Second Generation External Cavity Diode Lasers for Li-Yb Photoassociation Experiments

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We present a new generation of home-built external cavity diode lasers (ECDL) with improved stability compared to previously built lasers in our lab. We made several improvements in isolating the ECDL from external disturbances and achieved an order of magnitude improvement in long-term stability without any electronic feedback. We also constructed new diode protection circuits that are more robust than those provided commercially and designed locking software to improve the stability of the diode laser used for photoassociation (PA) scans.

I. INTRODUCTION

Over the past several decades atomic physics has grown and made several advances with single species or single atom traps. This has led to particularly interesting phenomena and new and blossoming research fields. An important achievement with single species atoms is the formation of a Bose-Einstein condensate, see Figure 1, where we cool a groups of atoms down such that they all occupy the same quantum state. Such a system allows us to explore quantum phenomena, study super fluids, or create atom lasers for precision measurements.

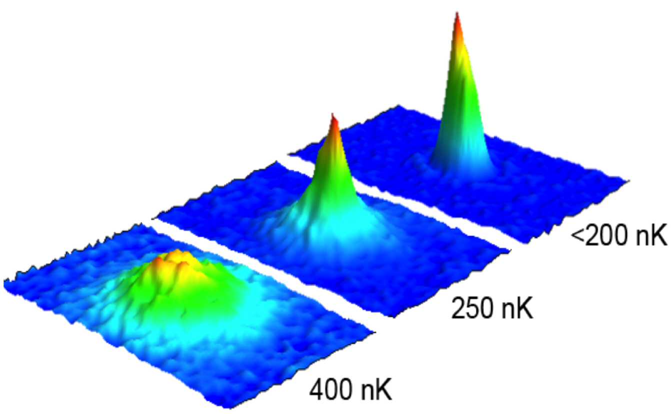

FIG. 1: One of the most notable achievements that arose because of atom traps are Bose-Einstein Condensates (imaged above). By cooling atoms down, we essentially force all of the atoms to occupy the same quantum state and this allows us to explore quantum phenomena. This plot shows a spatial density profile after releasing atoms from a trap and maps the momentum distribution of those atoms. These images are of Ytterbium atom clouds in our ultracold atoms apparatus.

While still interesting and relevant today, single species traps are limited in what we are allowed to control and manipulate. We are limited to controlling translational degrees of freedom and atomic structure such as spin state. A growing field is looking at dual species traps and forming ultracold molecules. What we gain with such a system is access to vibrational and rotational degrees of freedom and molecular electric dipole moments. Ultracold molecules give us the ability to look at long-range interactions between atoms, a means of studying controlled chemical reactions between single atoms, looking at how fundamental constants, such as the proton-electron mass ratio, vary over time using precision spectroscopies, and is a candidate for scalable quantum information processing [1, 2].

No matter if we are trying to trap single atoms or form molecules, the premise behind the implementation is the same. The general approach to cooling atoms is by accessing a 2-level system within that atom; namely, we try to find an atomic transition from an S to a P energy level that is short-lived. With the use of lasers, we shine coherent light all traveling in a single direction. If we aim this light onto an atom, and it excites the particular atomic transition within that atom, it will absorb the incoming photons. Because photons carry with them momentum, and momentum is conserved within a system, the atom receives a "kick" in the direction opposite the propagation of light. Similarly, the atoms emit the absorbed photons in random directions, which have the same effect of kicking the atoms in the direction opposite the emission. Done over a long enough period of time, the atoms receive an effective cooling force in the direction opposite the propagation of the laser light, slowing them down. Further techniques, such as a magneto-optical traps (MOT), evaporative cooling, and optical-dipole traps (ODT), explained further in [3], can further confine and cool atoms to lower temperatures.

In our current experiments, we are particularly interested in trapping Li and Yb and eventually forming molecules between them. With Li, the 2-level system goes from the $^2S_{1/2} \rightarrow ^2P_{3/2}$ at 671 nm light. For Yb, the transitions we use are the $^1S_0 \rightarrow ^1P_1$ at 399 nm light and the $^1S_0 \rightarrow ^3P_1$ at 556 nm. More information about different atomic transitions used and their specific purposes in the experiment is described in [4].

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The main roadblock in one of these systems is then trying to find a light source to activate these transitions. Diode lasers can be purchased off the shelf that are around the correct wavelength for these particular atoms. But, without any additional modifications, diodes often have too large a linewidth (a linewidth of about 100 MHz [5]) and are too unstable to be used effectively within an experiment. With these types of experiments, it is very difficult to access these transitions: the Li principal transition has a linewidth of $\Gamma/2\pi = 5.9$ MHz and the Yb lines mentioned have linewidths of $\Gamma/2\pi = 29$ MHz and $\Gamma/2\pi = 180$ KHz respectively, so an accurate laser is essential in achieving ultracold atoms. See Figures 2 and 3 for more information regarding the specificity of laser frequency and their effect on atomic experiments.

