SINGLE BUBBLE SONOLUMINESCENCE IN LOW GRAVITY AND OPTICAL RADIATION PRESSURE POSITIONING OF THE BUBBLE

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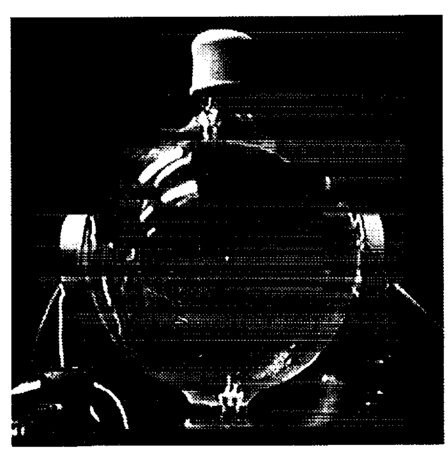
Background: Several groups of researchers have demonstrated that high frequency sound in water may be used to cause the regular repeated compression and luminescence of a small bubble of gas in a flask. The phenomena is known as single bubble sonoluminescence (SBSL). It is potentially important because light emitted by the bubble appears to be associated with a significant concentration of energy within the volume of the bubble. Unfortunately, the detailed physical mechanisms causing the radiation of light by oscillating bubbles are poorly understood and there is some evidence that carrying out experiments in a weightless environment may provide helpful clues. In addition, the radiation pressure of laser beams on the bubble may provide a way of simulating weightless experiments in the laboratory.

Goals and expected outcome: We hope to be able to distinguish between different models for the SBSL light emission process or to be able to extend the range over which stable SBSL is achievable.

Status: The investigation is being carried out in stages. In the first stage, measurements of the intensity of SBSL flashes from small bubbles in water are being carried out in the simulated weightlessness of NASA's KC-135 aircraft. A set of such measurements were recently completed by a team of WSU physics majors operating out of one of NASA's facilities in Houston Texas. The measured intensity in simulated weightlessness differ from measurements taken in ordinary and enhanced effective gravity of the accelerating aircraft. The causes of the shifts in intensity are currently being investigated. Other work is intended to partially simulate a weightlessness environment in the laboratory by using the radiation pressure of laser beams.

Timeline: This grant is for 1998-2000



Part 1: Measurements of SBSL intensity in reduced gravity and hyper-gravity

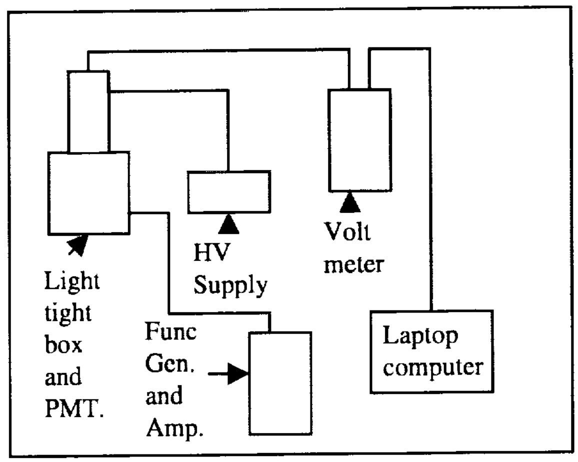


Figure 1: Diagram of SBSL apparatus flown in March 1998 on the KC-135 by WSU undergraduate physics majors J. Young, S. Richardson, C. Breckon, and S. Douthit. The effective gravitational acceleration is also recorded at the same time as the relative SBSL light intensity. Partially degassed water was used and the acoustic frequency was 34 kHz.

