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Controlling the Wavelength of a Laser Diode

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Abstract

The wavelength of a laser diode can be successfully controlled by using back-reflection, temperature stability and control, and a piezoelectric disk. The thrust of this project was to use a Rb cell to determine the wavelength stability and control of a laser diode set-up. Detailed instructions for set-up are included.

The purpose of this project was to develop a simple way to get a commercial infrared laser diode to be easily tunable over the atomic resonance lines of rubidium. This set-up was designed with future projects such as saturated cell absorption and atom trapping in mind. Many of the ideas included here came directly from K.B. MacAdam and Carl E. Wieman as referenced.

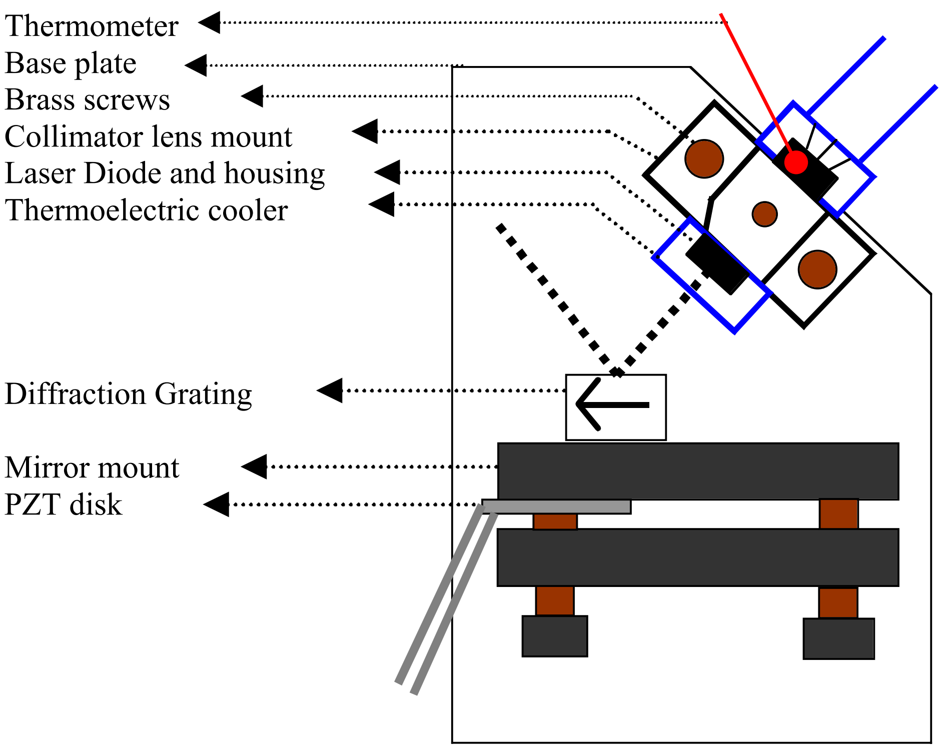
The two ways we used to tune the wavelength of the laser diode are temperature control and by creating a pseudo-external resonance cavity using a diffraction grating. Altering the temperature of the laser diode will cause the laser cavity to change size, which in turn changes the wavelength of the emitted light. The wavelength change is not continuous as a function of temperature; it behaves as a step function due to mode hopping. As the diode cavity hits various modes of resonance the wavelength can make abrupt changes. [2] These abrupt changes are undesirable both because they may skip over the desired wavelength entirely and for the future projects mentioned above a smooth transition through the rubidium resonance lines is desirable. A diffraction grating placed in the following configuration allows for continuous scanning of wavelengths around the wavelength already achieved by temperature dependence. The grating should be mounted with its ruling vertical and so that it diffracts its first order interference maximum back into the laser cavity. This creates a complex oscillator, however the optical feedback from the grating is more prevalent than that of the diode. Therefore you can change the wavelength of the output beam or zero-order beam by adjusting the distance between the grating face and the laser diode. [1]

List of our components:

Laser diode (GaAlAs) from Thorlabs model HL7851G
Mounting 3600 Kit from Optima
    design wavelength: 785nm
constant power laser driver from Thorlabs model LD1100
diffraction grating (1200 line per mm with 750 nm blaze)
standard commercial mirror mount

collimator lens mount (as described in MacAdam)
thermometer
thermoelectric cooler
Temperature and Process Controller Cni3252 from Omega
PZT disk PE-8 from All Electronics Corp
2 AC voltage generators
base plate (Aluminum)
metal box (Aluminum)
rubber feet
rubidium cell
CCD camera and television for viewing fluorescence

Set-up:



Several aspects of our set-up were designed just as the manufacturer or MacAdam described. Those directions will not be repeated in this paper, however they are generally described as follows. We assembled and collimated the laser diode and mounting kit as described by Optima. Purchased a commercial constant power laser driver and assembled as described by Thorlabs to run laser. Machined a collimator lens mount as described in MacAdam. Set up the thermometer and thermoelectric cooler with the Temperature and Process Controller and an AC power supply as described in the operation instructions for the cooler. We mounted the thermometer directly to the laser diode housing using scotch tape and set the Controller to work on its auto function. We chose the auto function because it achieved the desired temperature swiftly and maintained stability as well as the manual configurations we designed.

