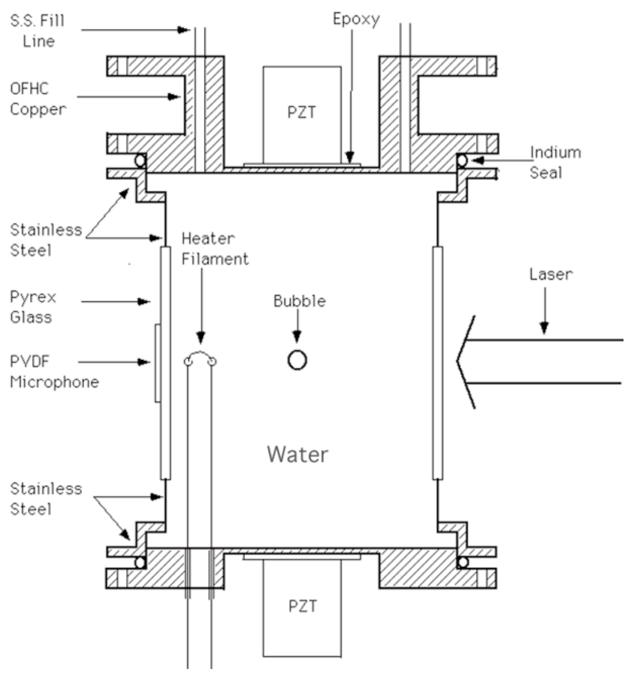
Physics 180D **Experiment #3**

Sonoluminescence

The objective of this experiment is to characterize the luminescence emitted by gas bubbles in water driven by a strong acoustic field. The time dependence of the light pulse is investigated, and correlated with the dynamics of the bubble oscillation.

The figure shows the cell, a cylindrical acoustic resonator driven by PZT piezoelectric drivers on both endcaps. A bubble is injected by briefly running current through the heater wire, and if a resonant mode is tuned that has an antinode at the center of the cell the bubble will be attracted to that spot and trapped there.



The dynamics of the trapped bubble can be studied by putting a laser beam on it and monitoring with a photomultiplier the the light that is scattered from the circular bubble, a process known as Mie scattering. The intensity of the scattered light is proportional to the square of the bubble radius, allowing a measurement of the radius versus time. The bubble expands when the acoustic pressure is negative, and then collapses rapidly when the acoustic pressure turns positive, followed by several small oscillations ("afterbounces").

If the acoustic drive amplitude is turned up there is a threshold value (about 1 bar pressure swing) at which the bubble begins to emit sonoluminescence. This coincides with the collapse point of the bubble on each acoustic cycle, and consists of a pulse of order 10^6-10^7 photons emitted in a time of about 100 ps. The physical mechanism that gives rise to this light pulse is still not completely understood, but is probably connected to the adiabatic compression of the gas in the bubble during the rapid bubble collapse. At the minimum radius the gas is heated to temperatures thought to be of nearly 17,000 K, which is enough to ionize it and form a plasma. The electrons in such a plasma would be subject to very large accelerations, leading to radiation over a wide range of optical frequencies that would reach peak intensities in the far ultraviolet (blackbody radiation).

EXPERIMENT:

A. First tune the resonator to one of the modes near 32 kHz and try to trap a bubble by flicking momentarily the switch to the heater current. It may be necessary to try several of the closely spaced modes until the bubble-trapping mode is found. The bubble is quite small (about 50 μm maximum radius) and difficult to see, so it may be helpful to train the laser on the center of the cell, since the Mie scattering can be quite bright. Adjust the acoustic amplitude to a value somewhat larger than the minimum needed to trap the bubble.

B. By monitoring the Mie scattering with the photomultiplier, measure the radius of the bubble versus time, scaled with respect to the maximum radius. Turn on the averaging function in the scope, averaging 256 or 1024 pulses to lower the noise levels. There is usually stray light in the room that will give a background dc offset to the photomultiplier signal, so also take averages of the light signal with the laser turned off.

C. Increase the drive amplitude and note any changes in the bubble dynamics. Watch for the appearance of a sharp spike at the minimum radius of the bubble, which is the onset of sonoluminescence. Continue taking radius-time data as the acoustic drive is increased, until the upper threshold where the bubble trapping is lost.

D. Retrap a sonoluminescing bubble and turn off the laser. Measure the time between SL pulses and verify that this is precisely the period of the acoustic drive. By expanding the time axis of the oscilloscope to its minimum, measure the width of the observed pulse on a nanosecond time scale. To eliminate the 10-20 ns jitter in the sync pulse from the oscillator, it is best to trigger the oscilloscope from the negative-going SL pulse itself. Turn on averaging to lower the noise.

E. Get an estimate of the optical spectrum of the SL by measuring the amplitude of the pulse as various filters are put in front of the photomultiplier to block different light frequencies. You may have to readjust the trigger level as the pulse amplitude decreases. Compare your intensity ratios to the intensities expected for a 17,000 K blackbody spectrum by integrating the blackbody spectrum with a lower wavelength limit of 250 nm and upper limit 800 nm, which are the limits of the PMT sensitivity.

SAFETY ISSUES:

Lasers are intense sources of light, and can cause severe permanent eye damage, possibly leading to blindness. Even a beam reflected from a glass or metallic surface can be dangerous. For this reason, **it is absolutely necessary for all persons in the lab to wear the supplied safety glasses at all times when the laser is turned on.** The door to the lab should be closed, and no other persons should be admitted to the room. This is a 10 mW laser, three times more powerful than laser pointers, and even those can cause serious damage.

This experiment involves high-amplitude ultrasonic sound. Although it cannot be heard, some persons may be sensitive it, and the medical effects of such high amplitudes have not really been determined. It is probably prudent to wear ear plugs during the operation of the experiment, which will be supplied.

Not a safety issue but an economic issue: the photomultiplier costs about $1000 and because of its high electron gain of about 10^5, **do not switch it on until the room is completely dark.** Even leaving it on for one second with the room lights on will completely destroy it from the very large electron currents generated. Also, be careful not to jostle the laser where the main beam or a reflection could hit the photomultiplier face, that will also kill it.