The Study of Optoacoustics

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Abstract

Various experiments were performed to determine whether sound can get louder with distance. While there were initial irregularities, the results ultimately showed that sounds become quieter as the distance from the source increases. Other experiments suspending a water droplet or measuring alcohol content with sounds were set up but not able to be completed.

Materials and Methods

Scientific Static Generator

Di-Electric breakdown is the phenomenon where a material (when put under enough current) becomes a good conductor. To study the process of Di-Electric breakdown we used a Macalester Scientific Static Generator, a microphone, and an oscilloscope. The oscilloscope allows the user to measure the amplitude of a sound wave generated which in this case would be produced with a spark. The generator has several volt settings that can be used. The further you move the spheres away from each other the more voltage you will get in the spark which results in a louder sound.

After setting up the generator I measured about 10.5 cm away from the point where the spark was generated. I turned on the generator (set the volt setting to 20kV) and measured the amplitude at this distance. I measured the amplitude of the spark every 5 cm and ended at 105.5 cm. This totaled 20 data points for each experiment. I did this exact process for the 40kV setting.

For the 60kV setting, the amplitude was so high that the original method did not give me enough change when I plotted it on a graph. As a result, I set the microphone 4 meters away from the source and measured in increments of 20cm. I plotted the Distance (m) vs. Amplitude (V) in Excel to give a visual representation of the falloff of amplitude over distance.

Nd: YAG LASER

The Nd: YAG (Neodymium-doped: Yttrium Aluminum Garnet) laser is a solid-state laser which means that it uses crystal in the lasing process rather than a gas. When the laser is turned on most electrons will be in their ground state. If we were to let photons interact with these electrons in this state, there would be no output of light. Therefore, we use a process called optical pumping. Optical pumping is the process by which you use a flash lamp to emit a burst of photons that excite atoms from their ground state.

Without stimulated emission through optical pumping the ground state electrons would almost equal the excited state electrons which would end up giving you the same number of photons out as you put in. Once the electrons are in a highly exciting state, many of them will quickly fall into what we call the Metastable state. The time electrons spend in the Metastable state is far greater than the time electrons spend in the excited state. As they are in this state the electrons will slowly trickle back down to the ground state. As the electrons fall from state to state they emit photons. Because the Metastable state lasts so long, we are given the ability to overpopulate the region.

The drop from the Metastable state to the ground is the part of the process where the lasing happens as seen in Figure 1. The photons emitted from this drop are then immediately caught in the resonator. The resonator is the combination of two perfectly aligned mirrors; one mirror is highly reflective while the other mirror is partially reflective. The photons are caught between these two mirrors and are bounced back and forth gathering charge from other emitted protons of the same wavelength and position. Once the beam of protons gains enough strength, it pierces through the partially reflective mirror which results in the beam that we know of as laser light.

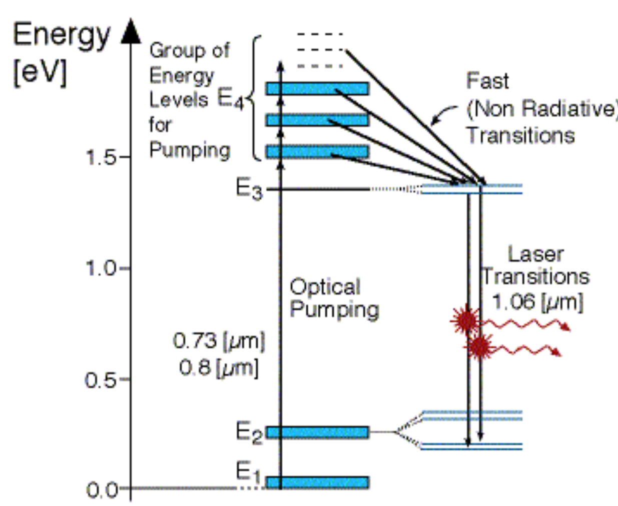

Figure 1

The Nd: YAG laser has a Q-switch embedded into it which gives us the ability to pulse the laser light. The Q-switch is a shutter mechanism such that when it is closed the laser light builds up inside the chamber and when the shutter is opened all the built-up laser light releases in an intensified blast. The buildup process lasts for around 100 microseconds and the pulse lasts for around 10 nanoseconds. When the shutter is closed, it holds many electrons at a metastable state which will result in a high-powered blast following the opening of the shutter.

For both laser experiments, we intend to detect a trace of gas in each capsule. When the laser beam is pulsed it should cause the gas to thermally expand which will create a sound. The end goal is to detect gases in air, but the first step is to detect them in the capsule.

Due to the beam of the Nd: YAG being infrared we are not able to see the beam with our eyes. One quick fix to that is to use an infrared camera. To gain this ability I deconstructed a Logitech webcam and removed the infrared lens. This will allow us to use the camera to focus the laser on the test cell and ensure that the laser is properly aimed at a target. This helps with overall lab safety.

