Temperature Control System for the Stabilized Laser Diode

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Abstract

We used a film heater, a DC-power supply, and a temperature controller to set up a stable controllable temperature system for the stabilized laser diode, which can be used as observing the cooling and trapping of Rb atoms and Bose-Einsten condensation.

Contents

1 Introduction

Due to Bose statistics, when the temperature become very low (at the scale of μK), the de Broglie wave length will be larger than the distance between the atoms. The atoms will all fall into the lowest state and have a high phase-space density. This is called Bose-Einstein condensation.

Carl E. Wieman [1] proposed a clever way to observe Bose-Einstein condensation using cheap homemade laser cooling and trapping system. The idea is to avoid the solidification of gas. To reach this purpose, he prevent the Rb gas to reach a true equilibrium by creating a vapor sample that quickly equilibrate to its proper thermal distribution as a spin-polarized gas, which takes a very long time to go to its true equilibrium state (solid).

Two core method needed in getting the Bose-Einstein condensation is
1.laser cooling and trapping
2.magnetic field (imhormogeneous) for trapping and cooling

Wieman recommended using laser diode for its easy set up and cheap price. Since the Rb vapor is very sensitive to the wave length of the laser, we have to maintain the laser system under a constant temperature preventing any wave length change under the fluctuation of the temperature. Cooling or heating the system depending on the actual requirement can do this. However, a heater is much easier to handle with.

As a result, we used a film heater (MINCO HK5207 R12. 5L12D (9928)), a DC-power supply (TEMMA TEST EQUIPMENT MODEL 72-6152), and a temperature controller (Omega Temperature and Process Controller (Cni3252)) to set up a stable controllable temperature system for the stabilized laser diode. Detail will de mentioned in the context.

2 Temperature Control System

2.1 Basic component

There are laser, mount block of laser, baseplate, heater, and temperature sensor (RTD thermometer).

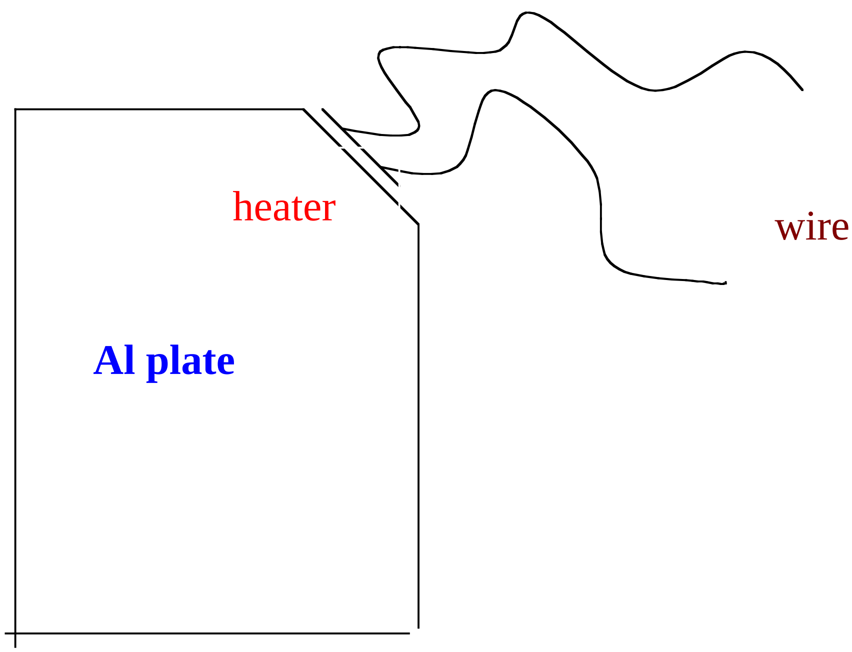


Figure 1

This shows the connection among the heater/wire and aluminum plate. The reason we use Al plate is that it is easy to be machined and will not oxidized. It also has no magnetic induction property as Fe.

