Physics laboratory, exercise number 110, room 4/33

Diode laser

Responsible: Dr. Ana Predojevic, tel: 6343

1. Introduction

Lasers, in general, are powerfully optical spectroscopy tools. One can classify lasers based on the process used to generate light: gas lasers, dye lasers, solid state lasers, semiconductor lasers etc. The semiconductor (diode) lasers are the ones where the amplification mechanism is based on the drift of the charge carriers between the conduction and valence band. The diode lasers, compared with other types of lasers possess various advantages: low-priced, robust and compact. In addition diode lasers cover very wide range of wavelengths and posses almost no amplitude noise.

Objective

You will investigate the optical characteristics of a diode laser. You will investigate the power and frequency dependence on the change of current and temperature.

Apparatus

Diode laser (675nm)
Current driver
Temperature controller
Oscilloscope
Function generator
Fabry-Perot resonator
Photo diode
(Powermeter)

2. Experiment

An optical cavity is an arrangement of mirrors that forms a standing wave cavity for light waves. Due to the condition that the standing wave has to form nodes on the mirrors only discrete wavelengths and/or frequencies are allowed to form a cavity. The pathlenght between the mirrors has to be a multiple of half a wavelength. Equivalently, the frequency of the light has to be a multiple of the so called free spectral range. For a linear resonator the free spectral range is equal to c/2L, where c is the speed of light and L is the distance between the mirrors. Optical cavity transmits only the resonant wavelengths and consequently acts as a filter.
The laser is formed by an amplifying medium contained in an optical resonator. Lasing operation is achieved for losses (mirror transmission, scattering, etc) being compensated by the amplification.
Laser diode used in this exercise consists of GaAlAs semiconductor. Due to the high index of refraction of this material compared with the air the end faces of the semiconductor form mirrors with reflectivity equal to 34%. This way they an optical cavity is formed around the semiconductor.
The more detail background is to be found in the second document entitled lasers and resonators. This document can also be found on the server.

Methodology

The laser diode is held in a housing whose temperature can be changed using a Peltier element (thermo-electric cooler) and controlled using a temperature controller. The temperature of the laser diode (and the housing) can be measured by a temperature sensor.
On the temperature controller front panel there is a switch which enables us to see the set point temperature or the actual housing temperature. These temperatures can be read out from the calibrated multimeter (10mV=1ºC).
Beside the diode laser the metal housing also contains the so called "monitoring photo diode". The diode laser can provide the laser light through both end faces. While one end face provides the light we are going to couple to the Fabry-Perot interferometer (Figure 1.) the light from the other end face is collected onto this monitoring photo diode. This photo diode is to be used in case a powermeter is not available during the exercise. The way to use this diode as the power control is to calibrate it at the beginning of the exercise using a powermeter as a reference.
The light from the diode laser is sent onto a lens called collimator which collimates the light beam. The light beam is than reflected of two mirrors which couple it into Fabry-Perot interferometer. The Fabry-Perot interferometer is, of course, an optical resonator. Its cavity length can be scanned by a piezo actuator which is holding one of the cavity mirrors. The piezo actuator is driven by a high voltage driver and the triangular scanning signal is provided by a function generator. The light transmitted through the Fabry-Perot cavity is detected by a photo diode. The signal from the photo diode can be seen on an oscilloscope. The oscilloscope should be triggered by the same triangle signal which is used for scanning of the Fabry-Perot interferometer. The example of the oscilloscope screen with detector signal and the triangle scanning ramp is given in the figure 2.

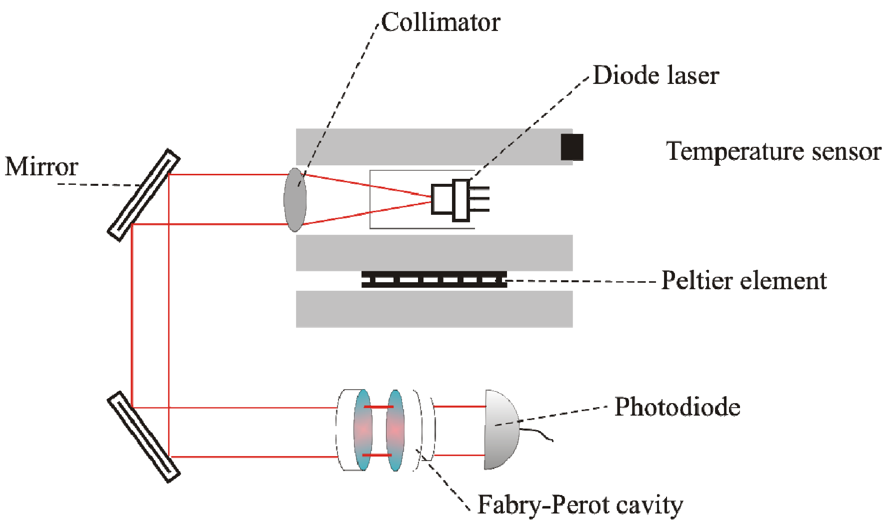

Figure 1. Schematic of the experiment

3. Tasks

1. Characterisation of the output power

Measure the output power of the laser as the function of driving current. You should repeat this measurement for three different diode working temperatures placed in the range between 10ºC and the room temperature. Plot the power-current dependence curves (diode characteristics) for all the measured temperatures and determine each characteristic's threshold current. From the curve determine the slope efficiency of the over-threshold laser.

2. Frequency-characteristics

Characterise how the emission frequency of the diode laser changes with the driving current and the temperature. Couple the light into Fabry-Perot interferometer and obtain the signal similar as the one given in the figure 2. Having the temperature constant change the current of the diode and observe the line shift and frequency sudden jumps (mode-hops). You should record this shift and frequency jumps my marking the initial position of the transmission lines and afterwards measuring how the line moves with the change of the current. Once finished this measurement repeat the same procedure but having the current constant and varying the temperature.
Plot the diagram Δv (frequency change caused by current or temperature change) vs. current and vs. temperature. The free spectral range of the Fabry-Perot cavity is 630 GHz and the typical free spectral range of the diode laser is around 150 GHz.

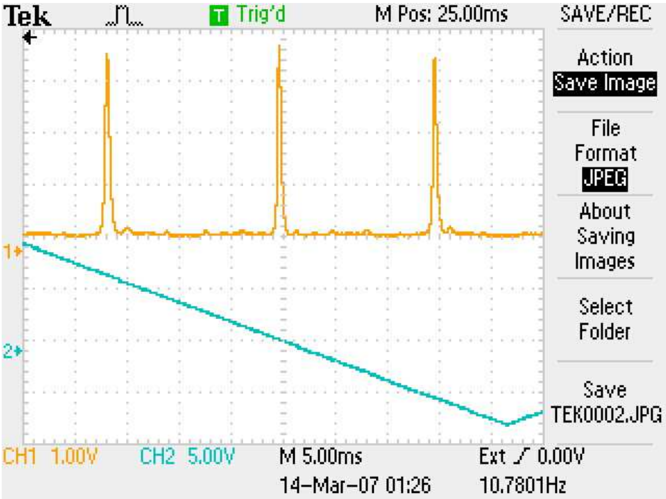

Figure 2. The oscilloscope screen

Useful questions:

1. What is the optical length if the diode laser?
2. Why the laser emission frequency changes with the temperature (current)?
3. How would you explain the existence of the lasing threshold?