Sonoluminescence

Apparatus and Suggested Procedure

By Steve Benton

Introduction

With a resonant standing wave in a tank of water, pressure forces can become sufficient to trap a gas bubble at an antinode of the standing wave. Sonoluminescence is a phenomenon in which such a trapped bubble collapses under pressure and emits a pulse of visible light. There is currently no widely accepted explanation of this phenomenon.

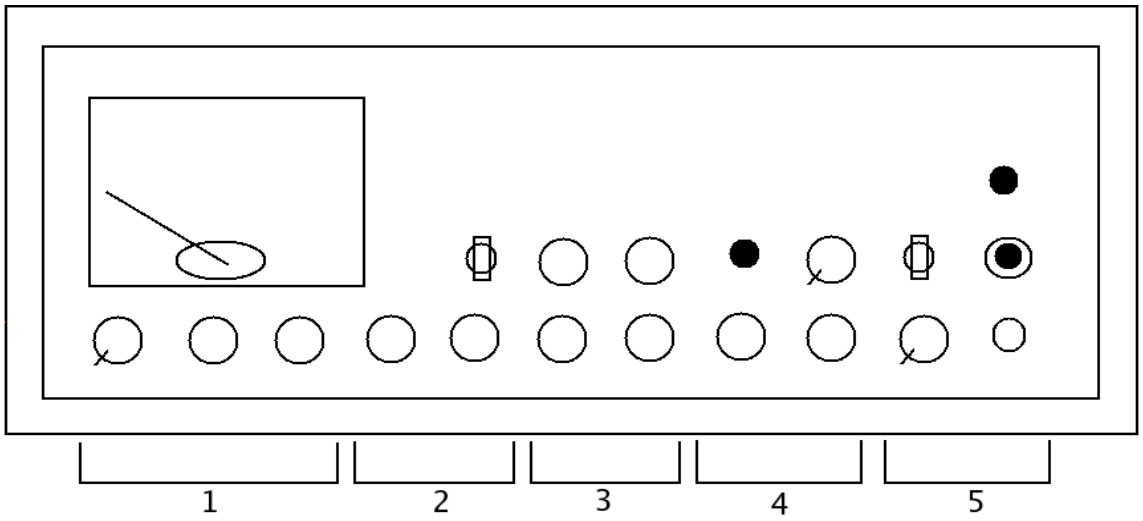
Apparatus

The apparatus consists of four major pieces. The first two are a digital oscilloscope and a function generator. The operation of these is self explanatory. The third piece is the cabinet in which lie two water tanks (I will only concern myself with the rectangular one), a funnel-shaped acoustic horn, and a photomultiplier tube. The last piece of equipment is the SL100B control box. The ultrasonic horn, rectangular tank, andSL100B control box are shown below[1].

A more detailed description of this portion of the apparatus follows. (The description is largely based on data in the Teachspin manual for the apparatus, which is available in the lab resource center)

On the SL100 there are 5 different groups of connectors, knobs, and switches.

[1] Image from http://teachspin.com/instruments/sonoluminescence/index.shtml



1. *Acoustic Horn Drive*
   This group contains all of the drive control for the ultrasonic horn. On the far left is a knob to adjust the output amplitude to the horn. Next to this is a TNC connector for the output to the horn. This is connected through a 2.7mH inductor to balance the capacitance of the ultrasonic horn. Last of all is a BNC connector for the input from the function generator. This input signal should have 1V amplitude. The meter at the top is not part of this group, but is the cell amplitude meter and goes with the cell transducer.
2. *Hydrophone*
   The hydrophone (a pressure sensor) can be used to monitor resonance conditions in the tank of water. It is the long metal device on (but removable from) a thin BNC cable and should be connected to the leftmost connector in this group. The next connector supplies output and can be observed on an oscilloscope. This output will always go through a high pass filter with a 4kHz corner to remove 60Hz noise. If the switch above is set to filtered, the output will also passes through a 5^{th} order high pass filter with a corner of 150kHz.
3. *Cell Transducer*
   This group corresponds to a piezoelectric pressure sensor at the bottom of the tank, and is the most useful measurement tool in obtaining sonoluminescence. The bottom left connector in this group is for the input from the cell transducer and is taken from the BNC connector under the tank and through the side of the cabinet. As with the hydrophone, the unfiltered output (bottom right) is run through a 4kHz high pass filter to remove noise, and the filtered output (top right) passes through a 5^{th} order 150kHz high pass filter. The HF Det (top right) output measured the amplitude of the filtered signal using a peak detector of time constant 0.1s. The amplitude (plus a gain of 4) of the unfiltered signal is available via another peak detector on the cell amplitude meter at the top left of the SL100.
4. *Photomultiplier Tube (PMT)*
   This group controls and processes data from the PMT. The PMT should be connected (through the outside of the cabinet) to the BNC connector at the bottom left of this group. The PMT power supply should also be connected through a power plug in the water tank's box, and to a switch on the outside of the cabinet. It is also connected to a switch just on the inside of the left side of the cabinet, but this switch can be taped in the 'on' position since it serves no purpose with no cabinet door. Above the input

connector on the SL100 is a knob to adjust the gain of the PMT. When this is turned fully counterclockwise, or when the switch on the cabinet exterior is down, the PMT is off. **The PMT should not be turned on when exposed to ambient light** this will overload and possibly destroy the device. The 'output' connector provides the peak of the signal via another peak detector; unmodified output can be obtained by splitting the input connector with a T-junction. The LED in this group indicates when the PMT is on.