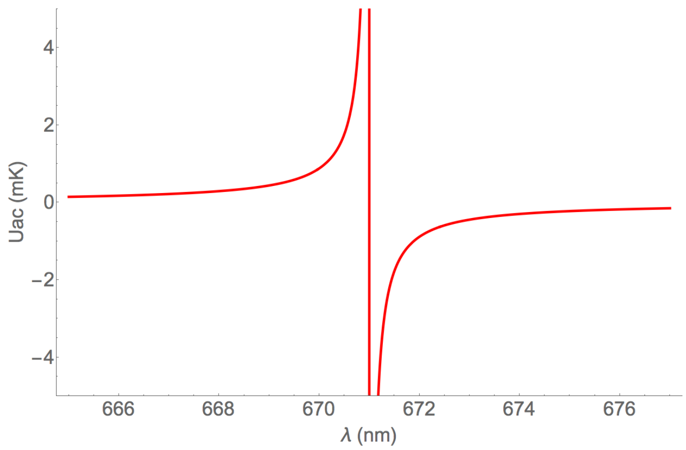


FIG. 2: AC Stark Potential Temperature (mK) vs laser output wavelength (nm) for Li with a power of 100 mW and a waist of 30 μm. In regards to the wavelength of the laser we use to trap Li, the farther we go from resonance of a 2-level system, the smaller the trapping force acting on the atoms gets.

With regards to photoassociation (PA) and PA spectroscopy [6], the need for accurate lasers to access these specific atomic transitions does not go away. PA is a method of obtaining molecules as opposed to looking for Feshbach resonances. In some cases, this is preferable because it gives us access to lower rovibrational energy levels not accessible by using Feshbach resonances and because Feshbach resonances do not exist for all types of mixtures [7]. Currently, we are performing PA spectroscopy experiments to find the specific frequencies of laser light that excite vibrational and rotational energy states in Li-Yb molecules. The difficulty here is still the need for accurate lasers to cool the atoms, as mentioned above, and the need for accurate lasers to scan for PA lines. Figure 4 shows the basic outline of PA spectroscopy, and Figure 5 shows a PA line in LiLi molecules.

One solution to this problem is expanding and modifying diode lasers, which have been used extensively in atomic physics experiments thus far. Diode lasers have become a particularly useful laser in atomic physics be-

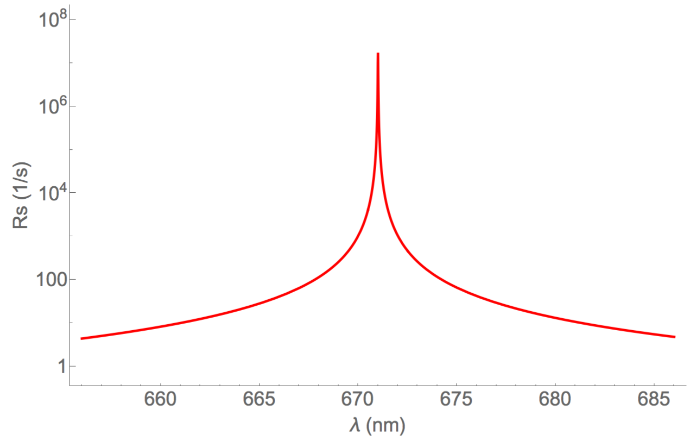


FIG. 3: Scattering rate (1/s) vs laser output wavelength (nm) showing the scattering rate of Li around its resonance with a power of 100 mW and a waist of 30 μm. If we shine light on a Li atom that is resonant with its atomic transition at 671 nm, we notice a large amount of photons scattering. But as we deviate, even by just a small amount, the number of photons that we notice scattering diminishes considerably. The width of this peak corresponds to the width of the atomic transition.

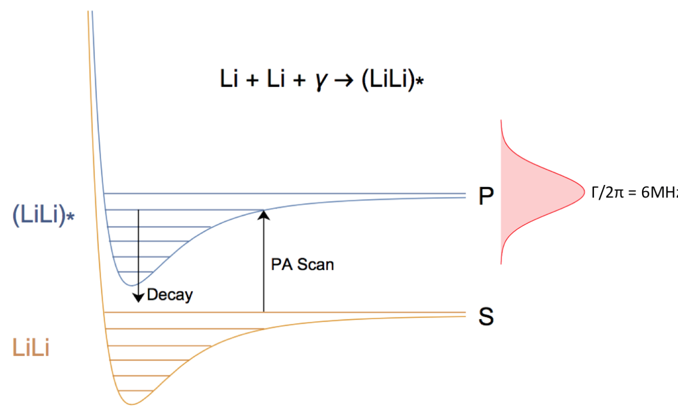


FIG. 4: The goal behind these PA scans is to find which frequencies of light resonate with vibrational and rotational energy states of a diatomic molecule. Finding these lines is difficult given the small range of wavelengths that cause resonance ($\Gamma/2\pi \approx 6$ MHz for LiLi molecules). This diagram shows a 2 particle scattering state transitioning via a photon into a two particle excited state.

cause of their low cost, reliability, range of wavelengths, and power [8]. Especially recently, the range of wavelengths achievable with diode lasers allows for the use of different atoms in experiments that were not accessible before. Diodes are made from semiconductors that, upon receiving a specific amount of current (the threshold current), begin to lase. Diodes themselves are also susceptible to temperature changes, which expand and

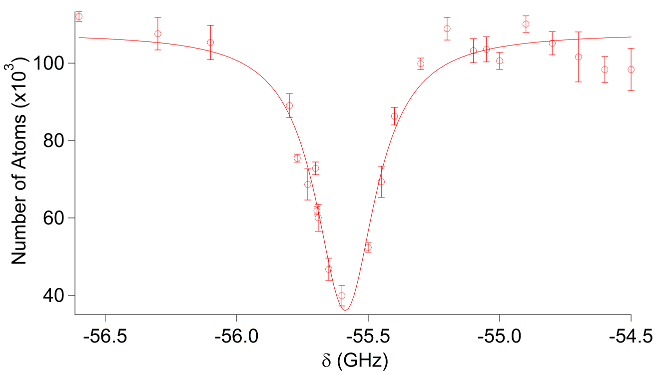


FIG. 5: Sample PA spectrum from our lab showing Number of Atoms vs detuning from the atomic line. This spectrum shows a LiLi PA line. PA spectroscopy is a loss spectroscopy, and we notice a loss of atoms in our trap once we hit resonance with a particular vibrational or rotational energy level in a molecule. Here, we notice resonance approximately 55.5 GHz away from the atomic transition in Li.

contract the diode itself changing the modes of oscillation allowed; a higher temperature increases the wavelength of laser light, and vice versa. Controlling the temperature and the current together allow for precise control on the wavelength and power of laser light, but it does not completely stabilize the output from a diode.

