**Abstract**

The response time of a semiconductor laser subjected to incoherent optical re-injection was measured and found to be ~500 µs. This is important for developing a model to describe the dynamics of a two-laser system. Also, diffraction gratings and atomic vapor cells were used to create different two-laser systems.

**Background**

The frequency of a semiconductor laser beam changes when an orthogonally polarized laser beam is re-injected into the original laser cavity, whether through single-laser feedback or the use of a second laser. The shift in frequency is linearly proportional to the intensity of the re-injected beam and is due to the change in carrier density in the laser cavity which increases the index of refraction.

Three different devices were used to vary the intensity of the re-injected beam as its frequency changed: an acousto-optical modulator (AOM), diffraction gratings, and atomic vapor cells. The AOM was controlled by a function generator and turned the laser on and off for the single laser systems. The diffraction grating changes the angle of deflection based on the change in frequency and this changes the intensity of the light in the laser cavity. The atomic vapor cell absorbs light of a specific frequency which changes the intensity of that light.

**Part One – Measuring the Response Times of the Semiconductor Laser**

The shift in frequency is not instantaneous due to the finite speed of light and the various electronic devices being used. The response time of the system, or the time it takes the frequency to shift after the laser has been re-injected, needs to be measured in order to better understand the dynamics of the system.

**Results:** The response time of the semiconductor laser was approximately 500 µs. There was a large shift in intensity that took about 10 µs and then a slower decay for the rest of the time.

**Part Two – Dynamics of Two Laser System**

The dynamics of this two laser system was modeled using the following coupled equations:

\[
\begin{align*}
\frac{d\omega_1}{dt} &= \gamma_1[\omega_1 - \omega_2 + 2\pi P]\beta \\
\frac{d\omega_2}{dt} &= \gamma_2[\omega_2 - \omega_2 + 2\pi \beta P]
\end{align*}
\]

where \(\gamma\) is a measure of the response time of the system, \(\omega\) is the initial frequency of the laser, and \(2\pi \beta P\) is the frequency shift that is equal to the product of the intensity \((P)\) of the re-injected laser and \(\beta\), which is the proportionality constant that depends on the system.

A second laser was added to the system and the output of one laser was re-injected to first one.

First, diffraction gratings were used, but almost no shift in frequency was detected. It was suggested that the resolution of the diffraction gratings, or the ability of the system to tell two frequencies apart, was too small. We need something that gives us a large change in intensity for a small change in frequency. Therefore, a Rubidium vapor cell is currently being used to modulate the intensity of the re-injected laser beam. No results to report yet.