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A Procedure for Getting the Sonoluminescence Lab Operational

This document should serve as a guide for PHY 327 students doing the sonoluminescence experiment. It is divided into three sections; the first section outlines the essential and fundamental steps to get sonoluminescence working. If these steps are not followed the experiment will not work. The second step outlines some troubleshooting procedures. The final section provides some theory and talks about additional and helpful tests students can do.

Section 1: Sonoluminescence Procedure

a) Pumping the Water and Setting up Electronics:

1. Fill the Erlenmeyer flask halfway with distilled water and connect it to the vacuum pump for half an hour or until it stops bubbling. Remember to open the valve on the pump so that it actually starts sucking air.

2. In the mean time, while the water is degassing, you can set up the electronics. This is done by plugging the cell transducer output into channel 1 of the oscilloscope. Then, plug the high frequency output into channel 2. All other circuitry should be already set up. I am including a full schematic of the wiring in my notebook, however, should a reference be required. Finally, BE SURE THE RAMSEY GENERATOR IS ON SINE AND NOT SQUARE WAVES.

3. Unplug the cable from the cell transducer input plug on the control box and replace it with the output from the function generator. With the function generator set at 30 kHz, adjust the amplitude of the signal so that it reads 4V on the voltmeter on the control box. This will serve two purposes: a) it tests the equipment, and b) it will ensure that the Ramsey generator input is not excessively high. The literature warns that having the input too high could fry the control box's circuits.

b) Finding Resonance:

4. Once the water is finished degassing, pour it slowly into the square container, filling it up to the 9.6 cm mark on the masking tape. Be sure to pour it slowly so as little gas mixes into the water as possible. Tap the sides of the container as to remove any bubbles.

5. Position the horn so its tip penetrates the surface of the water only by ~1mm.

6. Find the resonance frequency within the box. This is a frequency at 28-30 kHz that gives maximum peak-to-peak amplitudes for channel 1 on the oscilloscope. This corresponds to resonance in the pressure waves within the tank.

7. Once resonance is found, add ~2 mL of water using a syringe and find resonance again. Keep doing this until you notice that resonance amplitude starts to decrease.

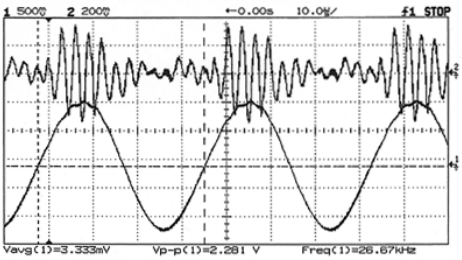
8. By this point, the cell transducer voltage should be reading between 3.8-5 volts. If it is not, adjust the drive so it is within this range. If you cannot take the drive high enough, you are probably not at resonance and should consult troubleshooting

c) Finding Sonoluminescence

9. Assuming you are now at resonance, observe channel 2 on the oscilloscope. This is the high frequency out put. It is essentially the same signal as going into channel 1 except the low frequency has been filtered out and the high frequency amplified. It should appear as periodic noise of ~ 1 to 2 volts peak 2 peak (check this).

10. Check to see that there are no bubbles stuck in pressure nodes or clinging to the sides of the tank. If there are, remove them because they will interfere with resonance. Next, use the syringe to fire some air into the tank just above where the cell transducer is located. Remove, using the dropper, any visible bubbles floating in the tank. Removing these is okay because the bubbles that actually sonoluminesce are much too small to see.

11. Look back at the high frequency output. If it appears to have a different character than it did in step 8, this is an indication that a bubble has been trapped. Ideally, for a sonoluminescing bubble, it will look like the output shown here.



12. If a reasonable high frequency output is seen, try turning off the lights and looking for a sonoluminescing bubble. It should look like a miniature blue star inside the tank, near the center of the tank's xy plane. In the z axis, they are located at either 1.5 cm from the bottom, just below the horn, or in the center of the tank. If no bubble is trapped, try going back and repeating steps 9 through 11.

d) Photomultiplier Tube

13. Once sonoluminescence is obtained, the light can be detected by the PMT. We found that the control box gives confusing output, to students are best to use the input from the photomultiplier tube directly instead. This can be plugged into Ch2 and amplified on the oscilloscope. We found the mean tends to drift, however. Perhaps the control box solves this problem by taking the first derivative of the signal.

