Understanding Sonoluminescence

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Abstract

Sonoluminescence occurs when a bubble within a liquid medium emits light due to excitation from a high frequency sound wave. This phenomenon has been studied since the 1980's, but the specific mechanism that is responsible for transforming acoustical energy into light is still unknown. Research has been conducted into the many properties of sonoluminescence; however, there exists minimal literature discussing a procedure for producing a robust apparatus capable of displaying this effect with minimal fine tuning. Procedures that are published are unclear and lacking detail making it extremely difficult to build a device to support sonoluminescence without any previous experience. This research will meticulously study the process of achieving sonoluminescence with the hope of finding how this can be done reliably. Published procedures will be studied and incorporated into our sonoluminescence experiment and a detailed description of our methodology will be created. From there, research into the physical phenomenon itself will continue.

Background

Sonoluminescence is a phenomenon that was first recorded in the 1930's during sonar research. What is known about why and how sonoluminescence occurs is minimal. We do know that sonoluminescence occurs when high frequency sound waves are applied through a medium such as degassed water. Then, once a resonant frequency is found for the body of water, a small air bubble is introduced. The air bubble becomes trapped in the sound wave and begins to resonate with the wave, causing its rapid expansion and contraction. It is not yet known what specific mechanism within the bubble creates the emitted light; however, there are many different ideas as to what this mechanism could be. Yet, there still is not substantial evidence supporting any one of these theories.

Objective

There are two objectives for this project. The first is to achieve a setup which can successfully create single bubble sonoluminescence. To do this, the former attempts at UNC to create sonoluminescence will be studied to find flaws that can be corrected. The second objective is to better understand how to mathematically model real world systems, like the electronic circuit driving our setup.

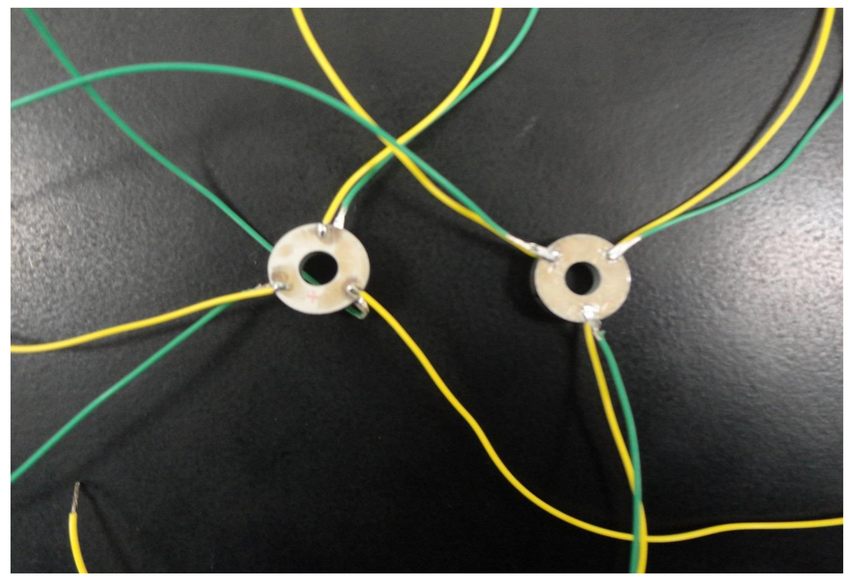

Figure A. The piezoelectric transducers that will be attached to the flask and serve as the source for the soundwave.

Figure B. The resonance vessel, or flask.

Figure C. The dissolved oxygen meter.