An external cavity diode laser increases the stability and flexibility of a standard diode laser,which ultimately increases the stability of experiments performed with these lasers. This is accomplished by seeding and promoting a specific oscillation within the cavity of the laser, reducing the linewidth in the output frequency significantly. In the Littrow configuration of an ECDL [9], see Figure 6, laser light is shone onto a grating, which reflects the output beam to a mirror and then out of the cavity. The mirror and grating are perfectly parallel and positioned such that for every angle, θ, that the grating moves through, the mirror moves through 2θ. This allows for the grating to be adjusted, changing the geometry of the laser, but keeps the direction of the output beam unchanged. The grating serves to diffract the output beam of the diode. The zeroth-order beam is directed out of the cavity, while the first-order beam is aimed back at the diode. The premise behind this comes from Bragg's law

$$\theta = \arcsin(\frac{m\lambda}{2d}) \tag{1}$$

where θ is the angle at which the laser light hits the grating with respect to the normal, λ is the wavelength of the light, m is the order light we are interested in, and $\frac{1}{d}$ is the slit spacing in the grating.

By changing the position of the grating (its angle) we change the geometry of the laser cavity. This coupled with the geometry of the diode itself further alters the modes of oscillation allowed by the laser light. The first-order light essentially seeds the diode, promoting a specific oscillation within the cavity of the laser, which in turn promotes a specific wavelength of light to be produced, which we see as the zeroth-order beam. The slit spacing is specific to the grating used in every ECDL and cannot be changed without changing the grating itself. Since we are also only interested in the first-order beam ($m = 1$), we can calculate the position of the grating necessary for any particular wavelength.

An ECDL also consists of a piezoelectric transducer (P2T) that can finely change the angle of the grating to achieve a more precise positioning. A temperature controller (TEC) adjusts the temperature of the cavity that a thermistor measures.

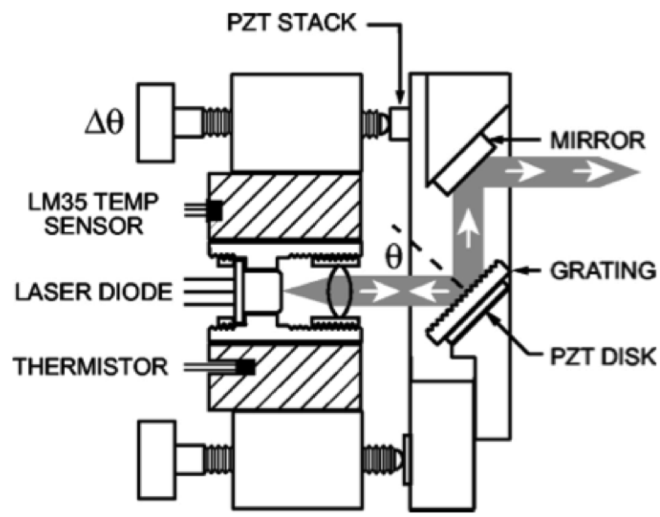


FIG. 6: The basic configuration of a Littrow ECDL. This diagram marks out the key components and their placement with respect to each other to form a functional ECDL. Laser light is shone onto a grating that reflects the first-order beam back into the diode and directs the zeroth-order beam out of the cavity. A piezoelectric is placed over the horizontal control for the stand to finely adjust the position of the grating. A thermistor is placed near the diode to monitor its temperature and a TEC is used to adjust the temperature of the cavity. (Image taken from [9].)

During the seeding process, the threshold current decreases and the amplitude of the output laser light increases for a given current as more light is shone back at the diode. Figure 7 shows this effect, and this can be used as a measure of how well aligned the components in the ECDL are. As the alignment improves between the two, the more amplified this effect becomes, and looking for this effect constitutes the main ECDL alignment procedure.

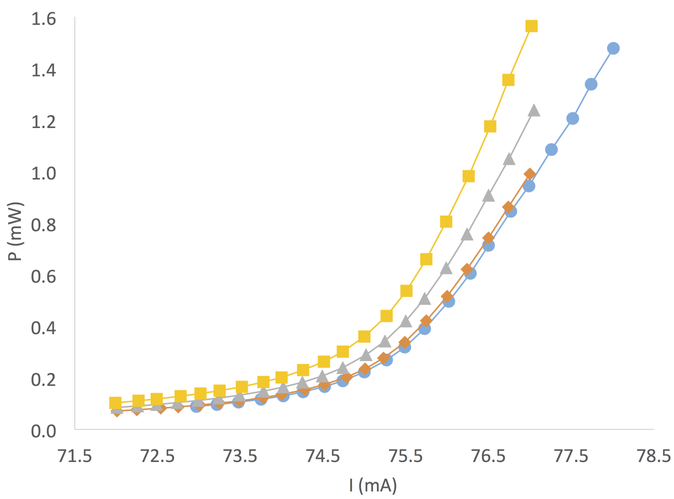


FIG. 7: Output power vs drive current for various seeding positions of a diode in an ECDL. This power versus current plot shows the threshold current for the same diode in an ECDL as the grating was adjusted to maximize the amount of first-order light seeding back into the diode. Each line (and each shape) corresponds to a different positioning. The more light that is reflected back into the diode, the lower the threshold current becomes. Here, yellow squares corresponds to the best alignment. The data was obtained using one of our old home-built ECDLs.