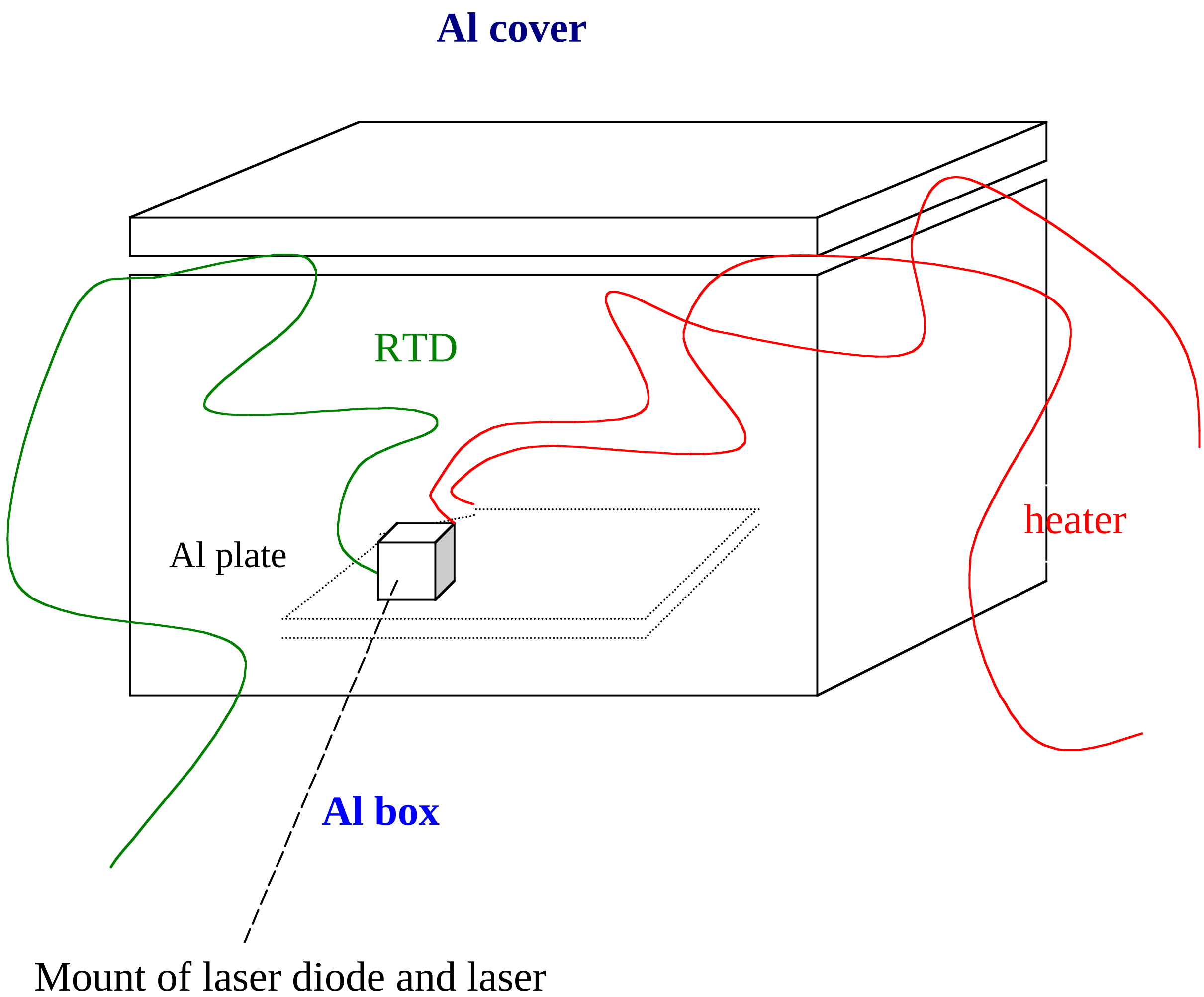


Figure 2

This show the location of Al plate, mount of laser diode and laser, heater, and RTD in the Al box.