After the water cooler was added we decided to check the flash lamps inside the lasing chamber. The flush tube (where the flash lamp is held) was highly damaged by rust. We used vinegar in the ultrasonic cleaner to de-rust the inside. We used pipe cleaners to wipe the inside. Once we deconstructed the flush lamp, I deduced that the flush tube was not able to be used due to the rust damaging the two poles of the lamp casing which would prevent the flash lamp from operating.

Discussion

There was an irregularity in the 20 and 40 kV settings. The amplitude increased for one or two points while the distance increased. The farther one moves away from the source of the sound the less amplitude it should have; however, as can be seen in Figure 1 for a moment it increases around 60 cm and in Figure 2 it increases just before 60 cm for two data points instead of one. This can be explained by the sound reflecting off various surfaces causing it to focus at one given point. In most rooms, this “triangulation” can be heard. If one were to walk around a room with constant noise, several points in the room will sound louder and others will sound quieter.

To test this theory, I experimented with a hard tabletop between the source and the receiver and compared it to the run without the tabletop in between. Coincidentally instead of having irregularities around 50 cm, we had irregularities at almost double the distance (85cm). This makes sense because the sound must travel to the floor to reflect instead of reflecting off the tabletop which was much closer. Some of these irregularities could be explained by a diffraction pattern. Like single slit diffraction patterns of light.

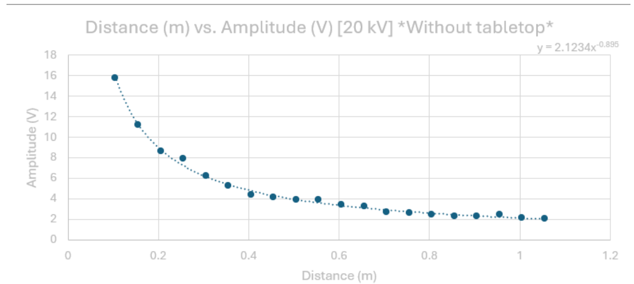

Figure 2

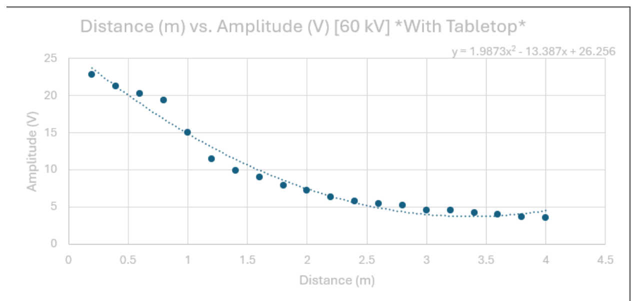

Figure 3

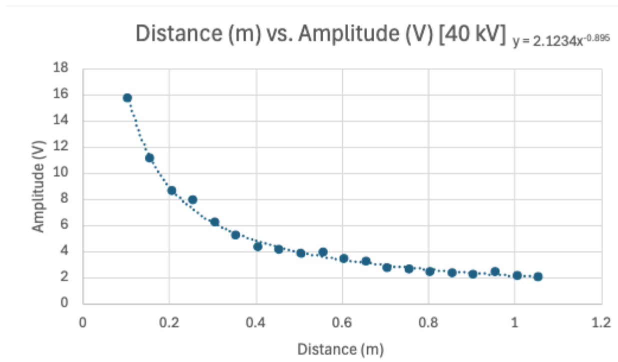

Figure 4

Conclusion

Dr. Cheyne and I also wanted to see how a water droplet that is being acoustically levitated would react to being hit with a laser beam. We hypothesized that the water droplet might quadrupole out to four distinguishable points (like a rounded square). It also has the possibility of di-poling or just outright exploding.

Due to the flush tube not arriving on time, we were unable to conduct the detection experiments. However, the groundwork for the project has been laid. The water cooler is connected, and the flush tube has arrived. All one would need to do is construct the flash lamp in the flush tube and the laser should be operational.

While we waited for the part to come in, I assisted Dr. Cheyne with his device that can measure the alcohol content of distilled alcohol. We mainly focused on coding for the device. The device consists of two transducers directly parallel in front of each other. One transducer acts as a receiver while another acts as a transmitter. The transmitter sends out a pulse that is then detected by the receiver, and how fast that ping is detected after leaving the transducer determines the alcohol content.

Knowing the temperature and the speed of the sound of the liquid, one can determine the alcohol content. Our main issue was that the Arduino coding system was timing out before we could receive a ping. Arduino is constantly running in the background of gathering data. Most of this is unimportant so we used the code “nointerrupts” to cut this background noise out and we resumed it by using the code “interrupts”. It forces the code to only focus on detecting the pinging.

This worked initially but later failed due to noise in the system. We hooked up the transducers to an oscilloscope and a function generator to make sure they were working. The reading we received showed us that the speakers were indeed working so our error lies somewhere in the coding, or Arduino itself. The pings could be arriving too fast to the transducer for the Arduino to pick up in the first place. In other words, the transducer can’t transmit and receive signals at the same time much like we can’t breathe in and out simultaneously. Once these hiccups are dealt with this device would make measuring the alcohol content much easier in local distilleries.

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