II. APPARATUS

A. External Cavity Diode Laser

Two ECDLs were constructed for use in the PA experiments. One diode operates at 404 nm to excite a long-lived state in Yb and will be referred to as the blue ECDL. The other diode[1] is meant to operate at 671 nm and redder wavelengths for Li-Yb PA spectroscopy and will be referred to as the red ECDL. Both diodes are operated using Thorlabs temperature and current controllers.

In contrast to the multi-part arrangement of the old ECDL, the new ECDL was cut from a single piece of phosphor bronze, the material chosen because of its strength and thermal conductivity. It was constructed from a single piece of metal with the idea that it would then uniformly expand and contract as the temperature of the laser changed during operation.

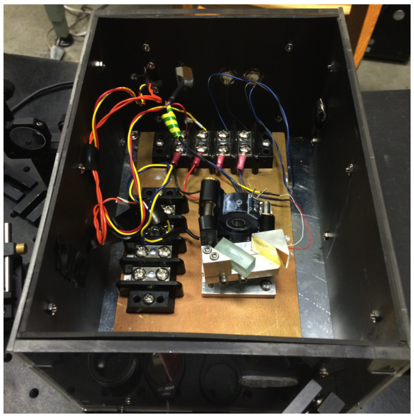
The cavity and enclosure were built to isolate the diode from the outside environment as much as possible. The cover is plastic to thermally isolate the interior from the room. There is a lip in the hole for the output beam so a piece of glass could be installed to limit airflow that would disrupt the temperature of the laser, and a circuit board and electronic connectors are mounted to cover the remaining holes of the enclosure to further limit air currents.

To further increase the stability of the system, the thermistor is located closer to the diode itself to more accurately report the current temperature of the diode to the temperature controller. Thermally conductive epoxy is used to secure it. Directly under the ECDL, where the collimation tube and diode rest within the structure, is the TEC, which controls the temperature of the apparatus. A layer of thermal paste was applied between the TEC and the phosphor bronze and between the TEC and the metal bottom for the ECDL. The piece of phosphor bronze is secured using nylon screws to further thermally isolate it from the base plate.

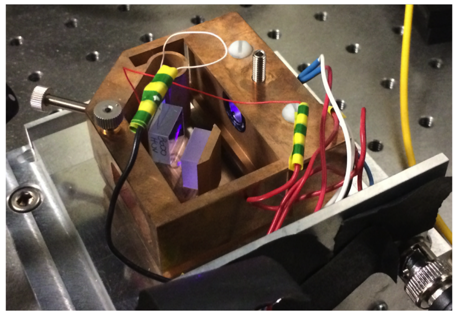
Compared to older ECDLs, where the angle of the grating with respect to the diode could be adjusted with three degrees of freedom, the grating in the new ECDLs were installed such that they only needed two methods of adjustment (vertical and horizontal). On the piece of phosphor bronze, the plates that would hold the grating and the mirror were machined to be parallel to each other such that the direction of the output beam would be fixed as the laser was adjusted. A piezoelectric is attached to the horizontal control of the grating and allowed for fine-tune control of the position of the grating. It also allows for the possibility of external software to control the position of the grating by supplying a voltage to help stabilize the output frequency of the diode.

The grating and the mirror are attached using epoxy. With the blue ECDL, the grating and mirror are attached directly to the phosphor bronze. We could not, however, properly seed the red ECDL with the current laser body without putting too much strain on the threads of the screws holding the platform with the mirror and grating, and this amount of strain meant that the piezoelectric would be ineffective at finely adjusting the grating because of the amount of force needed to move the stand. To rectify this, two wedges were milled our of copper at 6° and are attached to the phosphor bronze with thermally conductive epoxy where the grating and the mirror would rest. We chose six degrees because it adjusted mirrors enough that we could still seed the diode manually, relieved some of the stress on the threads and allowed the piezoelectric to adjust the grating, and still granted enough flexibility in the output wavelength achieved with optical feedback. Because of the limited amount of space between the grating and the mirror, and with the introduction of two new wedges, a thinner mirror is used such that the laser beam does not clip on any edges and still exits the cavity. The grating and mirror are attached to these wedges similarly to how they are installed in the blue ECDL. The red ECDL uses a grating with a line spacing of 1800/mm and the blue ECDL uses a grating with a line spacing of 3600/mm. Both ECDLs use silver-coated mirrors.

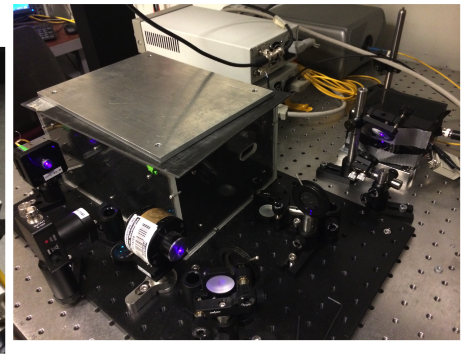
[1] An Eagleyard Photonics EYP-RWE-0670-00703-2000-SOT02-0000 diode was used and can be found by looking at Market Tech's website.



(a) Old ECDL



(b) New ECDL



(c) Both ECDLs. The old ECDL is on the left and the new ECDL under its enclosure is to the right.

