Non-Linear Atom-Laser Interactions Using Rubidium Pump- Probe Spectroscopy

Grace Neil, Physical Sciences Department
Faculty Mentor: Bereket Berhane

Background

A diode laser is a laser belonging to the semi-conductor class, using current to excite the electrons in its grain medium to create laser light. Used as a Class 1 laser, the diode-laser used was an Infrared Sanyo 2005 model, with a GaAlAs gain (see Image 1). The model produces tunable light at infrared wavelength using internal and adjustable external cavities with a temperature controlled internal current.

Image 1: The infrared diode laser contains an internal cavity that is temperature dependent and an external cavity that is adjustable with dials as seen to the left in the image.

The rubidium atom has energy levels for both of its naturally occurring isotopes, ^{85}Rb and ^{87}Rb. With ^{85}Rb being more naturally abundant, the diode laser was adjusted to excite the element's atoms from the $5S_{1/2}$ state to the $5P_{3/2}$ state, as seen in Figure 1 at about $780nm$. The energy required to excite these atoms is found using

$$E_{nl} = \frac{-13.6eV}{(n-\delta_{nl})^2} \qquad (1)$$

where n and l refer to the principle and orbital quantum numbers respectively. Here, δ_{nl} is the so-called quantum defect parameter. For this transition in rubidium, the energy required is $1.528eV$. In Graph 1, f_0 refers to this transition.

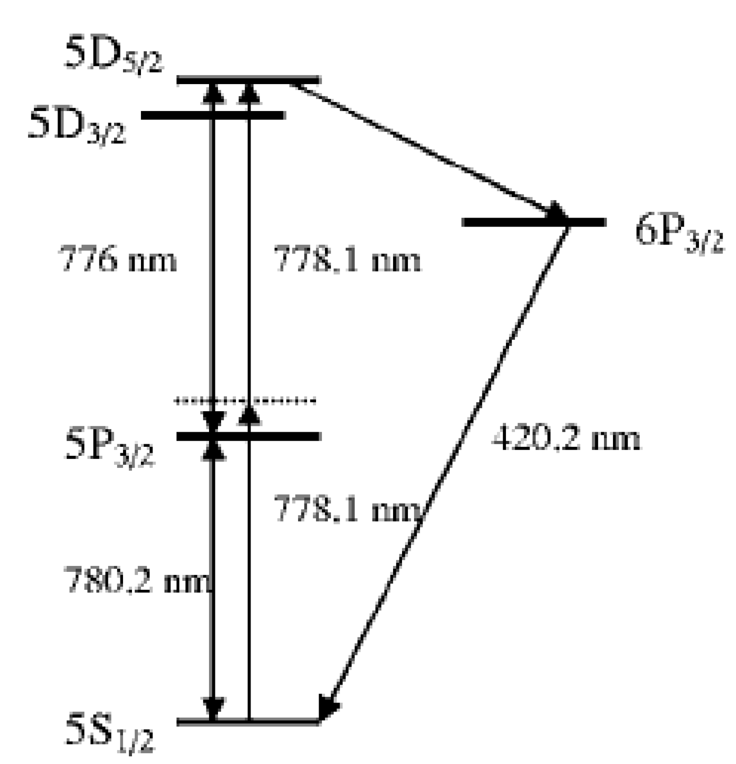


Figure 1: The energy levels of rubidium-85 include several different transitions. The laser was adjusted to target the $5S_{1/2}$ – $5P_{3/2}$ transition, as seen to the lower left on the diagram. The energy levels are slightly modified by spin-orbit coupling.

Experimental Set-Up

Our set-up began with calibrating the diode-laser, obtaining its bandwidth curve and characteristics. The mirrors, beam-splitter, and photodiode detectors were added and adjusted to achieve an operational pump-probe system. Following, the rubidium chamber was placed at the intersection point of the pump and probe beams (see Image 2) at a regulated temperature of 50ºC. The pump beam was then blocked and unblocked from the system at various laser cavity lengths while the probe behavior was recorded. The resulting waveforms from the oscilloscope were then ran through a MATLAB code to produce the final resulting graph, Graph 1.

