Diode Laser Spectroscopy Guide

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Introduction

This is a preliminary guide to the laser spectroscopy experiment. It will direct you to sections of other documents that will help you understand and carry out the experiment. The documents that you will be using are the Teachspin “Diode Laser Spectroscopy” user manual, and the Caltech Advanced Physics Laboratory - Atomic and Optical Physics - “Saturated Absorption Spectroscopy” writeup. These documents are available on the course website.

Warnings

– Note that whenever the laser is turned on YOU MUST WEAR LASER SAFETY GLASSES.

While wearing the glasses you can’t see the laser beam or any spots it makes. To see the beam, there are two tools at your disposal. The first is a special card that converts the infrared light to visible light that you can see through the glasses. The second is a video camera that is sensitive to the infrared part of the spectrum. There may also be special IR (Infrared) viewers to view the beam. Note that these viewers are very fragile, so don’t drop them or bump them into anything.

– DO NOT TOUCH THE OPTICAL SURFACES of any of the optics in the experiment.

This will get oil from your fingers onto the optics and degrade the quality of the light beams.

Advance Reading

Before starting the experiment, please read the following documents, available from the course website:

• Caltech Saturated Absorption Spectroscopy writeup: You can initially skip the section of this document labeled “Quantitative Picture of Saturated Absorption Spectroscopy: 2-Level Atoms.” You can come back to it later for a better understanding of the physics of the experiment.

• “Laser Physics” from the TeachSpin diode laser spectroscopy manual. This tells you how a diode laser works, and discusses the issue of mode hopping, and how to avoid it.

• “Getting Started” from the TeachSpin diode laser spectroscopy manual. This tells you how to operate the laser and how to setup initial measurement to measure the absorption due to the gas of Rb atoms.  
  Note: Do not make any adjustments that involve removing the cover from the diode laser assembly. These adjustments have already been made.

Experiments you will perform

Measurement of absorption of laser light by a gas of Rb atoms: The ground-state Rb hyperfine structure

This part of the experiment is discussed in Section II of the Caltech Saturated Absorption Spectroscopy writeup “Getting the Laser on Resonance” and in Figure 9 of that document. The “Getting Started”
section of the TeachSpin Laser Spectroscopy Manual also has instructions for setting up the absorption measurements.

When you look at the absorption of the light due to the Rb gas, you will also be able to see mode hopping of the laser. This will be evident by the sudden changes in the intensity of the light hitting the photo detector. The “Getting Started” guide will help you eliminate the mode hopping while scanning across the absorption spectrum

Saturated absorption spectroscopy: The excited-state Rb hyperfine structure

This is described in the Caltech saturated absorption spectroscopy writeup, as well as the TeachSpin “Getting Started” section.

Quantitative measurement of the Rb spectrum

Here, you will build an \textit{unbalanced} Michelson interferometer that you can use to make a quantitative measurement of the frequency differences between the various spectral lines. Techniques for setting up the interferometer are discussed in the TeachSpin “Getting Started” guide.

Other Experiments

If you read the documents from TeachSpin, you will find suggestions for other experiments you can perform. If you find any of these particularly interesting, talk to your instructor about the possibility of trying them. Examples are:

- \textit{Interferometric Measurement of Resonant Absorption and Refractive Index in Rubidium}
- \textit{Resonant Faraday rotation as a probe of atomic dispersion}

Control Panel

We discuss the various modules on the control panel (shown in Figs. 1 and 2) in turn:

![Figure 1: Laser Control Panel: Left side](image)
• The ON/OFF switch labeled LASER POWER in the lower left part of the controller (Fig. 1) turns the current to the laser on and off.

• **CURRENT module:** The 10-turn potentiometer controls the current to the laser. The current can be monitored by connecting the LASER CURRENT output in the **MONITORS** section to a digital volt meter. The laser current (in mA) is the measured voltage (in V) times 10. For example, 5V on the LASER CURRENT monitor corresponds to 50 mA laser current.

  The MODULATION INPUT allows one to modify the laser current by the application of a voltage to this input. The ATTENUATOR knob attenuates the signal from the MODULATION INPUT, reducing the size of the modulation.

• **CELL TEMPERATURE:** This indicates the temperature of the gas in the Rb cell. This is set by a control on the back of the control unit. You don’t need to change this.

• The **RAMP GENERATOR** module generates a voltage ramp in the form of a triangle wave. The upper two knobs control the frequency, and the amplitude (max voltage - min voltage) is controlled by the AMPLITUDE knob. The RAMP OUTPUT should be connected to the MODULATION INPUT of the PIEZO CONTROLLER and also to the MODULATION INPUT in the CURRENT section of the controller.

• **PIEZO CONTROLLER:** There is a piezo-electric unit on the laser head. This piezo unit is attached to a the diffraction grating so that when a voltage is applied to the piezo unit, the angle of the grating is changed by an amount proportional to the voltage. This results in a change of the wavelength (and therefore, the frequency) of the laser. To get the laser to scan through a range of frequencies the output from the RAMP GENERATOR is sent to the PIEZO CONTROLLER. The PIEZO CONTROLLER allows one to add a D.C. voltage offset to the signal from the ramp generator, as well to attenuate the ramp generator signal [QUESTION, WHICH OCCURS FIRST THE ATTENUATOR, OR THE DC OFFSET]. The MONITOR output is used for displaying the signal to the piezo unit on an oscilloscope. The MONITOR OFFSET knob allows one to easily control the vertical position of the ramp signal when displayed on the oscilloscope.
On the right side of the control unit is some analogue circuitry that allows one to process the signal from one or two photodetectors (see Fig. 2). The two inputs (DETECTOR INPUTS), can each be scaled by a factor between 0 and 1 (BALANCE). Then the difference between the two signals is taken, and multiplied by the GAIN. One can look at this amplified difference signal by connecting the MONITOR output to the oscilloscope. One can also filter this signal with a low-pass filter (attenuate the high frequency components), by setting the TIME CONSTANT. The larger you set the TIME CONSTANT, the more the high-frequency parts of the signal will be suppressed, and the less noisy the signal will look. But if the TIME CONSTANT is set too high, the shape of the signal will be distorted. After the low-pass filter, you can subtract a DC OFFSET. And again amplify this difference by adjusting the GAIN control on the far right side of the unit. This circuitry is particularly useful for looking at the saturated absorption signal. In the saturated absorption experiment, the laser beam is split into two (by a “wedge”), and the two beams pass through the atomic gas after which each beam strikes a photodetector. One of these two probe beams overlaps with a counter-propagating pump beam of higher intensity. By taking the difference between the signals from the two photodetectors, one can subtract away the Doppler broadened signal, leaving just the saturated-absorption signal.

This circuit is also useful for looking at the output from a single photodetector in which there is a relatively large d.c. (constant) component and a much smaller varying component. If one is just interested in the varying component, one can try to use the vertical offset knob on the oscilloscope, but often the range of the dc offset on the scope is insufficient. By using the DC OFFSET knob on the right side of the control panel, one has access to a much larger range of the dc offset than can be obtained with the oscilloscope.