FIG. 8: A comparison of the old ECDLs used and the second generation of lasers. The important point to notice is the change in size. The newer ECDLs are much smaller than their ancestors, allowing the temperature and air currents to be easier to control. Both lasers contain a TEC and thermistor, which are not visible from this angle, but underneath the diode, and a grating and a mirror.

B. Diode Protection Circuit

We wanted a more robust circuit that powered the laser diode and managed its temperature. This would ultimately reduce the noise produced by the control boxes and improve the stability of the lasers. We designed a board, based off previous models, that would combine the wires for power and temperature control onto a single PCB. These circuits are specific to the Thorlabs temperature controllers used because output pins may differ from supplier to supplier. What signal each pin corresponds to can be found in the manual for each controller.

The portion dedicated to the temperature controller just allows a DB-9 to be plugged into the board where wires branch off to the TEC and thermistor within the enclosure.

The current protection circuit offers several more layers of protection than the circuits that came with the diode. The capacitors in parallel and the resistor in series with them capacitors act as a low-pass filter to remove any large spikes in the incoming signal that may damage the diode itself. Different sized capacitors are used because the plastic capacitors used may fail at higher frequencies due to their impedance being frequency dependent. To rectify this, a smaller sized capacitor can be used to clean the signal, but they too gain resistance and begin to fail with certain frequencies. Thus, two sets of different sized capacitors are used to catch the majority of the spikes produced by the current source. The Schottky diodes are used to protect against any reverse biases. Finally, the Zener diode is installed so that, in the event that a damaging signal were to reach the laser diode, it would stop the signal and the Zener diode would break-down and short the circuit before the laser diode was destroyed.

C. Locking Software

The goal with the locking software was to provide a means of stabilizing the output frequency of an ECDL and to provide an electronic means of setting the output frequency. Without such software, the user would have to manually adjust the current or the position of the grating to change the output frequency, and stabilizing or reducing the noise with the output frequency is impossible to accomplish by hand.

The software was built and tested not with one of the new ECDLs, but with the laser used for PA scans. This was primarily because this laser was already working, so it was easy to test the effectiveness of the program, and because the scans performed required that the PA laser be stabilized.

The software is written in LabView and uses VIs provided by the Toptica wavemeter used in the experiments. The premise of the software is simple in that it is just a PID controller. First, the user sets a frequency they want the diode to lase at. The wavemeter sends the current operating frequency of the diode to the computer and the difference between the set point and the current value is determined. This produces the error signal that is sent to a proportional, integral, and derivative feed that all add to form a feedback signal optimized to try and push the lasing frequency to the set frequency. The feedback signal is a voltage that is sent from the LabView card installed on the computer to the controller for the diode. This supplies a voltage to the piezoelectric connected to the grating of the laser and adjusts its position in order to correct the lasing frequency. This process is done continuously in order to constantly stabilize and control the frequency of the laser.

Results show that the software is able to control the output frequency of the diode, but some residual noise

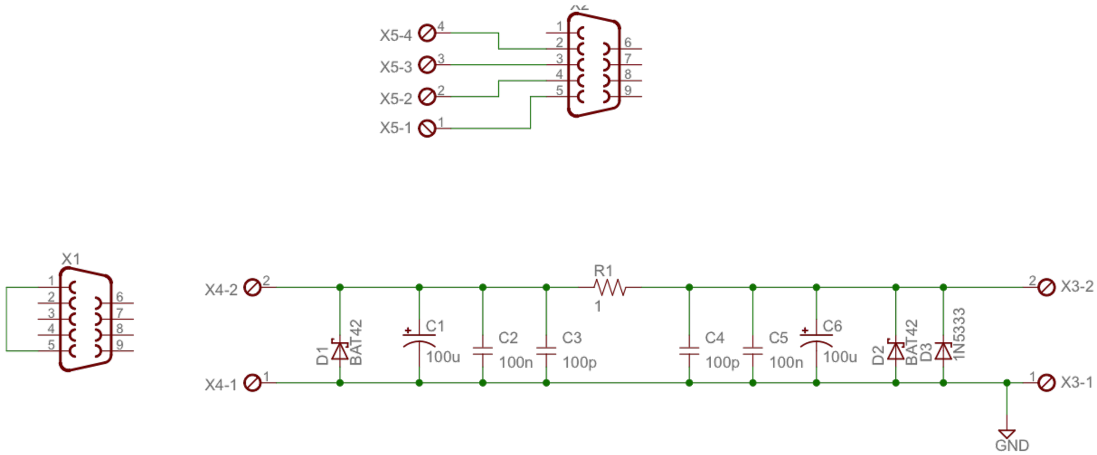


FIG. 9: A diagram of the circuit. The top portion just shows the interface for the temperature controller. The bottom portion shows diagram for the current protection circuit. Here, capacitors are in parallel and a resistor is in series with those capacitors. The Schottky and Zener diodes are also shown.

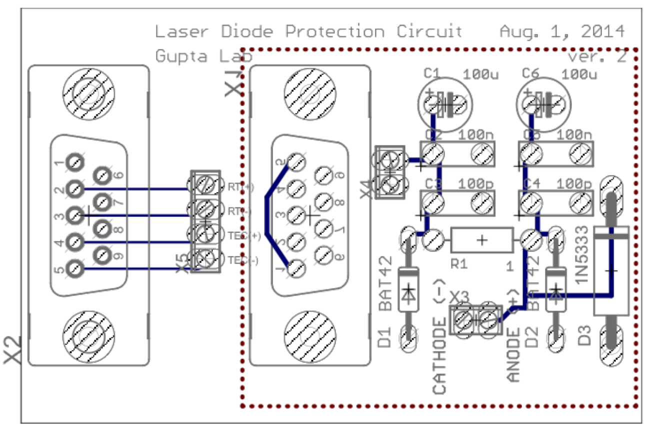


FIG. 10: A picture of what the circuit board looks like when the different electrical components are laid on a single PCB.

still exists. We also successfully specify a new lasing frequency electronically, and the software could respond accordingly. However, the software does not fare well when the laser becomes unlocked, at which point, the user must manually lock the PA laser to the appropriate frequency.

