Sonoluminescence:

That Elusive Glow

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Theory:

Nature of Sonoluminescence:

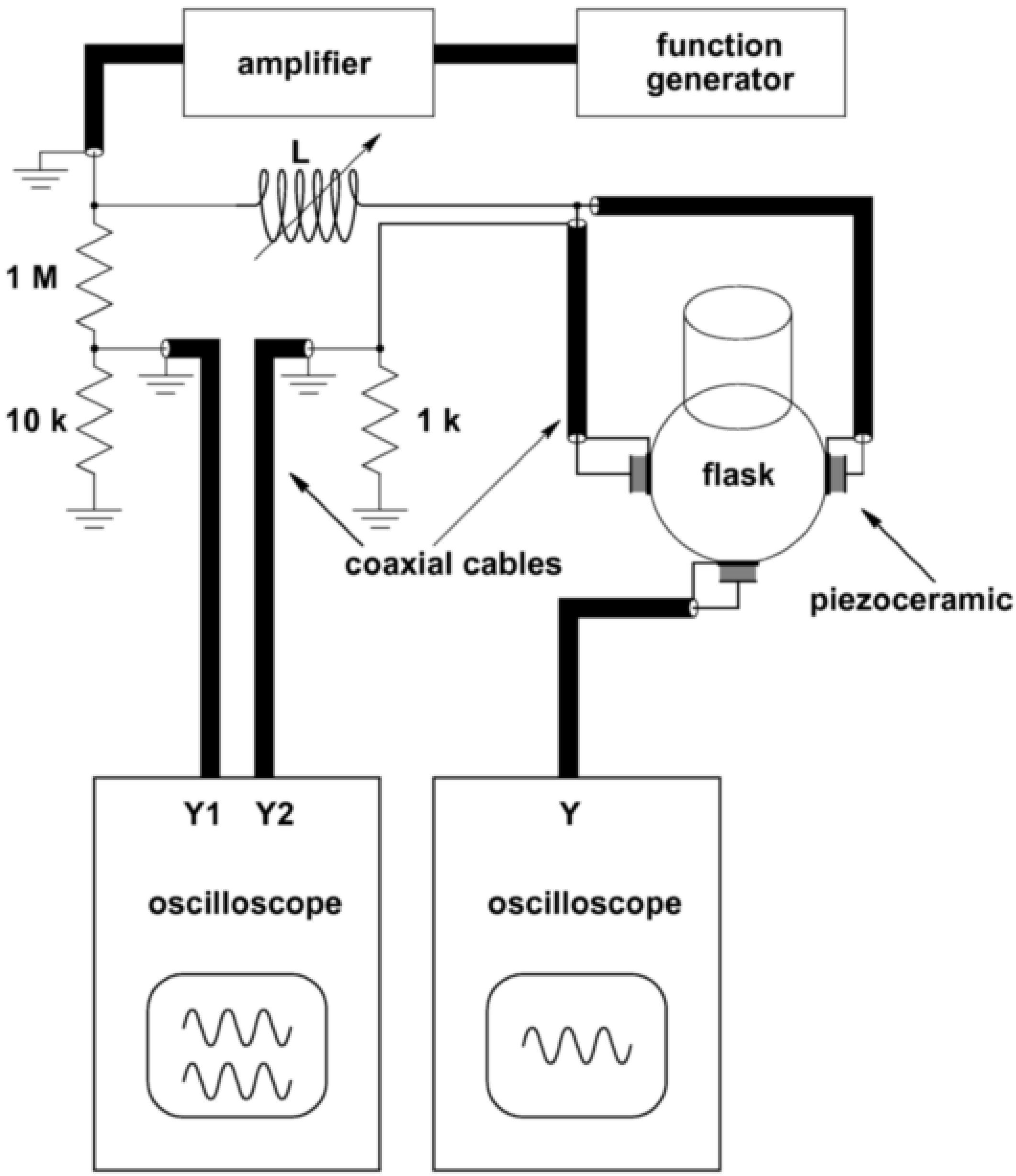
Sonoluminescence is a phenomenon in which a micron-scale bubble of air inside a liquid focuses sound waves, generating sufficient energy that light is released. Although the exact mechanism by which light is generated remains the subject of significant scientific debate, sonoluminescence has been consistently and reproducibly generated in a number of liquids, using a variety of flasks, and in both single-bubble and multi-bubble states. As single-bubble sonoluminescence (hereafter SBSL) is more stable and convenient to study than multi-bubble sonoluminescence, its 1988 discovery by Felipe Gaitan led to extensive study of the phenomenon and a greater understanding of the physical process. In SBSL, the bubble, if it is under sufficient acoustic pressure (about 110dB), remains positionally stable in the liquid and cavitates in a cyclic manner. If this cavitation is of sufficient magnitude, light is released in SBSL.

