Ruby Pulse Laser and Holograms

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INTRODUCTION

The ruby laser is a pulse laser with a very short pulse (a few nanoseconds) allowing us to make holograms of many types of objects including objects that normally can't be used to make holograms. Making holograms with normal beam lasers requires a completely stationary object because if there are any slight vibrations in the object, the hologram will not show an image of the object, but rather will look like sliced bread. However, if the laser pulse is very short, the objects appear to be frozen. Even if an object appears to be moving to us, it will not move any significant distance in the short pulse of the laser. So, we can make holograms of objects such as your hand. This is the main benefit of using a ruby pulse laser to make holograms.

Our goal for this project was to get a ruby laser working and hopefully make some holograms. This includes building a trigger circuit to time the flashbulb correctly, building a voltage multiplier to get a high voltage power supply, building a safety containment box, and wiring everything together to make the ruby laser.

HOW IT WORKS

Ruby lasers work by exciting a ruby rod, which then emits photons. The high voltage power supply provides energy to a quartz flashbulb in the laser cavity which then emits a brief flash of very bright light. This intense flash excites some of the atoms in the ruby rod to higher energy levels. When the atoms drop energy states, they emit particles of light called photons. These photons bump into other atoms causing them to change energy state and emit photons as well. This continues and the light intensity is quickly amplified. These photons are then directed out one end of the ruby rod and reflected toward a rotating prism. This prism only completes the optical path of the laser(see figure 1) for a very short period of time and for this reason we have a very short pulse of laser light that leaves the laser. The light that is emitted is all coherent and of the wavelength 694.3 nm.

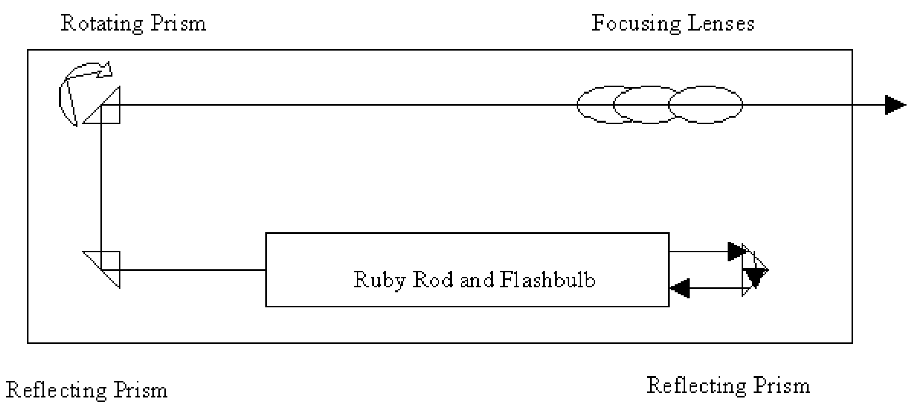


Figure 1.

A schematic diagram of the laser

LASER COMPONENTS

The component that required the most time and effort was our trigger circuit. This circuit was needed so that we could ensure that when the laser fired, the rotating prism would be aligned allowing the laser light to travel out of the laser. The first thing we needed to do was create a circuit that would strobe an LED at the same frequency as our prism was rotating. This was achieved by using the signal from the magnetic pickup attached to the rotating prism. Every time that the magnet moved passed the pickup, which was simply a coil of wire, an electrical pulse is sent out to the circuit. We then used these pulses to create an output signal that was the same frequency as the rotating prism. Then, using a series of resistors and capacitors in combination with a 556 chip, we set up a specifically timed delay so that by viewing the rotating prism with our strobing LED we could carefully align the position of the prism by simply rotating a potentiometer.

Since the ultimate goal of this circuit is to fire a flashbulb we need to have one single pulse coming out of our circuit that is timed correctly with the prism. To accomplish this we added a series of NAND gates and a 74123 so that when a switch was pressed a single, correctly timed pulse would come out. See figure 2 for the complete schematic of our strobe circuit.