III. MEASUREMENTS

With the construction of one of the ECDLs complete, we wanted to know how much of an improvement we gained compared to the old ECDL. To perform this comparison, we tested the old and new ECDLs using the same blue diode, allowing us to test the differences in the lasers' construction rather than test differences that might appear in different diodes. The same mode was not used for all testing, but a stable mode was found relatively close to 404 nm, the wavelength that the diode would be operating at. Because different enclosures and modes were used for testing, the temperature and current of the diode varied between tests. The current was always between 70 and 80 mA while the temperature varied drastically due to the different position of the thermistor and the amount of empty space in each enclosure. Only the blue diode and its old and new ECDL were tested because the red ECDL was not completed at the time. Barring any instabilities that might arise when using the red diode, its ECDL should perform similarly to what we found to be true for the blue ECDL. The following measurements were taken without any additional locking software to stabilize the output frequency and without the newly constructed diode protection circuits (the proprietary ones provided by the manufacturers were used instead).

We ran several tests to check the performance of the old ECDL to act as a base mark to see how much improvement (or worsening) we gained from switching to the new ECDL. These tests mainly questioned how knocks on the table and air currents affected the stability of the laser and how the laser drifted over the long-term.

Vibration data included knocking on the table repeatedly and simulated disturbances that might occur if someone where working on the same optical table or if someone knocked into the optical table in the middle of an experiment. For these tests, we were interested in the maximum deviation in lasing frequency that occurred and how long the frequency took to return to the original lasing frequency. "Waving data" acted as a way to test how the laser would fare due to air currents formed in the room, either by ventilation or someone walking by. We were less interested in how much the laser deviated, but how long it took the laser to stabilize again. Air currents were generated by waving our hands at the laser, and we were only interested in the decay time from the maximum (or minimum) of the laser's deviation to the original lasing frequency. Finally, we were interested in the long-term stability of the lasers. For these tests, we stabilized and seeded the ECDL and let it sit for an hour to see by how much the frequency drifted.

IV. RESULTS

Data collection was done with the software provided by the Toptica wavemeter. Our values are reported in terms of Δ, the deviation from the lasing frequency of the laser. Units are either MHz or GHz depending on the experiment. This convention was chosen because it offered an easy way to compare how much the output frequency shifted between the two lasers, which were operated at different modes.

Figure 11 shows the restoration rate of the old ECDL after being disturbed by an air current, and Figures 12 and 13 show how knocking affects the stability of the ECDL.

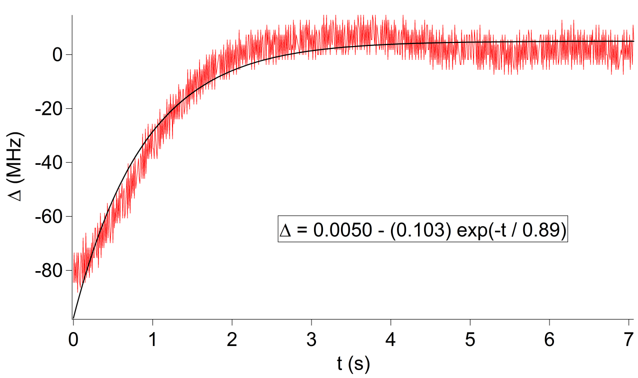


FIG. 11: Laser output frequency shift (MHz) as a function of time (s) showing the restoration rate of the old ECDL after being exposed to an air current. After being disturbed by an air current, the old ECDL has a mean lifetime of 0.89 s, and, in this case, took approximately 2.5 s to return to the original lasing frequency.

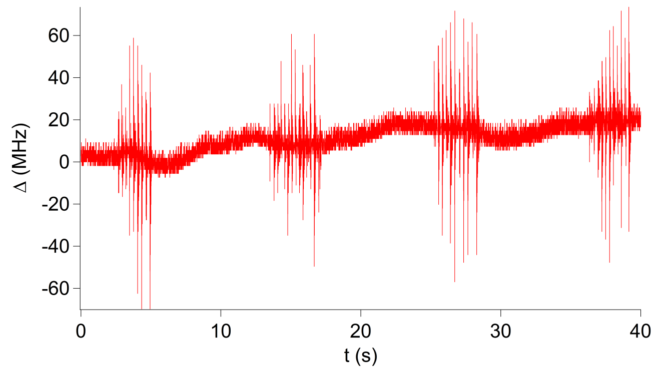


FIG. 12: Laser output frequency shift (MHz) as a function of time (s) showing how the old ECDL behaves with several series of knocks. Four series of knocks were applied to the table, in turn affecting the laser's output frequency.