Sonoluminescence in spherical glass flasks:

The most common experimental apparatus for producing sonoluminescence was outlined in 1995 in a *Scientific American* article by Barber and Hiller. This apparatus, a simple spherical glass flask driven by two equatorially mounted piezoelectric transducers, has served as a model for countless experiments attempting to achieve sonoluminescence. The spherical symmetry of the flask increases the focusing effect of the drive transducers at the center of the flask. If a glass flask is used, the frequency at which resonance occurs will not be the same as the resonance of the cavity alone. Taking this into consideration, the driving frequency must be adjusted to determine the most resonant effect.

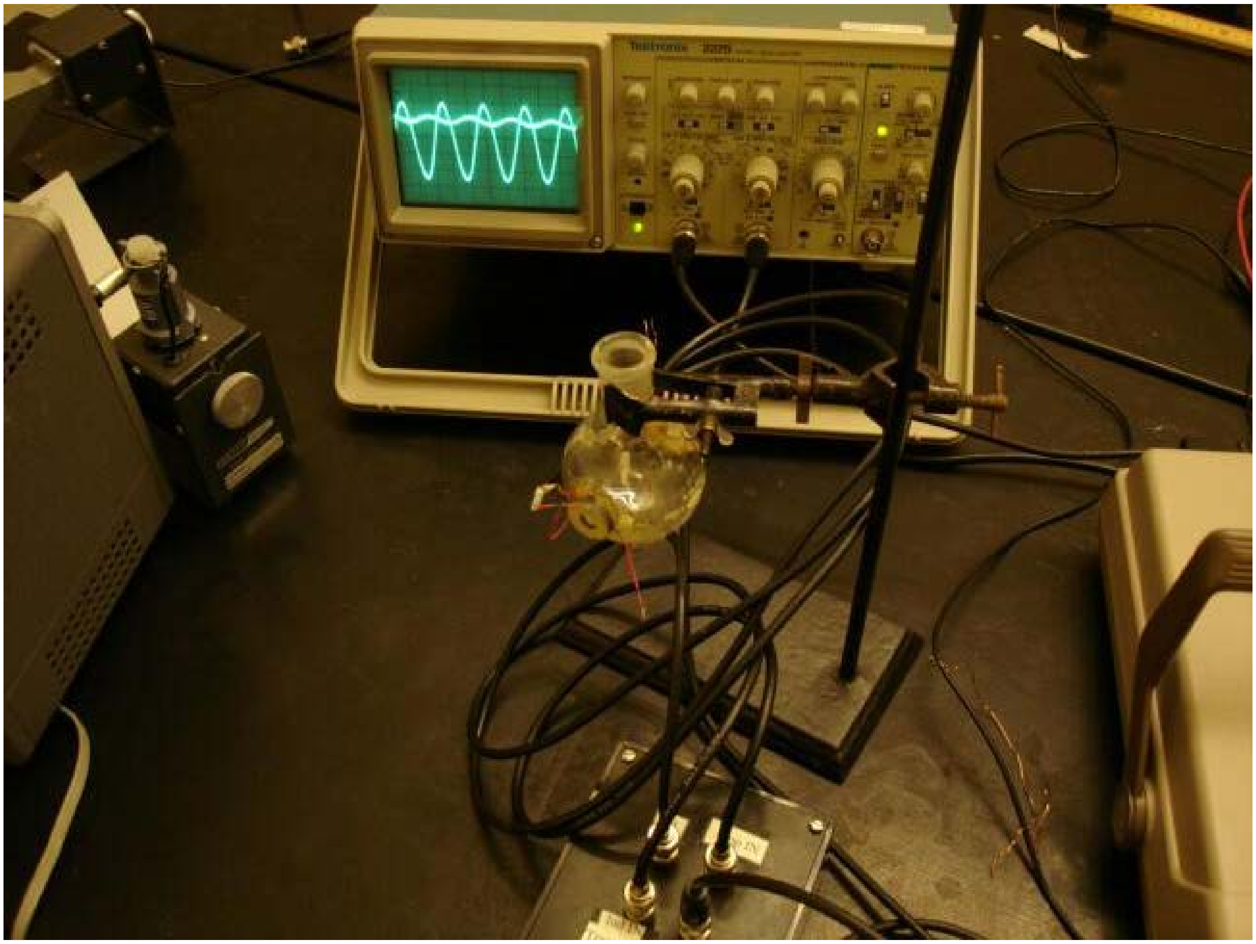
Apparatus set-up:

The following picture, modelled after one on Reinhard Geisle's web site, details the apparatus used for the experiment. As is typical for SBSL, two driving piezoelectric transducers (PZT) were mounted equatorial on exactly opposite sides of the flask using epoxy. A third PZT is attached (also with epoxy) to the bottom of the flask to serve as a microphone, which is read by the oscilloscope. In order to drive the PZTs with sufficient voltage, it was necessary to send the generated signal through an amplifier and a variable inductor. This is possible because the driving PZTs function in the circuit as capacitors, which allows the use of an inductor to reinforce a resonant frequency. The listed Y1 and Y2 oscilloscope feeds were used to monitor the output of the amplifier and maintain a steady trace. As a previous individual set up the flask and circuit, no major modifications to the equipment were made, although the Y2 trace was not typically used. Coaxial cable was used for most of the wiring, as this is considered to limit interference.



Equipment specifics:

The PZTs used were the standard Channel Industries set of 3 used by Barber and Hiller in their Scientific American article (and nearly everyone else since then). A Pasco digital function generator was used, due to its ability to control frequency to 1Hz in the 20-40 kHz range (it is possible that an analog generator may be preferable as it may maintain the signal more consistently). After an initial amplifier proved incapable of outputting sufficient voltage in the ultrasound range, a different, most robust amplifier was inserted, and although it was still originally designed for amplifying frequencies audible to humans, it proved a greater output at the necessary frequencies. A variable series inductor (which may have been commercially available at some point), capable of producing between 10 and 50 mH, proved very useful in tuning the circuit to electrical resonance.



Experimental Procedure:

Sonoluminescence requires that the water be mostly degassed, so that excess bubbles do not form inside the flask (this interferes with the focusing necessary for sonoluminescence). Therefore, prior to adding water to the flask, the deionized water was chilled (to increase brightness of sonoluminescence) and degassed using a vacuum pump and a bell jar. The water was then poured into the just emptied and rinsed flask (as debris impairs the focusing necessary) by tilting the flask stand (which had the wires tied to it) about 45 degrees and slowly pouring water from an Erlenmeyer flask down the side of the spherical flask, to minimize the amount of air added to the flask. Then the signal generator was tuned to maximal acoustic resonance of the flask, which was verified by ascertaining that the signal output would damp if the flask was lightly squeezed. Then the inductor was tuned to electrical resonance, so that the acoustic pressure inside the flask was maximized (as viewed on the oscilloscope).