For some aspects of our design and set-up we had to invent our own ways of accomplishing the tasks. The directions for the assembly and design are as follows.

Diffraction Grating

Our diffraction grating is a 1200 line-per-mm grating with 750 nm blaze and dimensions of 1/2" x 1/2" x 3/8". We cut the standard 1" x 1" x 3/8" grating into several pieces in order to get more than one set-up out of the gratings. To cut the grating, apply clear fingernail polish to the grating surface for protection. We used a diamond saw to cut the grating into four equal pieces by bonding the bottom of the grating to an aluminum-cutting mount using a product called Crystal Bond. To clean the pieces heat the aluminum mount and remove pieces, then with tweezers carefully set pieces into a beaker of methanol placed in an ultrasonic cleaner. We discovered that the pieces might need to be cleaned two or three times with fresh methanol each time. Pieces are clean when no residue remains on the grating surface. The direction of the blaze is toward the reflected output beam, see arrow on grating in figure above. Take care not to touch the grating surface as you mount the grating to the moveable side of the mirror mount. Aligning the blaze direction and getting the IR beam to hit near the center of the grating can be tricky, so we suggest using Duco cement as an adhesive because pieces bonded with Duco can be easily removed and rebounded if necessary.

Aligning and Back-Reflection

By using the configuration above you should already be close to back-reflection, the following is a description of our specific way of finding back-reflection. Poke a pin-size hole in a small scrap of paper. Position this hole between the laser housing and the diffraction grating. Then look at the laser with the CCD camera. You can see the back-reflection as an intense dot. Move laser housing in and out of lens mount and/or shift grating rotating lens mount course adjustment knobs until back-reflection is in the center of the laser beam as seen by the CCD camera.

Aluminum Base Plate and Box

The base plate was made out of aluminum and has to have holes drilled and tapped to screw down the lens and mirror mount. We also found it helpful to screw the base plate to the outer box so that the base plate remained stable as we rotated the screws on the mirror mount. The box should be of the dimensions suggested in MacAdam. The outer box needs to have several holes: one for the laser to exit (we suggest at least a 1/2" diameter), a couple for the laser, thermometer, and the thermoelectric cooler wires, one for the piezoelectric disk wires, and a couple to allow you to adjust the mirror mount screws. Rubber feet should be placed on the bottom of the box to reduce vibrations.

Fluorescence

Depending on your laser diode and your specific room temperature you may need to heat or cool your laser to find your fluorescence lines. Our laser needed to be cooled in order to achieve fluorescence. We found fluorescence by placing the Rb cell in the direct path of the laser and ramping the temperature down and then back up slowly. Watching for fluorescence in the Rb cell with the CCD camera. There should be several temperatures where resonance occurs caused by mode hopping. The temperatures of fluorescence might be significantly different on the ramp up vs. the ramp down. This is caused by hysteresis and can be minimized by ramping the temperature slowly. Determine the strongest fluorescence temperature and set the temperature controller to stabilize there. Stability may take several hours. Turn on the voltage source for the PZT disk and set it to an initial voltage that will allow you a range both above and below by 5 to 6 volts. Once the temperature has stabilized use the mirror mount screws to carefully achieve fluorescence. Then use the fine tune on the PZT voltage to scan over the atomic resonance lines. In rubidium are four resonance lines within a few hundred MHz of each other. If you change the voltage slowly enough you should be able to see all four. You will notice that one of them is brighter than the rest and all four lines may be more or less intense at different temperatures. Fluorescence should fade in and out and be the strongest at the center of the atomic resonance scan for one line. We found three temperatures of fluorescence and could scan over all four lines at each of the three temperatures using the PZT voltage; however we found that stability was easiest to achieve with the strongest of these lines. Our fluorescence temperatures were 12, 11, and 7.5 degrees Celsius with 11 being the strongest. We could achieve fluorescence stability for about a minute before it faded. Fading could be caused by mechanical relaxation in the PZT disk, small temperature fluctuations, or small vibrations. Using this set-up we found fluorescence easily, but if your having troubles see MacAdam referenced below.

References:

[1] MacAdam, K.B., Steinbach, A., and Wieman, C., "A narrow-band tunable diode laser system with grating feedback, and a saturated absorption spectrometer for Cs and Rb", American Journal of Physics, vol.60 no.12, December 1992, pp. 1098-1111.

[2] Wieman, Carl E., "Using diode lasers for atomic physics", Rev. Sci. Instrum, vol.62 no.1, January 1991, pp. 1-20.