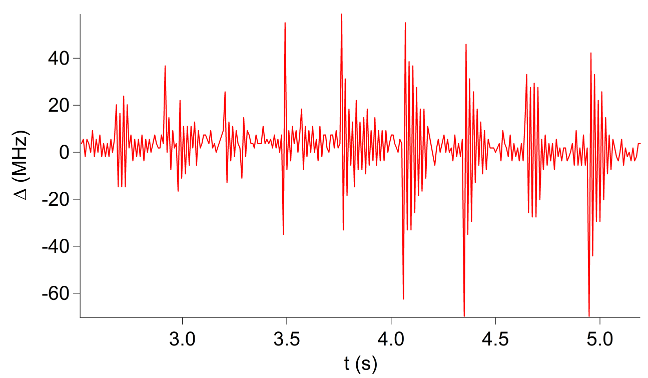
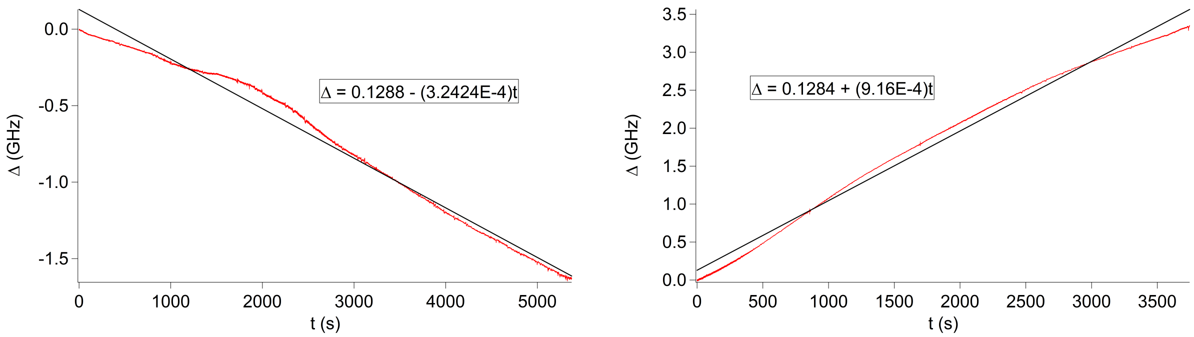


FIG. 13: Laser output frequency shift (MHz) as a function of time (s) showing how the old ECDL behaves from a single series of knocks. Each large peak is when the optical table was struck, and the following peaks and valleys are due to the laser "ringing" back to its original lasing frequency. At most, the output frequency is shifted by 60 MHz from the original lasing frequency, and the output frequency takes quarter of a second to stabilize.

The long-term trials were done twice for each ECDL: one was done in the morning and another in the afternoon. With the old ECDL, we found that the output frequency of the diode decreased over time in the morning and increased over time in the afternoon (an increase of wavelength in the morning and a decrease is wavelength in the afternoon). We speculate that the ambient temperature is the main cause of this shift. In the morning, we would expect the temperature to increase as people come into the lab, start moving around, and turn on machinery used for other experiments, while in the afternoon, the temperature would decrease as everyone leaves and the machinery is turned off. This increase and decrease in temperature coincides nicely with how we would expect the output frequency of the laser to shift with a change in temperature and with what we observe. Figure 14 shows the shift in the output frequency of the old ECDL in the morning and the afternoon.

With the new ECDL, we would hope that the improved stability and temperature control limited the frequency drifts that occurred due to outside stimuli. For the most part, we made several improvements. There is a significant decrease in the amount by which the new ECDL shifts due to air currents. Unfortunately, the same cannot be said for vibrations and their effect on the stability of the laser. A single knock perturbed the output frequency considerably more for the new ECDL than it did



(a) Data was taken in the morning, and the frequency decreases at a rate of about 0.3 MHz/s.

(b) Data was taken in the afternoon, and the frequency increases at a rate of about 1 MHz/s.

FIG. 14: Laser output frequency shift (GHz) as a function of time (s) showing the long-term drift of the output frequency of the old ECDL.

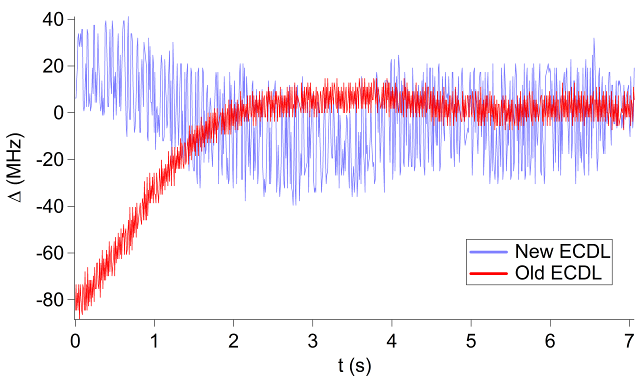


FIG. 15: Laser output frequency shift (MHz) as a function of time (s) showing the restoration rate of the new ECDL after being exposed to an air current. The blue line refers to the new ECDL and the red refers to the old ECDL. Despite the noise in the mode used to collect this data for the new ECDL, we find that the output frequency does not shift as much as it did in the old ECDL (20 MHz vs 80 MHz) and restores to the original lasing frequency faster than the previous generation.

