Figure 5. Loop Control used to determine the plant characteristics using a relay-type non-linearity.

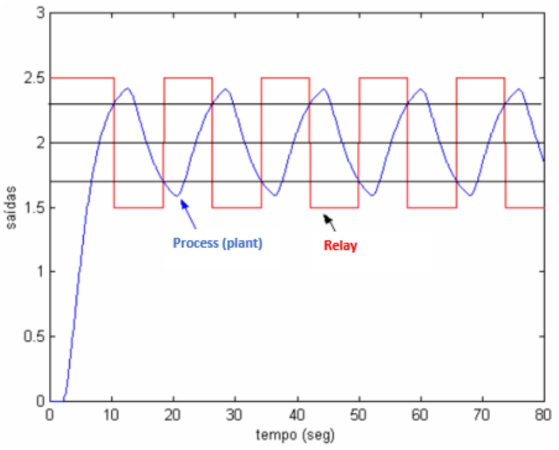

Figure 6. Relay signal and plant response.

The control was first implemented using LabView platform with a data acquisition board PCI-6259. The initial focus was to understand system behavior as well as their parameters, critical gain and critical period, with these two parameters the gains Proportional, Integral and Derivative are calculated using the method of Ziegler-Nichols [8]. Thermal stability found is already under 10 mK variation.

3. Current results

The optical table assembly has been completed, as shown in figure 7.

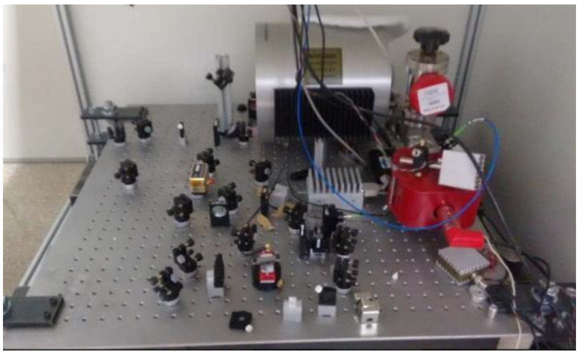

Figure 7. Optical table.

Adjusting the alignment of the laser beam at the entrance of the cavity and modulating the laser into current, we can visualize the transmission signal of the optical cavity represented in figure 8.

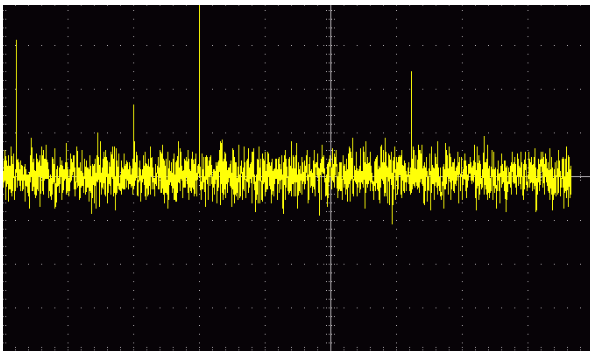

Figure 8. Transmission signal of the optical cavity.

4. Conclusion

We present the current status of an ultra stabilized laser at 1550 nm. The mechanical assembly and temperature control are being finalized. The next steps are design the control driver for laser locking, characterize the acoustic and mechanical vibration insulation system and characterize the ultra stable laser against frequency comb.

Acknowledgments

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