TEA Nitrogen Laser

Over this block, I have researched how to build a TEA Nitrogen Laser. I started with the “The Amateur Scientist.” article An unusual kind of gas laser that puts out pulses in the ultraviolet which gave me a good idea of how a low pressure pumped nitrogen laser works. I knew that my laser would be slightly less complicated than the Amateur Scientist laser, but more sensitive to electrode alignment and flaws in the electrodes. Paul Searing and Nathan Means’ had built a low-pressure nitrogen laser and their web page also had some good information, including how they built the power source, which I have permanently borrowed. Next, I researched general information on how lasers work. Professor Mark Csele of Niagara College has lots of theory and math as applied to many different types of lasers on his web sites. My last main source that I used was Sam Goldwasser's Laser Frequently Asked Questions, which had a lot of trouble-shooting help, and suggestions when I had problems getting lasing action.

My research pointed to several things that would help me make my laser. Throughout most of the process of building my laser I thought that there had to be a uniform spark across the gap between the electrodes; this means that I may have been doing extra stuff that wasn’t necessary, but in the end may have helped my laser work. In general, there has to be an extremely fast discharge of energy in the form of heat, light, or electricity that is absorbed by the electrons of the atoms that are the lasing medium. Using the formula $t=(36\text{ns})/(1+p/(58\text{ torr}))$ I can find the lifetime t of the upper energy level of the Nitrogen atoms; when p is atmospheric pressure equaling 760 torr, the lifetime of Nitrogen’s upper energy level is approximately 2.5 ns. So I thought that optimizing the discharge path might help my laser lase more effectively. This included making a good spark gap, using as thin a dielectric as possible, and making the aluminum foil as smooth as possible to rid the capacitor of air pockets, which would reduce its capacitance and therefore reduce efficiency. Therefore, I pulled apart everything that Paul and Nathan made and started from scratch with the exception of their high voltage power supply, which I was fairly certain, worked within acceptable parameters for my laser. Producing between 0 and 10,881volts ± 234volts, it charges the laser effectively (Means/Searing). I rewrapped the shelf board in aluminum foil and replaced the transparencies that are the dielectric. I also decided that the lead bricks I was using to hold the electrodes in place would make a better seal/connection with aluminum foil as compared to the copper plates, which weren’t entirely flat, so I replaced them with the foil; sacrificing the soldering connections for the electrode connection.

