Frequency Stabilization of He-Ne Laser

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Introduction

Frequency stabilized lasers are required for many optical experiments, especially for the laser cooling projects. Normally, the frequency of the lasers is locked to the reference laser which is the key to the frequency stabilization. In the previous work, various methods of obtaining frequency-stabilized He-Ne laser have been investigated[1][2]. This project gives a newly improved method for the frequency stabilization of He-Ne laser which preforms well to the disturbance from the environment.

Method

Frequency of He-Ne laser ($\lambda = 632.8$ nm) is determined by the length of the cavity which could be easily influenced by the environment. Thus the frequency locking process requires the electronic feedback system which monitors some property of the laser and then adjusts the laser as needed to maintain a constant frequency. This laser stabilization is based on two-mode polarization stabilization, an approach to stabilization first proposed by Balhorn et al[1].

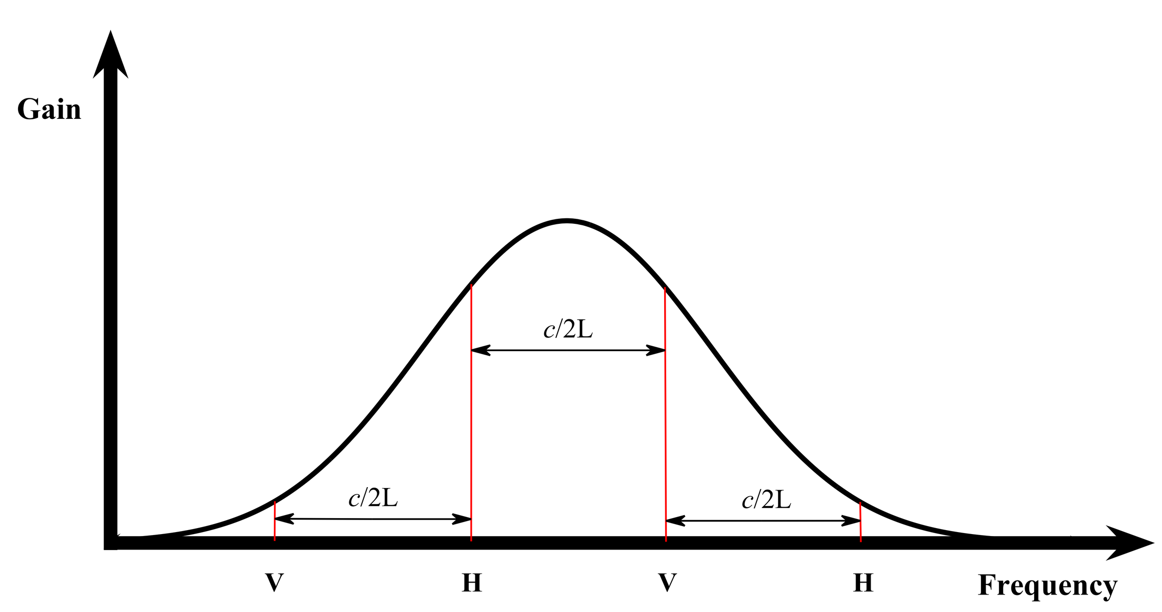

Fig1 .The longitude modes of the He-Ne laser. The difference of the adjacent frequency $\Delta v \approx \frac{c}{2L}$(c is the speed of light, L is the length of cavity)

By comparing the intensity of adjacent longitude modes, we get the difference of them which is called error signal and is used as a reference to adjust the length of cavity. Once the output frequency changed, the error signal reflecting the change in voltage guides the feedback circuit to adjust it to the preset value. One of the basis for stabilization was a thin-film heater attached to the laser that controls the laser tube's cavity length by changing temperature. The implemented feedback circuit is based on PID control and is constructed of inexpensive integrated circuits. Another part of the control system is the piezo feedback circuit which control the length of the cavity by piezoelectric effect. The piezo circuit has a high gain and respond very fast to the change.