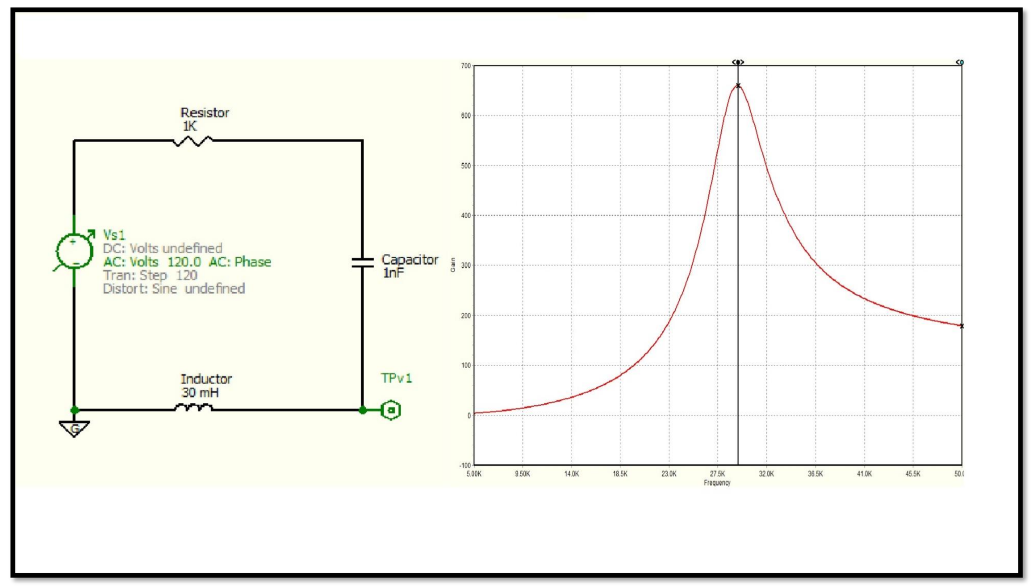

Figure D. The circuit modeling program, 5Spice, is being used to examine the electrical characteristics of the system. Shown here is a simplified circuit model under study and a plot of its gain as a function of frequency.

Methods

The first step in building this setup was to solder wires to the piezoelectric transducers (the speakers) which serve as the source of soundwave (Figure A). After this, the speakers were attached to the resonance vessel, or flask (Figure B), with a thin layer of epoxy. To ensure the symmetry in mounting the speakers, a laser was used to sight the position of the second speaker relative to the first. Once the speakers were placed on the flask, a microphone was placed on the bottom of the resonance vessel opposite to its neck in the same manner as the speakers. Then, the transducers become part of a LCR circuit. LCR circuits are comprised of inductors, capacitors, and resistors. For my circuit, I used a ceramic 1 ohm resistor and two copper coil air core inductors. The speakers on the flask act as capacitors completing the LCR circuit. The components of the LCR circuit were wired together using coaxial cables instead of simple wires. The two inductors were connected in series to give the desirable range of inductance. The total inductance of the system could be varied by inserting an iron rod into the core of the inductors. Having an adjustable inductance will be crucial in tuning our system to achieve resonance. The inductors were then connected to the function generator and speakers with the resistor inserted in series. The microphone was then connected to an oscilloscope with coaxial cables. This is necessary to monitor the output signal and to find the resonance frequency of the system.

Along with setting up the flask, a procedure for degassing water was developed. It is believed that excess gas (oxygen) negatively impacts bubble stability. 550 ml of distilled water is placed in a beaker and heated to a rumbling boil with the use of a hot plate. The water is then left to boil for ten minutes. After ten minutes, the hot plate is turned off, and the water is left to sit for five minutes before it is transferred to a one-liter screw cap container. The water is allowed to sit for another five minutes before the container is sealed, then placed inside a refrigerator. It remains there for a minimum of twenty-four hours before use. An oxygen meter (Figure C) is used to measure the effectiveness of this process.

Modeling

The second goal for this project is to understand how to create a mathematical model for the system that is being built. There are two parts to this system: electronic and mechanical. Our model will look at the system through the electronic lens. A circuit modeling program, 5Spice, is being employed to investigate a simplified version of the system (Figure D). In particular, the behavior of the system voltage as a function of frequency will be studied. Though the model will help narrow the range of possible frequencies, it will not definitively reveal the exact resonance frequency of the system. The model is restricted by assumptions made about the nature of the system. It is assumed that the wires carry no resistance or inductance. In reality, coaxial cable has a non-zero resistance and a layer of wire sheath that will produce both capacitance and inductance. The inductors in our system are assumed to have no capacitance, but inductors do carry some. The largest disconnect between our model and the real system is the treatment of the piezoelectric transducers (the speakers) as capacitors only. Transducers also have inductance and resistance. Moreover, they will experience a load, or electrical impedance, as they operate coupled to the water-filled flask and produce acoustical energy. A more accurate model would take such effects into account. Though the 5Spice model is useful to understand our system, hands-on work will still be needed to fine tune it to achieve sonoluminescence.

Conclusion

Changes that have been and will be made to the setup at UNC should allow for repeatable sonoluminescence. Now that the setup has been reconstructed, the next goal is to achieve resonance of the system. Achieving resonance will require fine-tuning the system using the variable inductance and possibly changing the resistor value. If resonance cannot be achieved, other setups will be studied and explored. If sonoluminescence is achieved, the next step will be to see how data can be recorded. The eventual goal is to use the data collected to try to better understand why and how sonoluminescence occurs.

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