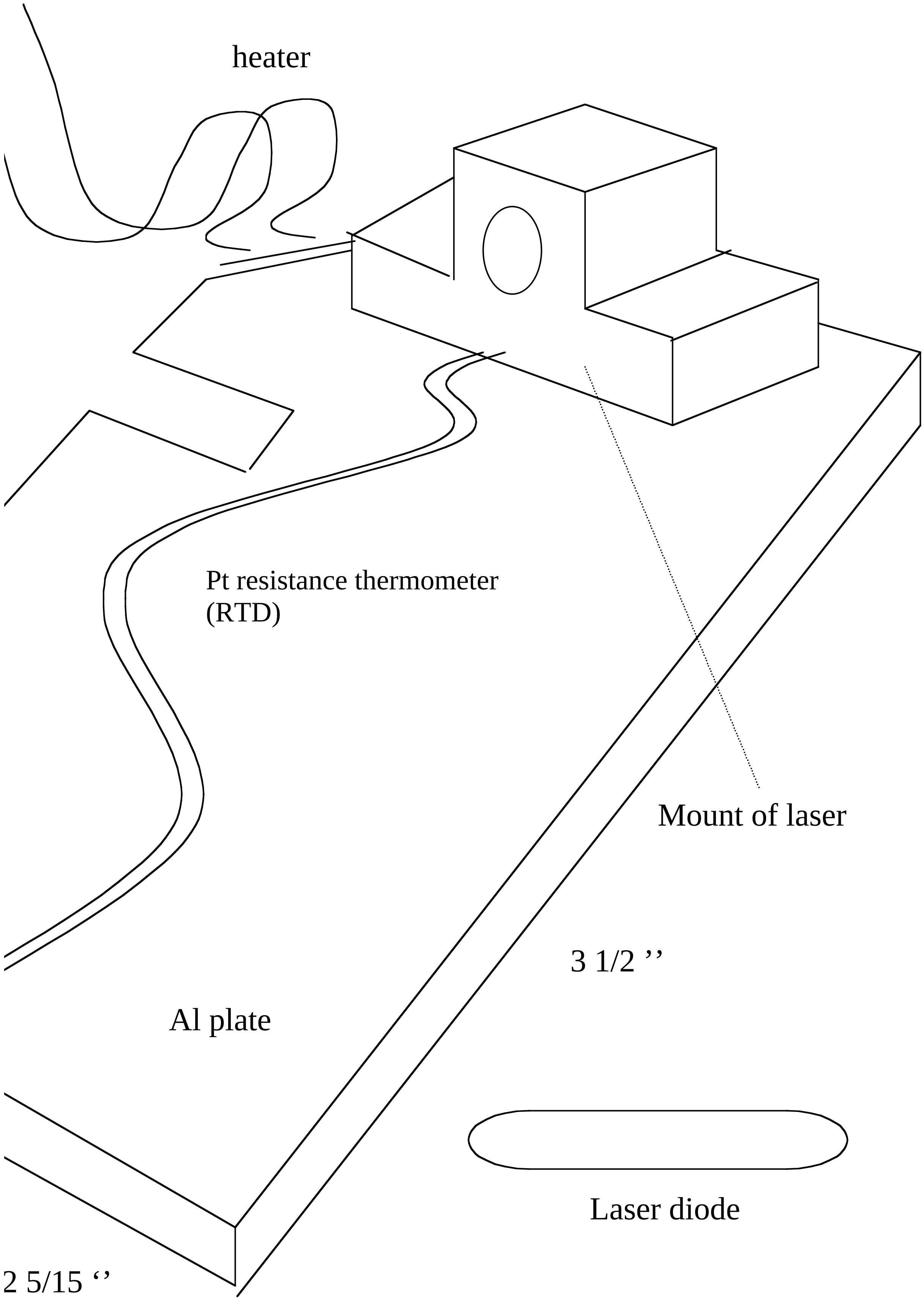

heater
Pt resistance thermometer
(RTD)
Mount of laser
3 1/2 ’’
Al plate
Laser diode
2 5/15 ‘’

Figure 3

Figure 3 shows the location of heater, Pt resistance thermometer (RTD), and mount of laser on the Al plate. The laser diode should be insert into the hole at the middle of the mount.

