ENGN 1560 Lab #2

Preparatory steps:

1. Read this manual before attempting to do the lab. No, really. Do it.

2. All students will do the lab in groups of two (as before, a single group of three is ok). It is not required that you have the same group as last time. But it's ok if you do.

3. You and your lab partner must schedule your laboratory session. This must be done by email. The lab may take anywhere between 1 and 2 hours to complete. If you need to reschedule your lab time, be aware that you must complete the lab before the end of the day on Friday April 26th, since the lab equipment will be disassembled and put away at that time.

5. As with Lab 1, the laboratory will take place in room 092, which is adjacent to the B&H elevators in the basement. The lab is locked at all times and we cannot issue keys – you will need the grader (Rabi Shrestha) to let you in. If you exit the room at any time during the lab, your lab partner will need to let you back in, so you should not both leave at the same time. When you complete the lab, be sure that Rabi knows that you have left the room and that the doors are locked securely. Do NOT prop the door open, at any time.

Preliminary comments:

You will find all the parts necessary for performing the lab on the laser table. Some of these have been set up in advance and pre-aligned: in particular, the HeNe tube, the Uniphase alignment laser, and the two mirrors in front of it are all carefully aligned. You will also find two cavity mirrors in mirror mounts, which are not set up or aligned. Your job will be to put these two mirrors on either side of the laser tube and line them up so that it lases. You will optimize the alignment to achieve the greatest possible output power, for a few different mirror locations.

The two cavity mirrors are both curved, with radius of curvature R (the same for both). However, the two mirrors are not identical. One is a high reflector (essentially 100% reflectivity at the HeNe wavelength). The other is an output coupler (intentionally lower than 100% reflectivity, so that some of the beam leaks through). You cannot tell the difference by eye – however, the output coupler is labeled with the letters "OC" written on the front of the mount.

Things not to do:

(a) **Do NOT EVER let the laser beam shine into your eye.** Scattered light is not dangerous (because we are using low-power lasers – with high-power lasers, even scattered light can be dangerous), so don't panic if you see a little red glint now and then. But getting the full beam directly in the eye could cause damage. So be aware of where the beams and reflections are going, at all times. Note that the laser beams propagate at a height of about 6 inches above the table, parallel to the table surface. It is good laser safety practice to never put your eye at this

level.

(b) Do NOT touch the Uniphase alignment laser or the mirrors that are used to direct that laser beam. These components are already carefully aligned. Realigning them is difficult and tedious.

(c) Do NOT touch the HeNe tube (except for perhaps the smallest possible adjustments to the four alignment knobs). It is also very carefully aligned, and it's even more tedious to fix this if it gets moved. Also, when it is energized, the ends are at high voltage. You'll get a very nasty shock if you touch this. (the alignment knobs are safe to touch even when the voltage is on – but don't make any major adjustments or else it will need to be realigned from scratch).

(d) Do NOT touch the surfaces of any mirrors or the windows at the ends of the laser tube. Fingerprints and dirt are the enemy of optics. These components are clean, and should never be touched. If you think they need cleaning or if you touch them accidentally, do not attempt to clean them yourself. Ask Rabi for help.

(e) There are two empty post holders screwed to the table on either end of the HeNe tube. These are the holders for the two end mirrors, situated at the locations where you will place them in your first attempt to make a laser. Do not unscrew these or move them.

Laboratory procedures:

Step 0: Be aware that this room is used not just by ENGN 1560, but also may be used by other groups. The "do not touch" signs are there to make sure that other people using this room don't touch our carefully aligned, delicate, expensive equipment. The signs don't apply to you. Move them aside, for now.

1. Turn on the Uniphase alignment laser. Use a white business card to follow the path of the beam (this is a better procedure than using your finger, because fingers can accidentally touch mirrors and that's a bad thing). Observe that the beam passes through the HeNe tube and emerges from the other end. When it emerges (and as it propagates away from the tube), it should remain shaped like a point, not like an arc or a circle. This indicates that the beam is pointing straight down the bore of the HeNe tube, and not scraping against the inner edge of the bore. To get a feeling for the sensitivity of this alignment, use one of the four alignment knobs on the HeNe tube mount to make a VERY tiny adustment of the tube position. You should observe that the point-like beam pattern transforms into an arc or circle very quickly as you move the tube. This arc or circle is a sign that the alignment beam is no longer propagating down the center of the tube, but instead is reflecting off of the internal curved surface of the tube. That's bad because it means that the tube is no longer parallel to the alignment beam. So reverse your tiny adjustment to get back to the point-like beam.