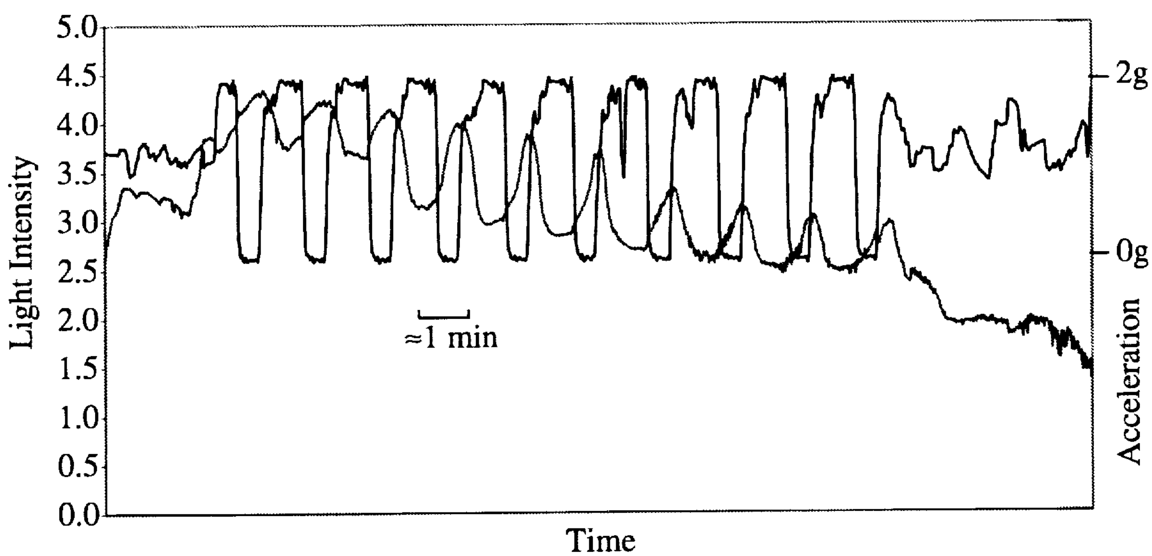


Figure 2: This figure shows the correlation between the light intensity (arbitrary units) and the effective vertical gravitational acceleration of the KC-135 aircraft.

Part 2: Optical positioning of the bubble in normal gravity

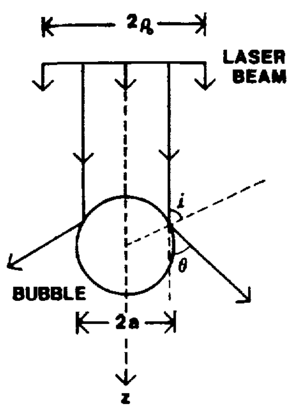


Figure 3: Idealized interaction of an optical plane wave with a bubble. Reflections are shown for two rays, each characterized by local angle of incidence i and scattering angle θ.

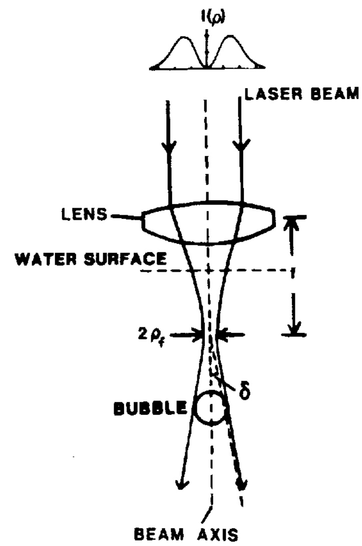


Figure 4: Optical trapping of a bubble in a focused beam with the divergence greatly exaggerated. The irradiance profile $I(\rho)$ at top is that for a pure TEM_{01}^* mode while, for the actual mode, the minimum in center was less pronounced.

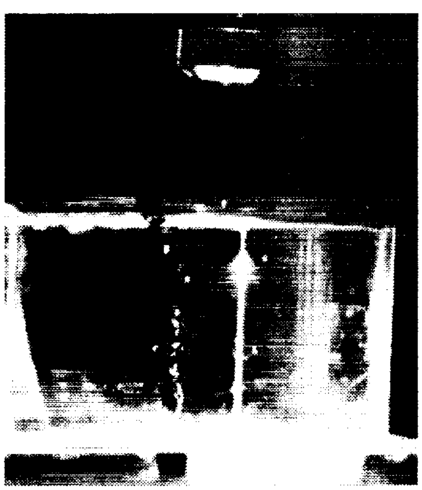


Figure 5: Photograph of a trapped bubble with $a = 15\mu m$. The beam path in the water is visible due to fluorescing and scattering in the water. The bubble is located at the top of the bright spot caused by reflection off the bubble's surface.

Bubble radius a (μm)	Beam power P (W)
10	0.11
20	0.87
30	2.93
40	6.95

Table 1: Estimated optical beam power required to levitate a bubble in water for a fixed beam radius to bubble ratio of 1.5.

Figures 3–5 and Table 1 from Unger and Marston, J. Acoust. Soc. Am. **83**, 970–975 (1988).