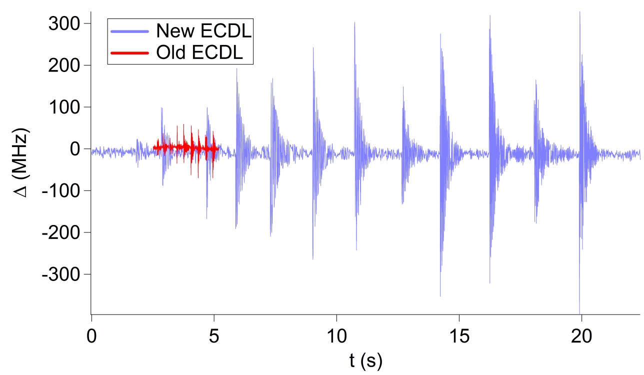
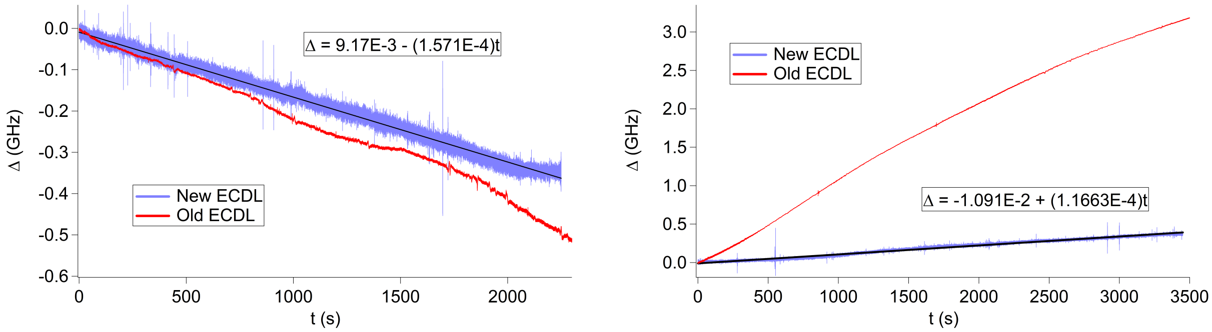


FIG. 16: Laser output frequency shift (MHz) as a function of time (s) showing how the new ECDL behaves from a single series of knocks. The blue line refers to the new ECDL and the red refers to the old ECDL. The new ECDL responds in a much more dramatic way to a knock on the table compared to the old ECDL, and it rings for considerably longer. We infer that because the new ECDL is screwed directly to the table (the old ECDL was not) the laser rings and vibrates with the table when it is hit.

for the old ECDL. The difference between the two is that the old ECDL sat on a layer of sorbothane and was not stabilized to the table via screws. Thus, when the table was struck, the old ECDL could move independently from the table and had a layer of rubber that absorbed most of the vibrations. The idea behind screwing the new ECDL to the table was to take advantage of the dampening properties of the optical table that blocked out most of the outside vibrations. We get a trade-off, however, because while the new ECDL is protected from outside vibrations, it is more susceptible to vibrations caused on the surface of the optical table, and essentially rings with the table.

Figure 15 compares how the new ECDL behaves relative to the old ECDL, and Figure 16 compares how the new ECDL behaves relative to the old ECDL.

The new ECDL behaves similarly to the old in that, for long-term drifts, we notice a decrease in the frequency in the morning and an increase in the frequency in the afternoon. However, the rate at which it increases or decreases is less than that of the old ECDL. This confirms two points: that the ambient temperature of the room affects the drift of the output frequency of the diode and that the new ECDL is thermally isolated from the environment more so than the old ECDL. We infer that the ambient temperature is the main reason for the drifts that we see because we noticed the same behavior happen with two different enclosures on two separate days.



(a) Data was taken in the morning, and the frequency decreases at a rate of about 0.2 MHz/s.

(b) Data was taken in the afternoon, and the frequency increases at a rate of about 0.1 MHz/s.

FIG. 17: Laser output frequency shift (GHz) as a function of time (s) showing the long-term drift of the output frequency of the new ECDL. The blue line refers to the new ECDL and the red line refers to the old ECDL. The best-fit line refers to the drift in the new ECDL.

More importantly, the fact that the rate of change of the frequency decreased compared to the old ECDL implies that the new ECDL is more thermally isolated and is less susceptible to the ambient temperature, which is a welcomed improvement. Figure 17 shows the shift in the output frequency of the new ECDL in the morning and the afternoon.

V. CONCLUSION

The need for precise and stable lasers is evermore necessary when trying to access atomic transitions that have a small linewidth. This is especially the case with the current photoassociation spectroscopy experiments to try and find vibrational and rotational energy levels of ultracold molecules. Home-built external cavity diode lasers offer a means to decrease the linewidth that naturally occur with inexpensive diode lasers, and allows for them to be a viable alternative to bulky, more expensive lasers. ECDLs give us the flexibility to control the frequency of light emitted by diodes, making them the optimal choice for atomic physics experiments.

We worked on the construction of second generation ECDL lasers that were intended to offer better stability than their predecessors. The main advantages with the second generation lasers was that they were easier to seed, occupied a smaller space and were thus easier to thermally control and isolate, monolithic, and comprised of a material with high thermal conductivity. These features combined resulted in a laser that was not as easily influenced by outside temperature shifts and relatively more stable and easier to use than the previous version. In addition to new ECDLs, we constructed new diode protection circuits that are more robust than the ones provided commercially with the purchase of the diode lasers, and we also designed locking software to electronically stabilize the lasing frequency of an ECDL.

We found great improvements with the design of the new ECDL, the main improvement being the thermal isolation we can achieve. This ultimately adds the most to the stability of the output of the ECDL. During experimentation, however, a better mode could have been selected to run the experiments with, which would ultimately lead to less noise in the provided graphs and might reduce the severity of the shift of the new ECDL with vibrations. Instead, what we propose is to put a layer of sorbothane underneath the new ECDL, like in the old ECDL, and secure it to the table to hopefully get the benefits of the stability in the optical table while removing the vibrations that may happen if it is hit. Furthermore, to increase the isolation of the ECDL, the enclosure for the old ECDL can be retrofitted to house the new ECDL, and this can only help control the temperature of the system.

Still, these improvements in construction have helped to improve the usability and stability of the ECDLs used in the PA experiments.

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