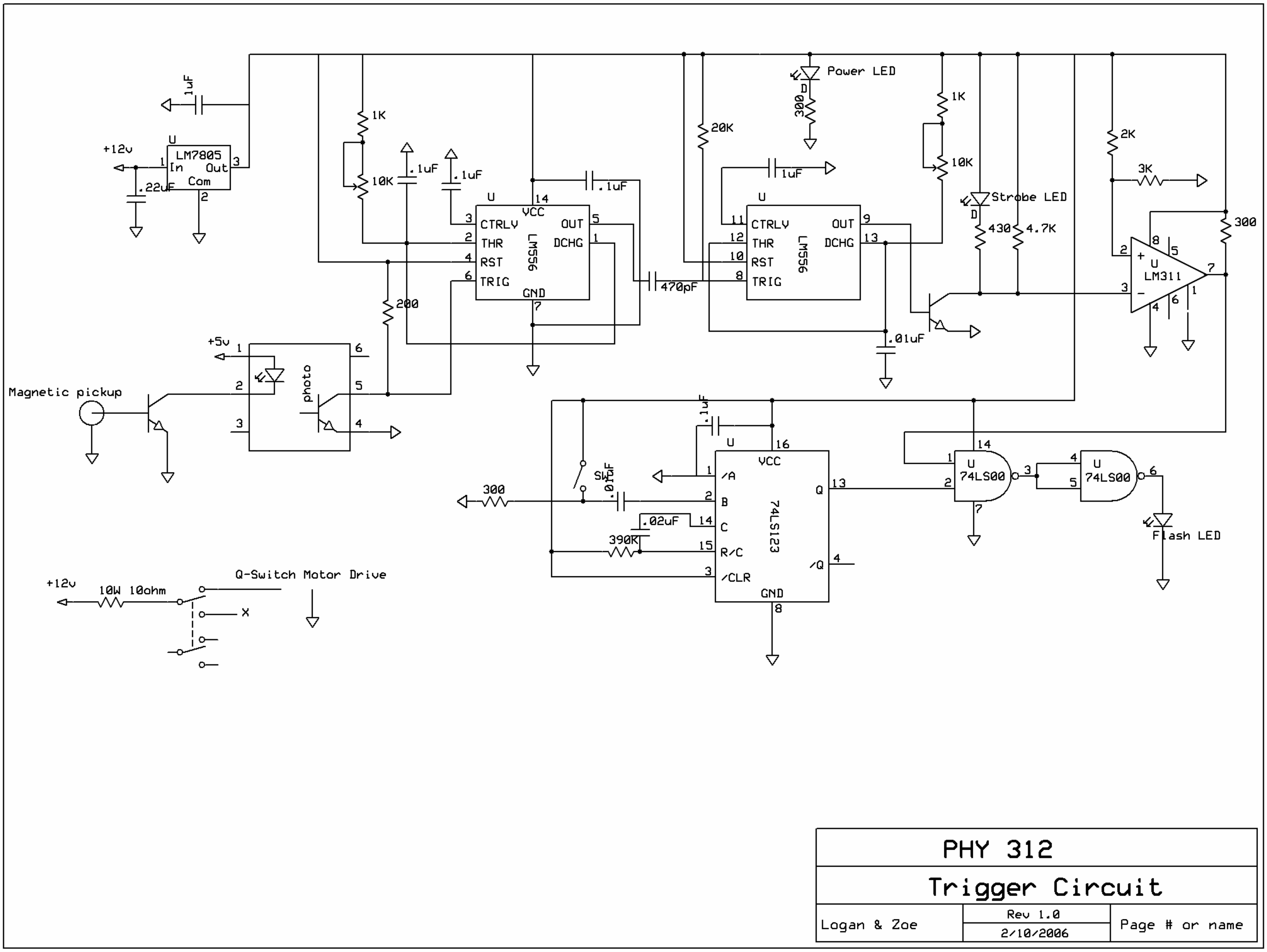
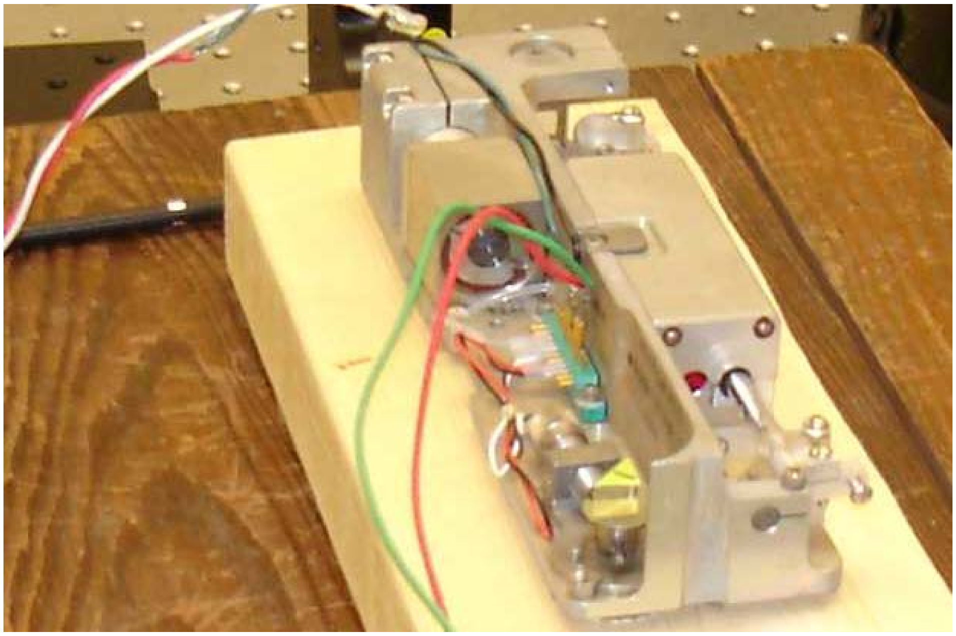