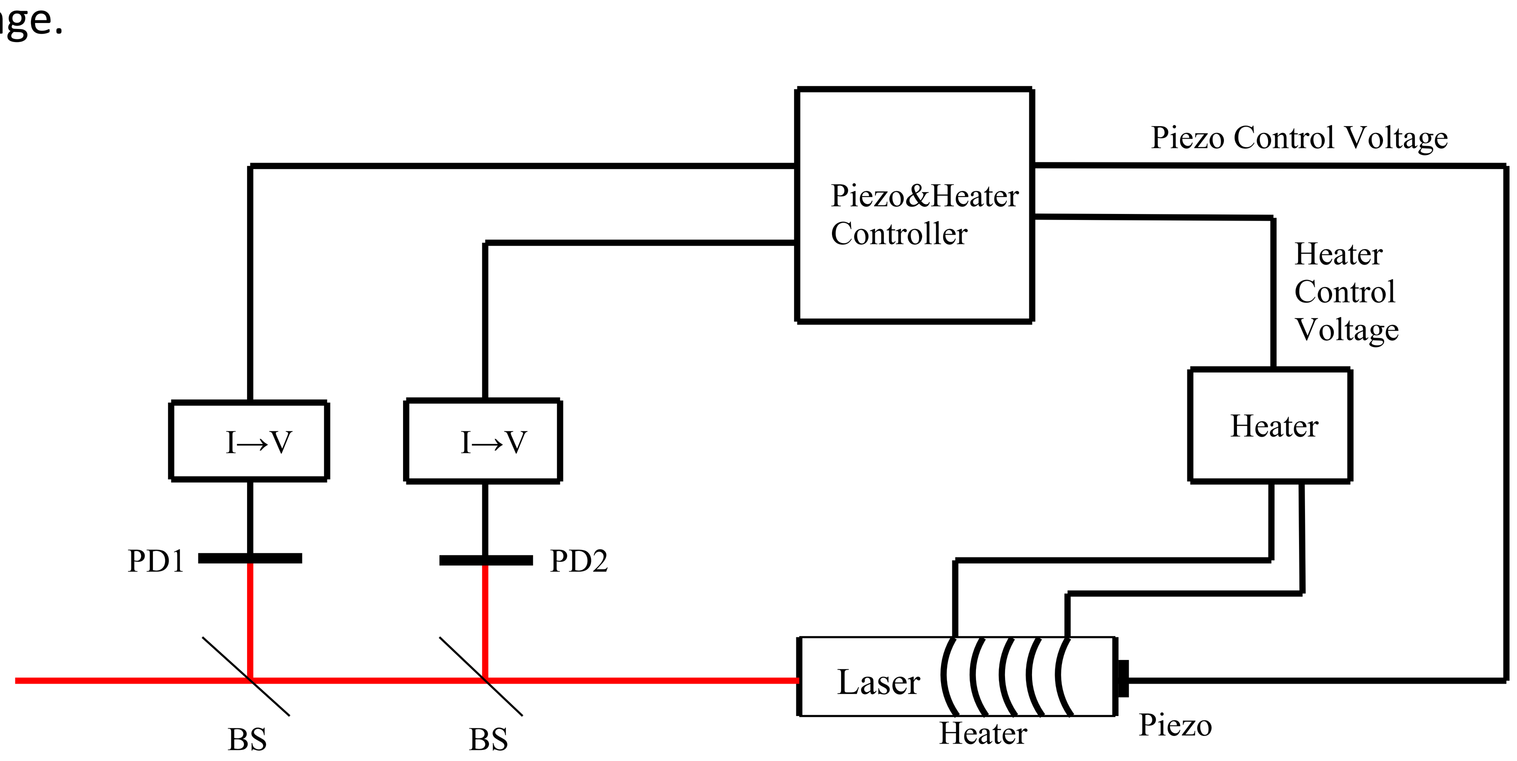

Fig 2.Schematic diagram of electronic control system.

The two adjacent longitude modes of He-Ne laser are separated by the beam splitter (BS) and sent to the photodiodes (PD). Then the current signal is transformed into voltage signal and sent the controller. The heater control voltage and piezo control voltage dominate the response of heater and piezo separately and keep the length of the cavity free from the influence of environment.

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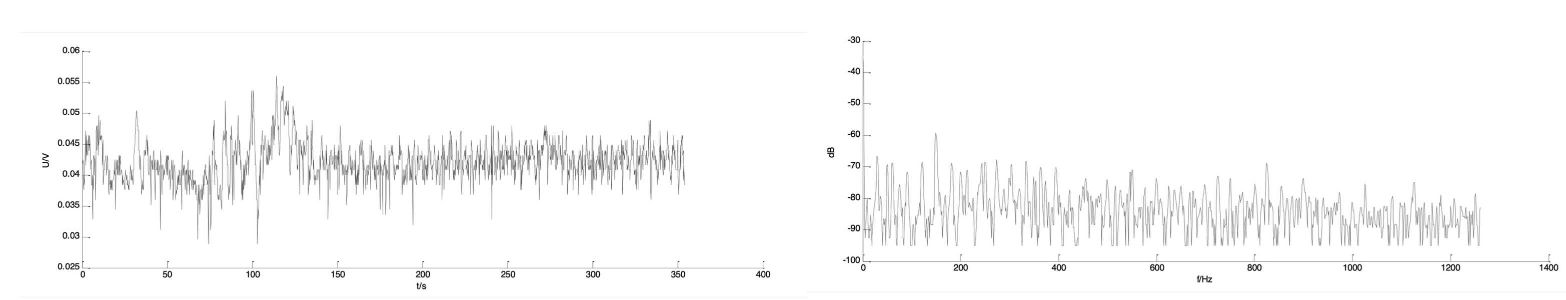
Result

Here the error signal from the oscilloscope is used to evaluate the stability of the He-Ne. Based on theoretical analysis, 1V error signal respond to 104.9 MHz. Thus, the frequency change

$$\Delta v = (\Delta U_{error} \times 104.9)\ \text{MHz}$$

Here, we evaluated the stability of frequency from three different aspect.