A: Output (to power supply), Analog, 0-10V, pins 4,5

B: Input (from RTD), pins 1,2,4,5

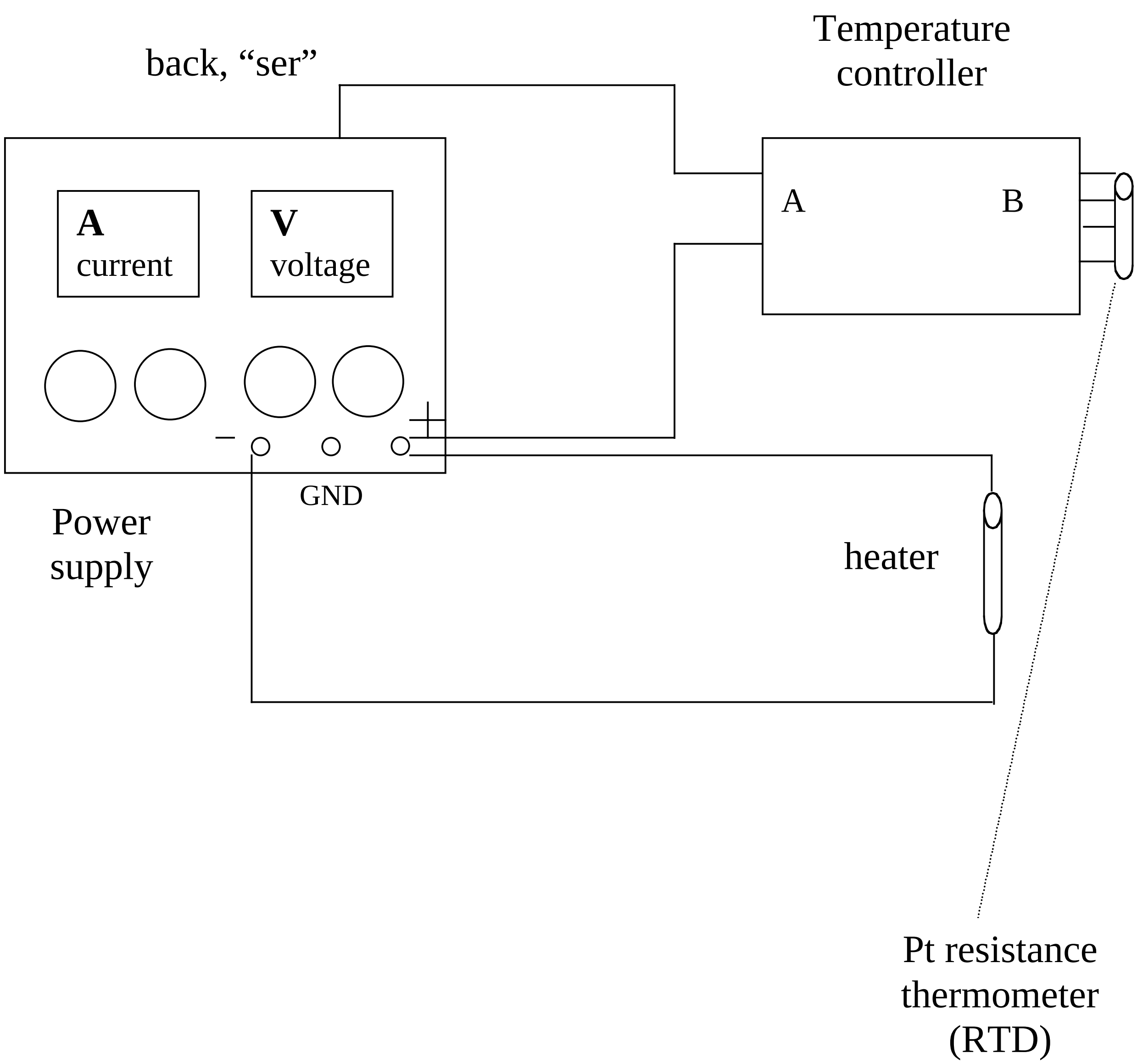


Figure 4

This figure shows the connection between the power supply, temperature controller, Pt resistance thermometer (RTD), heater, and wires.

2.2 Basic concept and component of the control system

Precise control of the temperature of both the baseplae and the laser diode is essential for the long term reliable operation of the laser at a certain wavelength. The base plate of the laser system is in thermal equilibrium with the room temperature. The laser diode mounting block should be kept 1-2°C warmer than the base plate [2].