Figure 2: The trigger circuit

The next component that was essential in firing our laser was our high voltage power supply. This was needed in order to fire out flashbulb. Normal rectified line voltage is only 170V and we needed 880V, so in order to achieve this voltage we built a voltage multiplier circuit. A voltage multiplier circuit sequentially steps up the voltage in various stages using a combination of capacitors and diodes. For our multiplier we used 6 stages thinking that this would give us the voltage needed. This however, provided us with too much voltage, approximately 1900V, so we had to tap off of the 4th stage which gave us approximately 880V.

In order to get enough energy stored up to fire the flashbulb we needed a series of capacitors. We started by using the WE-SP1 Ruby Laser power supply circuit shown on Sam's Laser FAQ website www.repairfaq.org/sam/laserssc.htm. We used a set of 6 capacitors: three 1000 uF capacitors and three 1200 uF capacitors, each rated for a voltage greater than 350V. Each 1000 uF capacitor was connected in parallel to a 1200 uF capacitor for a total value of 2200 uF. Each 2200 uF capacitor was then connected in series for a total value of 733 uF. Because each capacitor was rated at 350V, the capacitor bank could handle 1050V. Since the capacitors may jostle around when they discharge we built a holder for them. Next we put large resistors across each capacitor in order to bleed of the charge when the power is shut off. This is simply a safety precaution so that our capacitors are not just sitting holding a large charge.



The ruby laser. One end of the ruby rod is visible as a red dot on the side of the aluminum box housing the ruby rod and xenon flashlamp. The spinning prism has a light green piece of paper taped to the top with a black line drawn through it. This was used with the white LED and trigger circuit to test the timing of the trigger circuit.

The final safety precaution we took was to isolate our high and low voltage components of our circuit into separate boxes. The box for our high voltage components was made of Lucite and aluminum. We used nylon bolts and nuts and made sure that there was no metal on the inside of our box that could conduct any electricity due to the high voltages.

TROUBLESHOOTING

We learned a couple of very valuable lessons from this project that will probably prove useful in future projects. First, always check the power supply for noise. Our strobe circuit was behaving abnormally, strobing at the wrong intervals and different intensities. After checking each component of the circuit we finally check the power supply line and found it to be very noisy. This noise was caused by the motor, and we were able to suppress it by using an optocoupler and a 7805 voltage regulator.