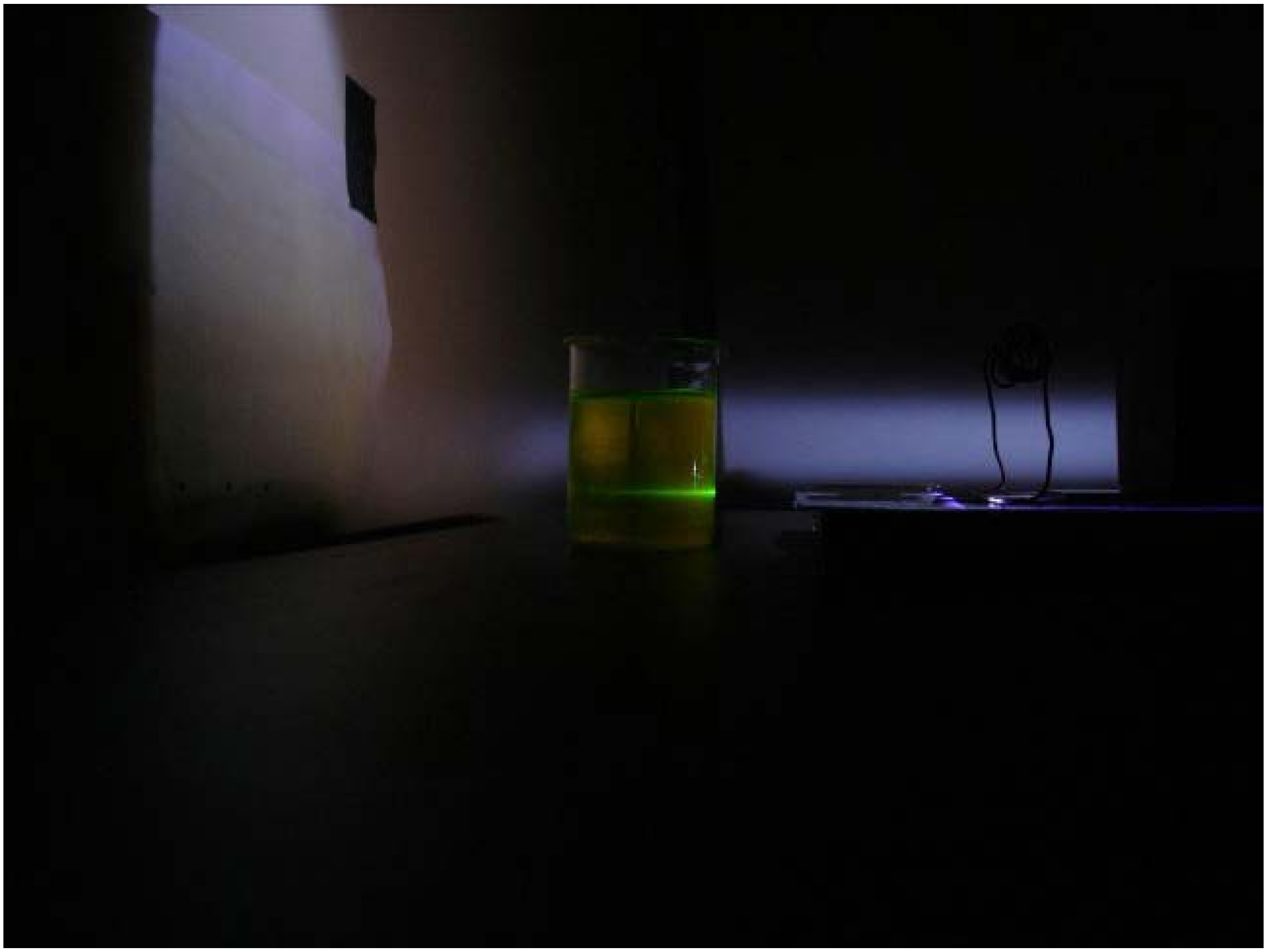
The TEA laser and power supply. The power supply is contained in the box at the top left. The laser capacitor consists of the aluminum foil and transparencies wrapped around the shelf board. The laser discharge path is formed by the two strips of aluminum underneath the two lead bricks. The spark gap is housed underneath the plastic tube at the bottom.

The bottom plate of the capacitor ended up being 30cm by 50cm, basically just attaching aluminum foil to the board. The two top plates are 11cm by 30cm with about a 2 cm gap between them. Between the plates are two layers of transparencies which cover most of the bottom layer. The electrodes are made of an aluminum L bracket that is 3mm thick, 3cm wide and 23cm long. The L bracket is cut in half so there are two flat pieces, with one edge beveled. The electrode gap is set to about 1.1mm ± .1mm, and the spark gap is set as close to 4mm as possible. Another part of the laser that I wanted to fabricate was a better, adjustable spark gap. I did this by bending a piece of aluminum into an S-shape and putting a bolt through the top and cutting a piece of PVC pipe to the right length and then the screw can move up and down adjusting the spark gap. I rounded the bottom of the bolt so that the discharge would occur from the same point each time. Under the bottom of the PVC spark “chamber” is a piece of copper plate to eliminate the spark from burning through the aluminum foil. This adjustable spark gap however doesn’t seem to work possibly because of the increased impedance. It seems that two pre 1983 pennies make the most effective spark gap. I found that the larger the spark gap the more likely the lasing was to occur, but when the gap was set larger than 4 mm, there wasn’t enough voltage to spark across the gap. By observing lasing action occurring at almost every spark; I hypothesized that the larger the gap and the higher the voltage the more likely lasing action is going to occur.

The laser discharge path. Each lead brick rests on a separate aluminum strip. The spark between the aluminum strips provides the energy to power the laser. Each aluminum strip is about 2cm wide. The red inductor permits both capacitor places to charge and forces the charge to flow through the gap when the capacitor discharges. The diffraction grating at the bottom right was used to measure the wavelength of the laser light.