Section 2: Troubleshooting

a) Problems Degassing

1. To improve the effectiveness of the vacuum pump, I found it useful to wet the sides of the cork before putting it in the flask. This will allow the cork to form a firmer seal with the glass.

b) Problems Finding Resonance:

2. If you are having trouble finding the peak resonance in steps 5 and 6, one problem could be is that you are taking too long to add the water. It has been experimentally verified that resonance amplitudes and optimal resonance frequencies drift with time due to the diffusion of gas into the water and due to the water returning to room temperature. (See section 3 point 1 and note that the water is cooled to ~13 degrees by the degassing)

3. Sometimes it is difficult to find the peak frequency and still measure peak to peak amplitude as step 4 recommends. This procedure can be made easier by using a splitter to plug the cell transducer's output into both channels 1 and 2. Then, by turning on the oscilloscope's measure function you can take peak to peak resonance readings from channel one. Then, on channel 2, zoom in on one of the peaks of a sinusoid. This allows for subtle changes in resonance amplitude to be detected and makes it possible to get more accurate resonance frequency readings.

4. The horn height also plays a factor in finding resonance. If the horn is too deep in the water, it can interfere with the formation of standing waves. (This is apparent by sticking the horn down very deeply and trying to get resonance). There should be an optimal point for horn depth where it is not so deep that it interferes with resonance but it is deep enough to have a sufficiently strong driving force standing waves of significant amplitude.

5. Large bubbles can also interfere with resonance formation. Remove any large bubbles by running the syringe along the inside edges of the tank. Small bubbles can be removed by turning off the horn for a second. This allows bubbles of all sizes trapped in nodes to float freely up to the top of the tank.

6. Do not rely solely on the high frequency output to determine whether a large bubble is trapped in the tank and whether there are any large bubbles interfering with resonance. The lamp supplied with the lab equipment is actually very useful as well. Try shining it on the tank and looking for bubbles, especially along the edges and corners of the tank.

c) Problems Getting Sonoluminescence once Resonance is Found

5 If you are seeing a distinct high frequency signal but still no sonoluminescence, try jimmying the drive knob a little. Raising and lowering the amplitude of resonance will shake up the system. Since often multiple bubbles can become

trapped, this can interfere with the resonance in the tank and prevent sonoluminescence from occurring.

6 If problems are still encountered, you can "reset the system." Try turning off the horn altogether and tapping the sides of the glass; this will allow any small bubbles that have been trapped to be removed. Then inject some more air in and try again.

7 You may find that you are getting sonoluminescence but the bubbles are not lasting long. You may also notice that the bubble's brightness does not appear constant and the bubble appears to be moving around in the tank. This is a sign that your standing waves are not sufficiently stable; in other words you need to find resonance again. First try adjusting the frequency and seeing if this improves (increases) in the peak-to-peak cell transducer amplitude. If this does not solve the problem, another approach would be to simply remove

d) Problems with the Photo Multiplier Tube

1. To reduce the strange PMT mean drift, you can try adjusting the frequency and the water height to get a better resonance. This should reduce fluctuations in sonoluminescence brightness.

Section 3: Background information

1. After degassing, the water temperature tends to drop to around 13 degrees. Therefore, if you wish for temperature to be held constant during your experiment, it would be advisable to reheat the water before beginning step 3.

2. The reason for step 7 lies in the fact that resonance is occurring in a three dimensional environment. Therefore, resonance approaches a maximum when all three barriers are integer multiples of the wavelength. By varying the water height, we are trying to find the height at which there exists a driving frequency which allows for resonance to occur in all 3 directions.

3. The relation between water depth and resonance frequency and amplitude is an interesting one. An optional exercise for students would be to keep a log of the amount of water added versus the resonance amplitudes and frequency. This will allow students to get a feel for the resonance in the tank and help them to find resonance more quickly later on.