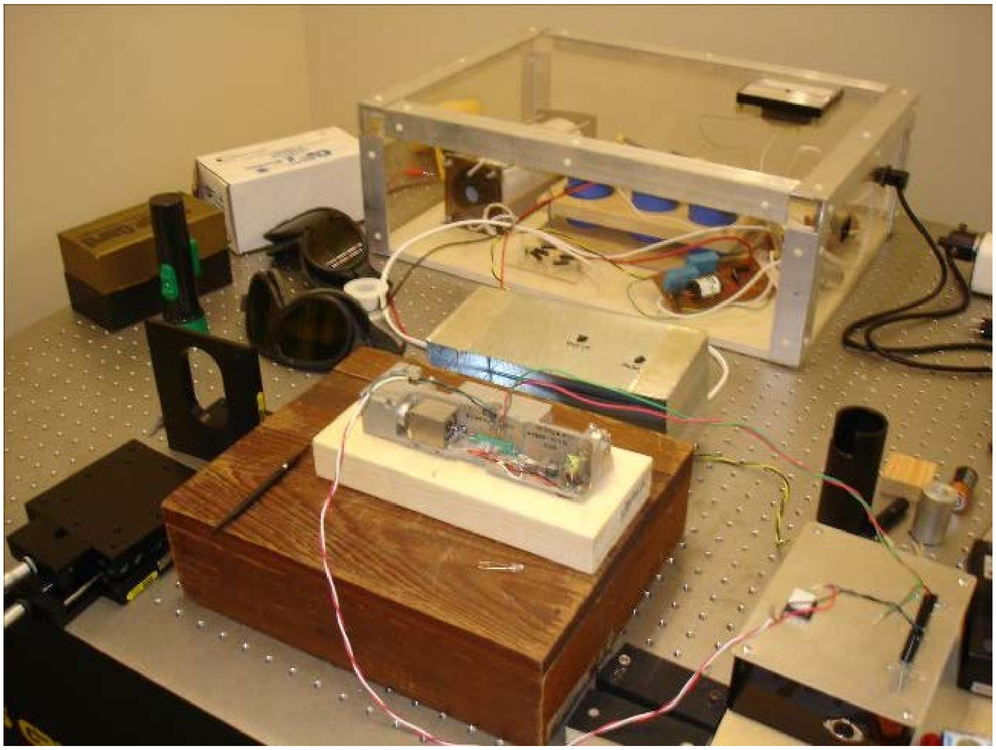
The second lesson we learned is that, when possible, bolt materials together rather than using epoxy of glue if a lot of pressure is going to be applied to them. When making our inductor we tried three different types of epoxy and glue to fasten the Plexiglas ends to the PVC pipe; all of which failed when we tried to wrap the inductor. We found that it was much more stable to run a threaded rod through the middle of the inductor, wrap the wire around the PVC, secure the ends with four threaded rods on the outside of the wire, and then remove the one from the inside. This method held the ends secure for wrapping, but did not interfere with the inductance in the end.

RESULTS

Although, at the time this paper was written, the laser had not been fired, many of the laser components have been tested and working properly. We tested our final strobe circuit and every time the button is pushed the LED strobes at the correct time. Sometimes when the button is pushed the LED strobes twice, both when the prism is correctly aligned. However, the second strobe will not do anything because the laser will have already fired, so the capacitors will be discharged.

We were able to test the voltage multiplier we made and find the level to get the voltage we wanted. We measured the voltage of the voltage multiplier while it was connected to the actual resistors we would use across the capacitor bank. This gave us the actual voltage being applied across the inductor, which we found to be 880V. We used the weights.xls spreadsheet from the www.rotorwave.com web site to find the desired inductance, and from that the dimensions of our inductor.

We tested our inductor using an LRC circuit to find the inductance. We found the resonant frequency, which we then used to calculate the inductance. We were aiming for an inductance of 734mH, and we measured an inductance of 672mH. Our measured value is slightly lower than ideal, but will work fine with our circuit.



The ruby laser and the electronics used to power it. The ruby laser is sitting on top of the wooden block in the front of this picture. The capacitors are the large blue cylinders inside the plastic box. The inductor is the large white cylinder to the left of the capacitors inside the plastic box. The meter on the top of the plastic box reads the voltage on the capacitors. The motor control and trigger circuit are inside the metal box to the right of the ruby laser.

When we tried to fire the laser initially we blew a fuse in our isolation transformer and had to make several adjustments in the circuit to eliminate the large current that was flowing backwards in our circuit. We also encountered a problem in charging the capacitors due a short which was later discovered in the box containing the laser. In our final time charging the capacitors they were able to charge to 800V, but when we went to fire the laser, we discovered a short in our trigger circuit which has yet to be fixed. We plan on fixing this problem and firing the laser sometime next block.