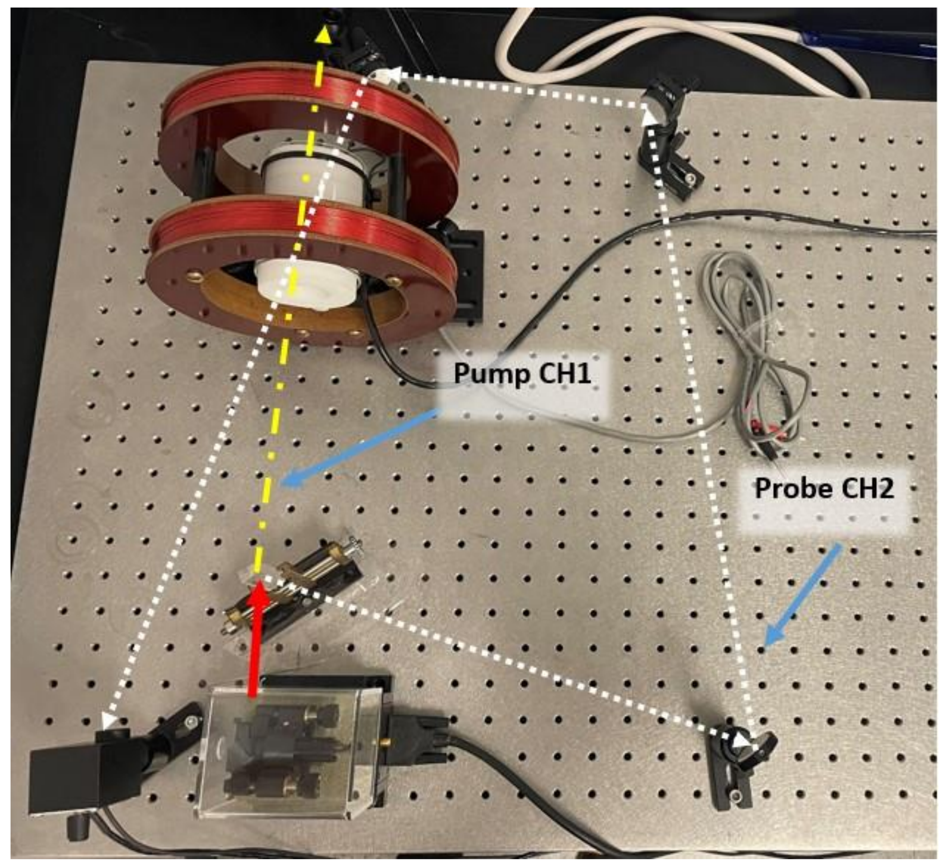
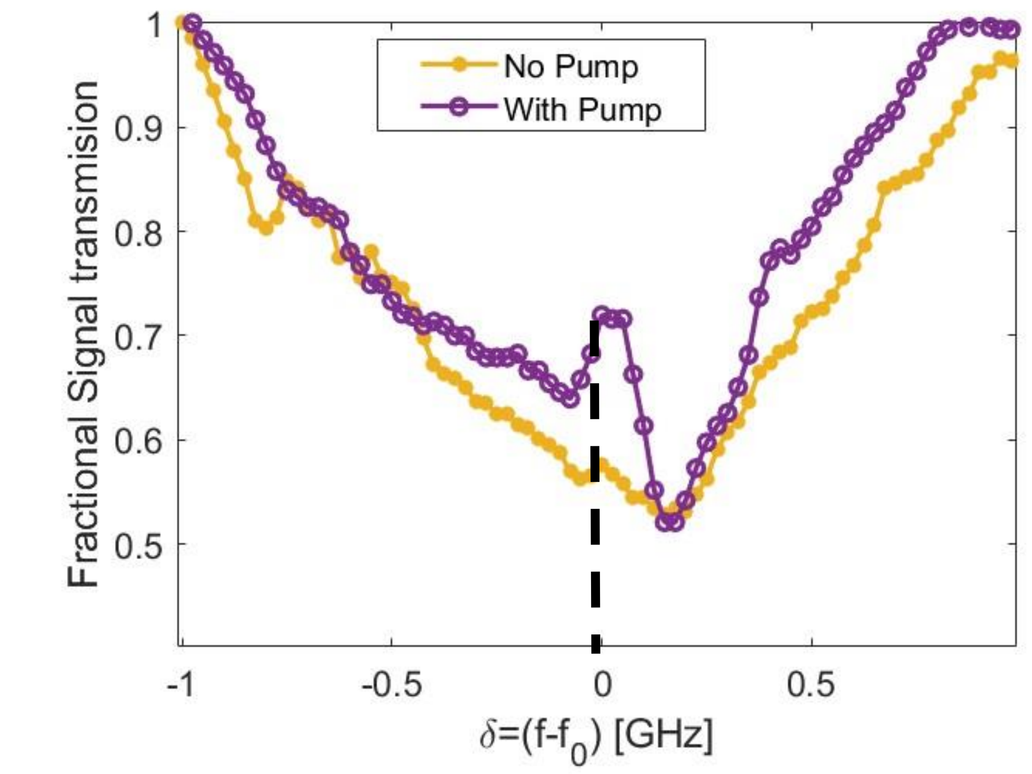


Image 2: Two photo-diode detectors were placed at both receiving ends of the pump and probe beams. The mirrors provided a direct path of intersection between the beams situated in the center of the rubidium chamber.

Resulting Non-Linear Absorption

In the pump-probe mechanism, the probe is absorbed resonantly, or at the frequency f_0, without the pump being present. At the probe, the expectation is to observe the most absorption in the rubidium gas. However, the pump excited a significant fraction of the atoms into the $5P_{3/2}$ state. Therefore, these atoms are not available to absorb the probe. When the probe comes through the rubidium chamber, the atoms are not available to absorb the photons and the absorption is reduced. As a result, the probe shows an increase in transmission. Therefore, the transmission of the probe is significantly dependent of the pump at the resonant frequency f_0 . In the case of a single-beam laser transition, this effect would not be possible. The behavior of the probe shows the non-linear interactions of these two beams which could be used as the basis of demonstrating quantum entanglement.



Graph 1: The probe displays a significant transmission at the resonant frequency when the pump is present.

What is Next?

We plan to continue forward with this project, upgrading equipment and obtaining instrumentation. These changes would allow us to perform several experimental methods to observing quantum entanglement in real time.

References

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