We used a film temperature sensor to measure the temperature, and used a temperature controller to activate the heater if the temperature of the base plate is lower than the setting value. For heating up, the mission is done by a film heater, whose current is provided by a DC power supply.

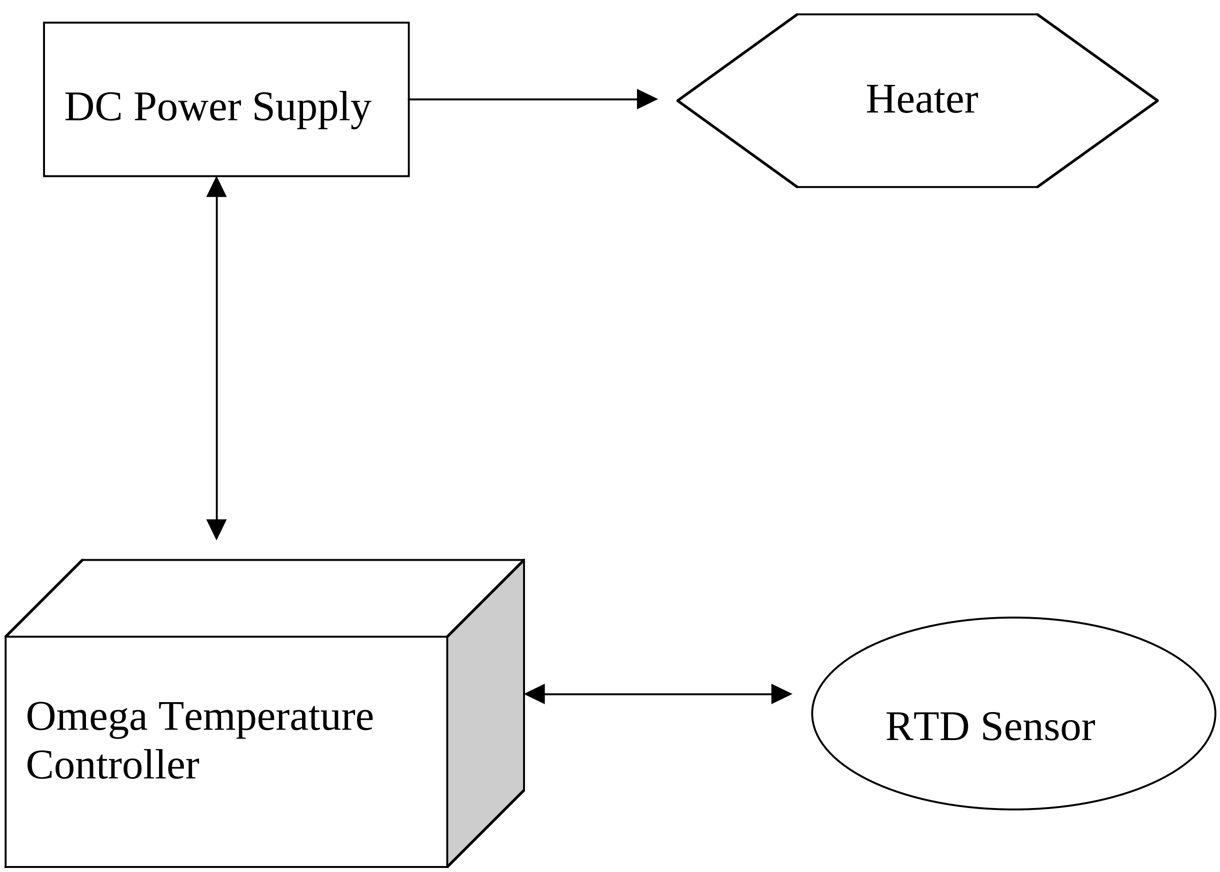


Figure 5

The temperature sensor is a 4 wire RTD, Resistance Temperature Detector. It has 2 red ends and 2 black ends. Both red ends are the same, so do the black ends. One out of the 2 red ends cooperates with one of the black end to measure the voltage across the target. The other 2 ends measure the current. It was carefully screwed under the laser diode mounting plate. We put some vacuum grease between the sensor and the plate to make sure that there is good thermal conduction.

