Sonoluminescence

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Background:

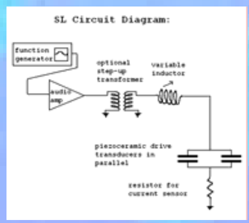
Sonoluminescence (SL)literally means light from sound and is the process where light is emitted from bubble cavitations in a liquid in a sound field. SL was first observed in the 1930’s. Researchers stumbled upon multiple bubble sonoluminescence (MBSL) while investigating propeller corrosion problems caused by bubble cavitation. Interest in the phenomena waned as MBSL was difficult to study and little could be learned from uncontrollable clouds of bubbles.

There was a resurgence in enthusiasm, however, when single luminescent bubbles were isolated through the discovery of single bubble sonoluminescence (SBSL) in 1989. Now SBSL is widely studied; the extreme nonlinear mechanism produces tremendous heat and pressure in an unassuming apparatus but is not well understood. There are a variety of theories that seek to explain the phenomena. Our principal goal this summer was to set up a SBSL experiment to observe the phenomena.

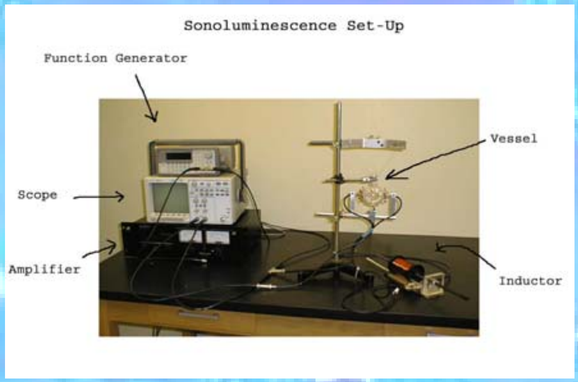
Apparatus:

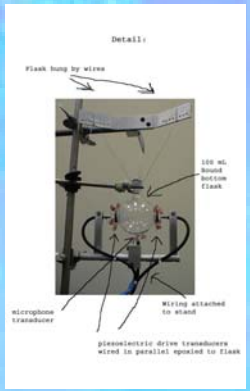
- Equipment:
  - Function generator
  - Audio amplifier
  - Transformer
  - Matching inductor for maximum power transfer
  - Spherical flask with attached transducers
  - Degassed water
  - Scope
- Set-up Overview:
  - Piezoelectric transducers are epoxied to a spherical resonance chamber containing distilled water. The transducers are driven by a an amplified sinusoidal signal at about 25 kHz.

Circuit:



A sine wave is output by a function generator and amplified with an audio amplifier. An audio transformer can then be used to step up the voltage. The drive transducers behave like capacitors so an inductor is employed to balance the capacitive load due to the transducers and provide for maximum power.





Operation:

The spherical flask serves as the resonant chamber and concentrates the sound energy. The resonant frequency of the flask can be approximated by:

$$f_{resonance} = \frac{v}{d}$$

where v is the speed of sound in water and d is the diameter of the flask.

Two drive transducers are attached with epoxy exactly opposite each other along the equator of the flask. The transducers are piezoelectric elements that change shape in response to a voltage applied across them. They vibrate the flask, introducing sound into the system and when driven at the resonant frequency, there should be a pressure anti-node at the center of the flask.

An additional smaller transducer is attached to the bottom of the flask to serve as a microphone to observe the sound energy in the system.

Tuning the frequency:

The driving frequency is tuned to the resonant frequency for the chamber; in our case the frequency should have been about 25Khz. Driving the system at the resonant frequency should boost the output. A maxima is sought on the microphone scope, and the frequency adjusted for maximum amplitude. The inductor is then tuned for that frequency, to maximize power delivery to the transducers, further increasing the amplitude on the microphone signal.

At this point, a bubble is introduced into the flask and if all goes well, one can coax it to glow by turning up the drive power and tweaking the driving frequency. At least that’s how it’s supposed to work…

Problems:

- No light was observed.
- An amplitude Maxima was not observed at the resonant frequency for our size of flask.
- Although bubbles were captured and observed to levitate, they were not in the center in the flask, nor were they captured at the resonant frequency.
- The quality factor,Q, of the flask was measured and found to be very poor.

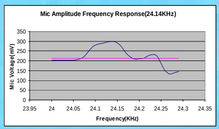
Flask Q factor:

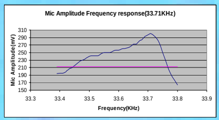
As a result of the poor performance of the apparatus, the quality factor, Q, of the flask was measured. Q is a measure of tightness of the resonance and is given by:

$$Q = \frac{f}{\Delta f}$$

where f is the frequency at the maximum amplitude and delta f is the frequency spread at half power

The Q was measured and found to be about 100, much poorer than recommended.





Conclusions:

The apparatus is apparently very sensitive to having a precise geometrical configuration, as the problems that we have had with it indicate. The poor Q factor for our flask is a good indication that the fault lies with the resonant chamber and not the electronics.

A new chamber is being constructed, utilizing a different flask, that will hopefully have a better Q and allow us to achieve Sonoluminescence.

Sources:

- **Journal Articles**
  - Brenner, Michael P., Hilgenfeldt, Sascha., and Lohse, Detlef., 2002, “Single Bubble Sonoluminescence” Rev. Mod. Phys.74, 425-484.
  - Hammer, D. and Frommhold, L., 2001, “Spectra of sonoluminescence rare-gas bubbles” Phys. Rev. Lett. **85**, 1326-1329.
  - Holt, R. G., Gaitan, D. F., Atchley, and A. A., Hozfuss J., 1994, “Chaotic Sonoluminescence”, Phys. Rev. Lett. **72**, 1376-1379)
  - Putterman, Seth J, 1995, “Sonoluminescence: Sound into Light,” Scientific American Feb. 1995, 32-37.
  - Putterman, Seth J, 1995, “Sonoluminescence: the Star in a jar,” Physics World May 1998, 38-42.
- **Web Articles**

  A how-to page on SBSL on the Lawrence Livermore National Lab site:
  - http://www.llnl.gov/adiv/projects/dfroula/Meth.html

  A well written site discussing the details of constructing a SBSL apparatus:
  - http://www.techmind.org/sl/
- **Background Pic Courtesy of:**
  - http://www.gravityquest.net/imagesgallery/pages/Bubbles.htm