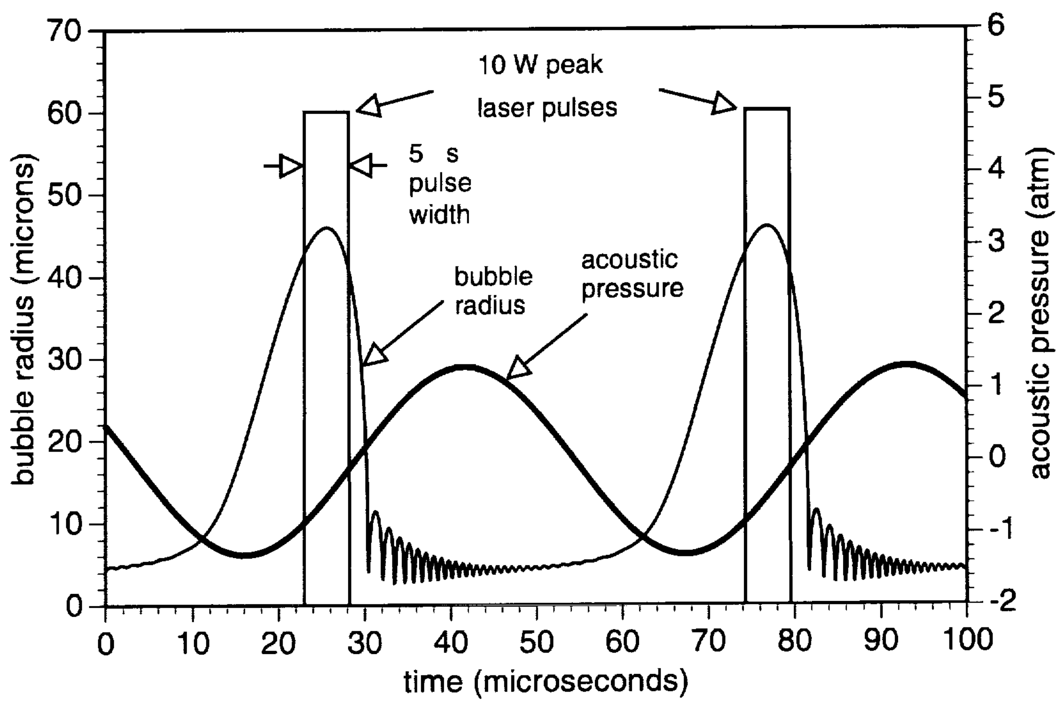


Figure 6: One of the curves shows the bubble radius as a function of time used to calculate the buoyancy and optical radiation force on an SBSL bubble. The radius-time curve is given by integrating a modified Rayleigh-Plesset equation for the indicated acoustic pressure oscillations. The power as a function of time is also shown for a laser pulse timed to coincide with the maximum bubble radius.

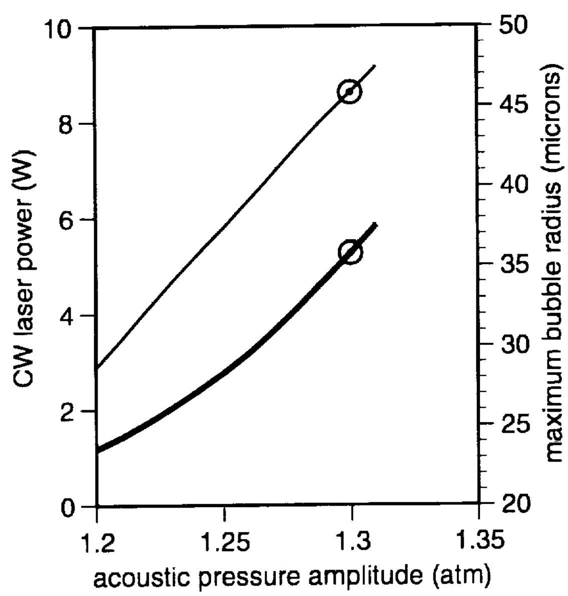


Figure 7: The upper (lighter) curve shows the maximum bubble radius calculated as a function of peak acoustic pressure where the points show the example given in Figure 6. The lower (darker) curve shows the approximate CW laser power required to counteract the average buoyancy entirely with the average optical radiation force.

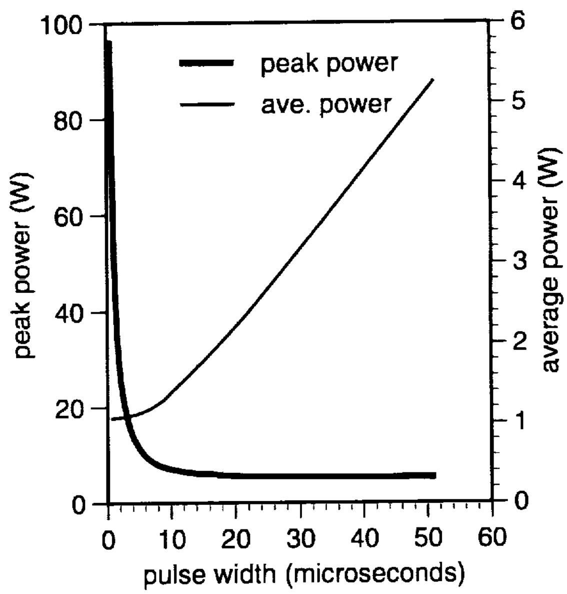


Figure 8: For the situation shown in Figure 6 the laser is pulsed as indicated. With the average optical radiation force matching the bubble buoyancy (as in Figure 7), the estimated peak and average laser powers are shown as a function of the pulse width.