Omega temperature control has 4 digits. We set it to be 2 decimal place. It has a good reliability. The function of the controller is to record the temperature of the base plate regularly. And give instruction to the power supply whenever the temperature is lower than the setting value.

A DC-power supply (TENMA Laboratory DC Power Supply 72-6152) provide a constant output power for the heater resistor. The output voltage of the power supply is remote-controlled with the external voltage, which is provided by the Omega temperature controller. The current needed is around 0.2A and the voltage needed is around 2.6V.

2.3 Programming Instruction for the Omega Temperature Controller

The menu of the Omega temperature controller is not comprehensive. So we would like to provide the programming instructions and the explanation of it.

Input: RTD, pins 1,2,4,5

Output: Analog, 0-10 Volts, pins 4,5

Behavior: Acting as PID control, Proportional Intergration Differention, with 0-10V output active when T<SP1. Besides, the color changes at Alram2 high level.

Programming:

CNFG – configuration mode

INPT – RTD (Pt resistance thermometer, RTD)

– k (Omega typr K controller)

RDG – reading

– deC (decimal number)

– FFF.F

–temp (temperature degree)

–°C (reading in Celcius degree)

FLTP – 0002 (filter)

ANGL– dsbl (disable analog mode. If we choose enbl, the output voltage will be proportional to the input temperature; when we choose dsbl, output voltage will be constant or 10V when the temperature is below SP1)

ALR2 – Enb1 (when Enb1, the color of reading will change from RED to GREEN)

AbSO (absolute, no reading for temperature below 0°C)

LTCH (letch)

CtCl constant closed = N.O. (normal open)

ActN - AbOV (above STP1, ALR2 will be active)

ALR.L (low setting temperature)

ALR.H (high setting temperature) (ALR2 is active if low < T <high)

LOOP – dsbl

b. Tm 00.09

R.adj 000.1

OUT1 – SELF – dsbl

% low – 0

% high – 0099

Current Output:

4-20 – dsbl (if we use this mode, we can control the current from 4 mA to 20 mA)

ACTN – RVRS

Auto – dsbl

Ant1 – dsbl

Prop – 003.0 (precession of the temperature reading, like "P" control) [4], [5]

REST – 0180 (rate of taking data, like "I" control)

RATE – 000.0 (like "D" control)

dPNG – 0003 (damping)

OUT2 – dsbl (OUT2 is Solid State Relay, we don't use this because it is using alternative current and voltage outputs)

RAMP – dsbl

ID – CH.ID (input your favorite password)

FULL – dsbl

SP1d – dsbl

COMM –NONE

COLR – N.CLR =RED (normal color, under SP1)

1CLR = AMBER for ALR1

2CLR = GREEN for ALR2

3 Rough Calculation of the thermal effect on the wavelength of the laser diode

Since we are using Al for base plate, we would like to know what's the effect of thermal expansion?

The thermal expansion coefficient α of Al is 23×10e-6(1/°C).

$$L = L_0[1 + \alpha(T - T_0)]$$

And since there is always a fluctuation of temperature about 0.1°C , the changed length is ΔL.

$$\frac{\Delta L}{L} = \alpha \cdot \Delta T = 23\times 10e\text{-}6\times 0.1 = 2.3\times 10e\text{-}6$$