5. *Miscellaneous*
   In the left this group are controls for the Peltier cooler in the cylindrical tank which is not described here. The rest of the connectors are for the boiler module which is not used to seed bubbles since it draws too much current. At the top is a light to indicate when the SL100 is on. The power switch is in the back left of the box.

Note: the different groups in the SL100 are not perfectly isolated. Noise can be found in some groups that clearly corresponds to signals from other groups.

Suggested Procedure

This method does not guarantee success, but it is a very reliable way to achieve sonoluminescence. A touch of luck and finesse are involved, but not too much.

1. Ordinary tap water contains many small pockets of gas which will inhibit the ability of a stable bubble to be trapped. For this experiment, water must be degassed with a vacuum pump prior to use[2]:
   - Ensure oil level on pump is sufficient (viewing port on side)
   - Fill flask to about 800mL and insert black rubber stopper. Place flask in metal garbage pail in case it implodes.
   - Close main valve from stopper (turn clockwise) and tighten pinch valve to close the T-junction on the tube.
   - Turn on vacuum pump and then open valve coming from stopper
   - Let pump operate for 20-30 minutes, ensure tube between pump and stopper doesn't kink
   - **Before turning off the vacuum pump** close the main valve (otherwise vacuum inside flask will suck oil out of the pump) Turn off pump.
   - Slowly open pinch valve from T-junction
   - Slowly open main valve and remove rubber stopper. The water is now ready to be used.
   - Pour water carefully into tank to minimize bubbling. Fill up to the 10cm line on the tank (marked in tape)
   - This water is good for about 2 hours.
2. Set up input signal to SL100. Turn on the Ramsey generator, set its frequency to around 27kHz with a 1V amplitude. It is easy to set the amplitude by temporarily connecting the generator to the Cell transducer input on the SL100 and turning volume up until 4V is read (1V before amplification) on the cell amplitude meter.
3. Place the tip of the ultrasonic horn in the tank and ensure (*this is critical*) that it is well centered and no more than about 5mm deep.
4. To achieve resonance, turn the horn volume about half way up, and scan

[2] Degassing instructions adapted from guide by Jonathan Hillel, included in teachspin manual

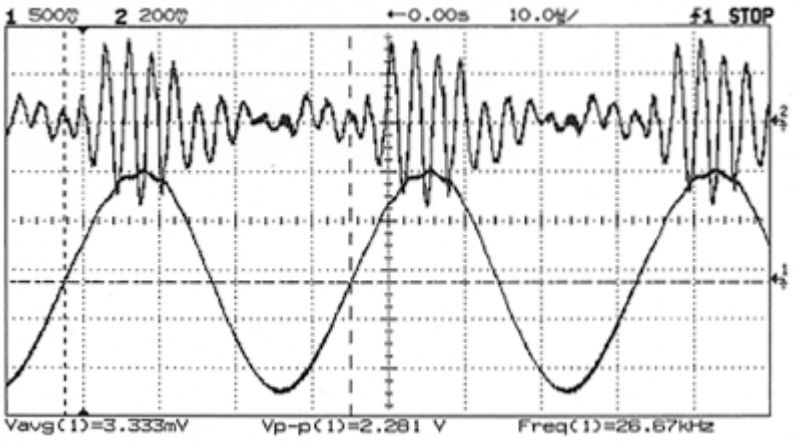
frequencies until a maximum amplitude is reached. The amplitude can be observed best using the cell transducer, and the cell amplitude meter. Once resonance is reached, turn down the horn power until the amplitude meter reads about 4-5V. The apparatus may buzz slightly from noise in the signal.

5. There are two ways to try to seed bubbles at this point; both can work but you will probably find one more reliable than the other.
    - The simplest way is to use an unmodified eyedropper to remove some water from the tank, and then squirt it quickly at the surface of the water. This should create many bubbles and cause a large drop in cell amplitude. After a minute of two though there will often be a bubble trapped at each of the three vertical antinodes in the tank. They may be too small to see, but if you turn off the room lights or stick your head under the curtain, it is possible to see a faint blue glow with the naked eye.
    - The other method is to use the elongated eyedropper to directly squeeze bubbles out near an antinode. This however, will often create bubbles that are too large to be trapped, and it can be tricky to remove the eyedropper without disturbing the bubbles.

Tips and Tricks

If sonoluminescence just won't happen here is a list of things to try that may help:

- The resonant frequency will change as degassing wears off, and as other conditions fluctuate. Drive frequency should constantly be adjusted to match it.
- There are many other resonant frequencies near 45kHz. Although it is easier to trap a bubble at them, the trapped bubbles will not always exhibit sonoluminescence.
- Try adjusting horn power up and down by about a volt (on the amplitude meter). Too much or too little power can prevent a bubble from getting trapped.
- When a bubble is trapped, the high frequency output from the cell transducer may have a characteristic behaviour (high frequency on top, unfiltered below):



Possible Experiments

A good description of some theory for this experiment, as well as details about suggested measurements/experiments is available from:
http://sonoluminescence.com/sl-experiment2.pdf