2. Locate the high reflector end mirror (it's the one that **doesn't** say "OC" on the mount). Slide this mirror into the post holder at the opposite end of the tube from the Uniphase alignment laser

(the knobs on the mirror mount should be pointing away from the HeNe tube). Adjust the mirror's tilt so that it reflects the laser beam back through the tube. The first step is a coarse adjustment, just twisting the post so that the mirror faces in approximately the right direction. Then, tighten the knob on the post holder, to hold the mirror in place, so that you can further optimize the mirror tilt with fine adjustments using the knobs on the mirror mount. When you have the mirror in about the correct orientation, you should be able to see the back-reflected beam, which passes back through the tube, hitting the rear side of the iris which has been screwed to the table near the alignment laser. Try to get this back-reflection to point as accurately as possible directly back into the alignment laser, by centering it on this iris. As with the discussion in step 1, if you are close but not quite right then the beam will look like a circle or an arc on the back of the iris. When you are right on, it becomes a spot (somewhat larger than the initial beam size because it is diverging after reflecting off of a curved mirror).

3. Now, put the other laser mirror (the output coupler) into the other mount that is adjacent to the HeNe tube (the one on the same side as the alignment laser). Again, do a coarse and then fine alignment, just like you did with the high reflector. This time, you should align the back-reflection from the back side of the output coupler. Again, align it to go straight back through the center of the iris into the alignment laser. With the tape measure, measure the distance between the two laser mirrors (but don't touch the optics, just the mounts!).

4. Turn off the alignment laser, and switch on the power supply for the HeNe tube. It should energize within a few seconds. If it doesn't, turn the switch back to the 'off' position and go tell Rabi that something is wrong (this should not happen, but just in case...). In any event, DO NOT TOUCH the tube once it has been energized.

5. Once the tube comes on, you might see lasing immediately. If not, then you can make small adjustments to the output coupler mirror in order to get it to lase. If that's not enough, then you can try to also make VERY TINY adjustments to the high reflector mirror (but be aware that this is extremely sensitive). If this STILL doesn't work, then turn off the HeNe tube and go back to step 1.

6. Repeat steps 1-5 until you see lasing.

7. Once you see lasing, turn on the optical power meter and position it so that the beam is going straight into its center. Observe the power reading on the digital meter. Note that the meter has a 1000x attenuator on the front, so if it is reading "μW" (microwatts), that's really milliwatts. Tweak the output coupler and the high reflector to optimize the output power. At this point, you can also make VERY TINY adjustments to the HeNe tube position using any of the four alignment knobs, in order to try to optimize the power. Be aware that this is extremely sensitive – even a small twist of the knob will misalign the laser and it won't lase at all any more. However, careful iteration between the tube position and the mirror angles can gradually lead to improved power output. Continue this procedure until you can't get the power to go up any

higher. Make a note of the best power output you can achieve.

8. Once you have optimized the power, you should no longer touch the high reflector or the laser tube at all. Turn off the HeNe tube, remove the output coupler from the post holder that is screwed down adjacent to the tube, and insert it into the post holder attached to the magnetic base. This allows you to reposition this mirror easily, just by turning the magnetic base on and off. Move this mirror to a different location, farther from the tube, in order to make your laser have a longer cavity (i.e., greater distance between the two mirrors). Measure the new cavity length. Use the Uniphase alignment laser to position the output coupler, as you did before, and then turn the tube back on and get it to lase again with this longer cavity. Since you have not touched the high reflector or the tube, you should be able to get it lasing by adjusting only the output coupler. Optimize the power for this longer cavity and note the maximum power you can achieve.

9. Repeat step 8 so that you have measurements for several different cavity lengths (the more the better). Start with the shorter lengths and work your way to longer and longer distances. Each lab partner should be in charge of making the laser work for at least one of these lengths – don't let just one person do all the tweaking. Record the maximum power achieved for each cavity length.

10. At a certain point, the laser cavity will be too long, so that you are outside the region of stability ($0 < g_1 g_2 < 1$) and it will no longer lase at all. Can you experimentally determine the maximum laser cavity length for stable operation? Given that the two cavity mirrors have the same curvature (so $g_1 = g_2$), use this length to determine the radius of curvature of the cavity mirrors.

11. When you have completed the lab, you should do all of the following:

(a) remove both mirrors from their post holders and replace them where you found them, so that the next lab group starts from scratch just like you did.

(b) make sure that both the HeNe tube and the Uniphase laser are OFF.

(c) put the "do not touch" signs back in place.

(d) make sure the room lights are off and the doors are locked when you leave.

WRITE-UP: *Each lab partner* should include a write-up (not more than one page) describing the procedures, including the measured data (e.g., a plot of output power vs. laser length). Also include a discussion of how you determine the value for the radius of curvature of the cavity mirrors, and what value you obtain. This should be done independently by each student, not as a team write-up. It should be turned in with your solutions to problem set 10 (it will be problem 1 of that problem set).