- ☐ How much did the frequency vibrate in normal environment:



(a) (b)

Fig 3. (a)Error signal after being stabilized.(b)Fast Fourier Transform (FFT) of error signal

Maximum change of the error signal is 1.09MHz; $\frac{c}{2L} = 474684$ GHz

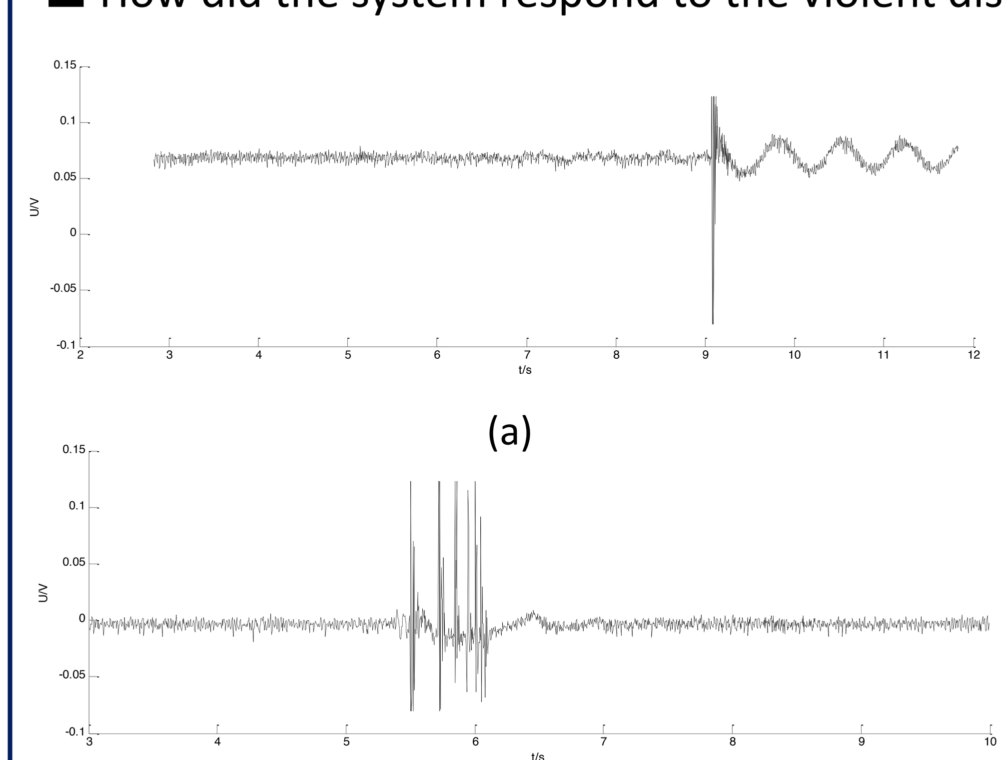
Frequency stability: $S_v(\tau) = \frac{1.09\ \text{MHz}}{474684\ \text{GHz}} = 2.30\times10^{-9}$ $(\tau = 100\ S)$.

- ☐ How much did the frequency change after a long time:

Time(h)	Change of Frequency Δv(MHz) (compare with the initial state)
24	1.5
36	1.5
48	1.5

Table 1. The frequency change after different period of time.

- ☐ How did the system respond to the violent disturbance after being controlled:



(a)

(b)

Fig 4.(a)Without the feedback circuit, after being disturber at 9s, system did not return to a stable state for a long time.

(b)With the feedback of heater and piezo, the system could return to stable state very fast after being disturbed violently.

Conclusion

The feedback system contains two feedback elements: heater and piezo. The error signal is used to monitor the change of frequency and adjust the response of the feedback elements separately to keep the frequency a constant. Based on this, the result shows the nice behaviour of the laser in three aspects :

- ☐ Accurate control;
- ☐ Robustness of the control system;
- ☐ Stability for a long time.

Reference

[1] Balhorn R, Kunzmann H, Lebowsky F. Frequency stabilization of internal-mirror helium–neon lasers[J]. Applied optics, 1972, 11(4): 742-744.

[2] Bennett S J, Ward R E, Wilson D C. Comments on: Frequency stabilization of internal mirror He–Ne lasers[J]. Applied optics, 1973, 12(7): 1406-1406.