After resonance was reached, the voltage output of the signal generator was adjusted to around 3 Volts peak-to-peak, although care had to be taken that the signal did not increase to the point that the amplifier started to clip the peaks of the signal and distort the waveform (as the bubble seemed to respond better to pure sine waves). Once this level was reached, a bubble was introduced. Although many methods for introducing bubbles have been discussed, using an eyedropper (or any similar device) to remove a small amount of water and then drop it gently back into the water proved simplest. This usually introduced a few bubbles of appropriately small size into the water. As these bubbles are typically too small to be readably visible (~5microns), the flask was backlit using an incandescent bulb powered by a Variac, which changed the brightness in its role as an oversized dimming switch. Once the bubble was introduced, the oscilloscope output typically dropped and usually formed a ripple. The voltage then was slowly increased until the bubble dissolved and the ripple disappeared. As sonoluminescence occurs just below the threshold where bubbles instantly dissolve, this should allow the voltage to be slightly scaled down so that sonoluminescence might occur when the next bubble is added. In practice, weeks or months of patient fine-tuning, adjusting, and even experimenting with different resonance points may be necessary before sonoluminescence occurs. If sonoluminescence does occur, the oscilloscope trace should still have a ripple, although it should line up fairly well with the peak, and the bubble should appear stable. Then, if the lights are turned off, the glow should be visible as a steady blue glow. Unfortunately, it may take awhile in order for most experimenters to manage to see the light.

Observed phenomena:

When using chilled, degassed water, the output voltage frequently reached 6-7 volts peak-to-peak, implying that sonoluminescent behavior ought to be obtainable with the equipment on used. Despite this, the detector used (the human eye) did not observe any undeniably sonoluminescent phenomena. There were a few points when a bubble of air may have been dissolved by the acoustic pressure, but this could not be consistently repeated or verified.

Conclusion and possible future adjustments:

Although nothing conclusively sonoluminescent was observed, there was no immediately identifiable property of the system that should preclude the possibility of the apparatus used from generating sonoluminescence. It may simply be a matter of fine-tuning the experiment more closely (most of the literature available implies that the range of variables in which sonoluminescence can occur is rather small). A few possible modifications might be to more tightly control the cooling and degassing process, so that trials would be more repeatable. Also, adding a cooling mechanism to the flask itself might keep the temperature more stable (and low), allowing the water to remain nearer the optimal temperature longer. Also, if the experiment were set up so that the oscilloscope display did not reflect off of the flask, observing sonoluminescence would be easier (especially as many false glows were seen when the oscilloscope display reflected off the surface of the glass). Another simple way to make the phenomenon more observable might be to add a dark background, thereby increasing the contrast with the light.

Useful websites:

Some websites I found to be particularly helpful in putting together this project. Steer's site was my constant reference every time I was trying to figure out just what I was seeing in the flask. Geisle's site was put together well and served as the model for the construction of the apparatus. Also, Robson's site proved very useful in providing the theoretical background of the phenomenon. I must also acknowledge the influence that the February 1995 *Scientific American* has had on the field as a whole, providing a generally standard apparatus and introducing many individuals to the joys of trying to achieve their own "star in a jar."

References:

R. A. Hiller, B. P. Barber. "Producing Light from a Bubble of Air." *Scientific American* Feb. 1995, 78

R. Geisle. "Single Bubble Sonoluminescence How-To." (unpublished) May 1996. Available online at

http://www.physik3.gwdg.de/~rgeisle/nld/sbsl-howto.html

S. J. Putterman. "Sonoluminescence: Sound into Light." *Scientific American* Feb. 1995, 32

S. J. Putterman. "Sonoluminescence: The Star in a Jar." *Physics World* May 1998, 38

J. Robson. "Sonoluminescence" (unpublished) October 2000. Available online at

http://www.dawnlink.ltd.uk/sl/report.html

although the site has been down for a while.

W. A. Steer. "Sonoluminescence" (unpublished) September 1997. Available online at

http://www.techmind.org/sl/

A general list of sonoluminescence web sites, including some sites which discuss the nuclear fusion potential.

http://www.molisearch.com/dwodp/index.php?c=/Science/Technology/Acoustics,_Ultrasound_and_Vibration/Ultrasound/Sonoluminescence/