I read on Professor Mark Csele's web site that the electrodes must be extremely straight so they will be parallel and also extremely smooth to get the best gap. Sam's FAQ site suggested that electrodes worked better with a bevel and when they come to a sharp point they have a more specific spot for the spark to occur between. This led me to try a number of different electrodes styles and materials. This source, along with Professor Derin Sherman, also suggested that I use sandpaper of at least 600 grit to smooth the electrodes in order for a good laser electrode gap, Prof. Sherman also suggested finer sandpaper and steel wool and paper towel to get the electrodes extra smooth and remove flaws and also any metal particles that may have remained on the electrodes. I tried many different options including two different types of aluminum door jam covers (suggested by Prof. Mark Csele's web site), that had to be cut to the right length and one side cut off so the beveled edge could be used, then they had to be ground down a little so they would sit flat on the top plate of the laser and then I sharpened the beveled edge with sandpaper and smoothed them with steel wool and paper towel. Another option I tried at the suggestion of Professor Derin Sherman was two blades from a utility knife, they are beveled and sharp, but in the end I think had too much coronal discharge and sparked very inconsistently, mostly at the two ends. I also tried to wrap copper sheet around the edge of an L bracket thinking that maybe the copper would be smooth enough and might conduct better than the aluminum I had been trying. I then used steel wool to shine/smooth the copper electrode end and wiped it with paper towel. The first pair of electrodes I tried was taking the aluminum L bracket and cutting it down the middle to form two flat electrodes with a beveled edge, this ended up being my best option, but after sanding them, but they weren't strait enough. I machined another set using the milling machine in order to make them strait. The next step was to sand them so they were completely even and smooth, these two steps took several hours, but in the end was worth it because it is the only set that I have observed laser action occurring. With all of the electrodes I had an inconsistent spark, but it wasn't entirely necessary to get a uniform spark across the entire gap, it only needed to be evenly distributed.

The laser is all set to fire. The laser is pointed at a beaker of fluorescent dye. When the laser fires, the beam will make the dye glow. The dots on the wall show the positions of the laser beam after it passed through a diffraction grating.



The laser is firing. The thin, bright green streak of light in the beaker is due to the laser. The purple glow near the laser is due to the spark gap.

Some results from my project were testing my laser to make sure it was actually lasing. There are several ways to do this, the first was is using a fluorescent dye in a beaker diluted with water, the laser clearly lazes sending a streak of ultraviolet light through the beaker, almost like a fluorescent bullet. Another way of testing the laser is measuring the wavelength of the ultra-violet beam that is produced. I painted a sheet of paper in order to be able to see the beams point on the wall, and then placed a diffraction gradient, with 500 lines per mm, 26.3 cm ± .2cm from the wall. The beam had three very visible dots on the paper with the distance between these dots equal to 4.6 cm ± .1 cm. With this information I can calculate the wavelength using $\lambda=d*\sin\theta$ where the distance equals the distance between slits and the sin of θ equals opposite divided by hypotenuse. The value then calculated is 344.6nm ± 9.9nm, which puts the researched 337.1nm for Nitrogen lasers within that range.

Another experiment that I would have liked to do is to use the laser to determine distance using a time delay and the known value for the speed of light. Using a beam splitter I can send half the pulse into a device and measure the delay between when the other half of the beam returns from reflecting off of a corner cube. However, this experiment can be done more safely perhaps with a laser pointer.

References

1. Professor Mark Csele of Niagara College has lots of theory and math as applied to many different types of lasers.

http://www.technology.niagarac.on.ca/people/mcsele/lasers/LasersTEA.htm

2. Sam Goldwasser's Laser FAQ had lots of trouble-shooting help.

http://repairfaq.ece.drexel.edu/sam/lasercn2.htm

3. Nathan Means and Paul Searing’s webpage also had some good information.

http://www.cornellcollege.edu/physics/courses/phy312/Student-Projects/Nitrogen-Laser/Nitrogen-Laser.html

4. An unusual kind of gas laser that puts out pulses in the ultraviolet. “The Amateur Scientist.” June, 1974. *Scientific American.*