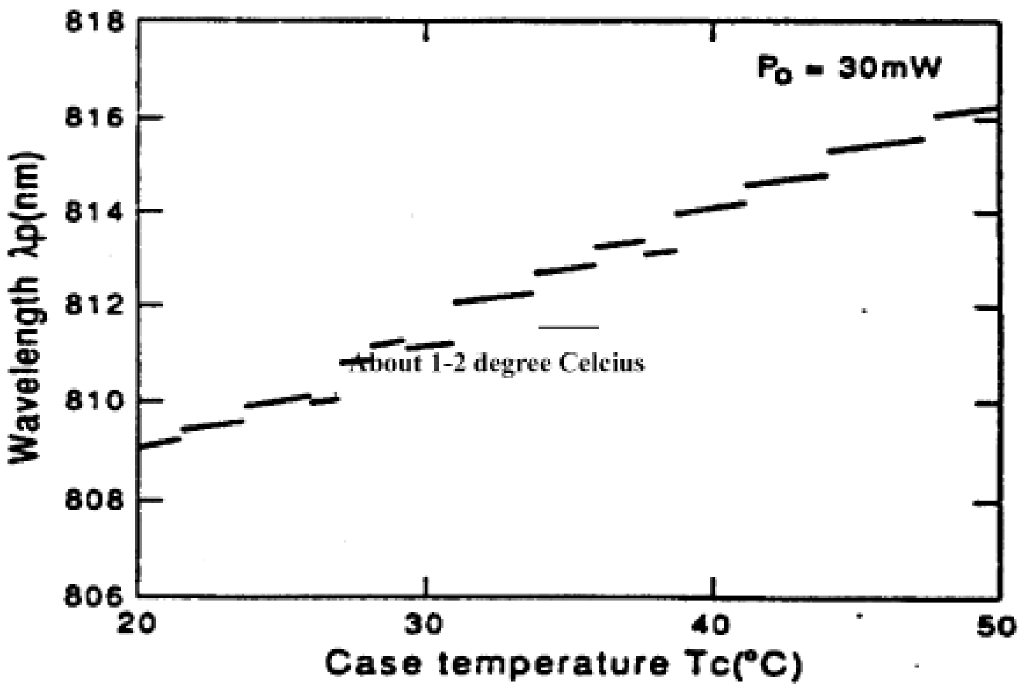
L=5cm=the distance between the laser and the mirror

∴ΔL=0.05×2.3×e-6=1.2×10e-7

λ of laser diode is 780nm=7.8×10e-7

$\Delta L/\lambda = 15\%$

The following graph, figure 2, is the relation between laser output wavelength vs. the temperature of the base plate. The bar of step is about 1°C wide or more, so ΔL might not effect too much. However, if we are at the border of the bar, we can try to align the wavelength to the center of the step bar (though it might need help from expert).



Laser output wavelength vs the temperature of the laser case. The short continuous segments indicate the tuning of the optical length of the cavity for a given longitudinal mode. When the peak of the gain medium has shifted too far, the laser jumps to another mode. This is indicated by the breaks in the curve.

Figure 2

4 Conclusion

The most frustrating thing is there is a continuous fluctuation of the temperature. The value of fluctuation is 0.1°C, and the average time is 3-5 second.

We located the temperature controller in a closed Al box. However, the situation didn't improve. We did try to minimize the effect of the air fluid by locating it in a closed Al box or using sorbothane rubber to absorb the mechanical vibration, but none improve the situation. So maybe it's the limit of the Omega temperature controller.

The fluctuation might come from two reasons: the device and the environment noise. How can we distinguish between them? We suggest put the whole system, the temperature controller, RTD, and the Al plate, into a cooling system. If the fluctuation comes from environment noise, it should depend on temperature. So when we lower the temperature to a significant lower temperature, such as -20°C, there should be a obvious decrease of the noise and the fluctuation time should become longer. However, if the fluctuation comes from temperature controller's intrinsic property, the fluctuation time should remain the same.

However, the Omega temperature controller did show a good ability to maintain the temperature at the setting point. As a result, we believe this temperature control system can supply a stabilized laser diode system to make it remain at almost the same wavelength.

5 Reference

[1] Carl E. Wieman. The Richtmyer Memorial Lecture: Bose-Einstein Condensation in an Ultracold Gas. Am. J. Phys. 64 (7), July 1996.
[2] K. B. macAdam, A. Steinbach, and C. Wieman. A narrow-band tunable diode laser system with grating feedback, and a saturated absorption spectrometer for Cs and Rb. Am. J. Phys. 60 (12), December, 1992.
[3] Carl E. Wieman and Leo Holberg. Using diode lasers for atomic physics. Rev. Sci. Instrum. 62 (1):1-20,1991.
[4] Digital control using digital signal prossecing. Prentice Hall PTR, 1999. Farzad Nekoogar & Gene Moriaity.
[5] Design and Analysis of Control System. CRC Press, 1999.