Measurements of the dynamical response of single-bubble sonoluminescence near the luminescence and extinction thresholds

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Abstract: Single-bubble sonoluminescence (SBSL) is bounded by a lower (luminescence) and upper (extinction) drive pressure amplitude threshold. Stable SBSL can occur between these two thresholds; however, near the thresholds, the bubble responds in a transient fashion. Experimental measurements of the bubble's motion in these transient regions are described. Evidence for gas exchange and instabilities are obtained from these measurements.

INTRODUCTION

Measurements of the dynamical motion [R(t) curve] of a sonoluminescence bubble have provided researchers with valuable insight into the mechanism for transducing sound energy into light energy. Utilizing light-scattering techniques (1,2), the R(t) curve is easily measured if the bubble is in a steady-state (the measurement actually produces a voltage, which can then be converted into a radius by fitting to a specific nonlinear dynamics model). Unfortunately, near the lower (luminescence) and upper (extinction) thresholds, the bubble shows transient behavior. Measurements of the radial response of the bubble in these regions is difficult, and precludes the use of averaging techniques. Furthermore, cycle-to-cycle variations are difficult to observe without collecting large amounts of data. We have explored these regions using a fast digitizer with expanded memory. By capturing the motion over each acoustic cycle, we can explore the dynamics and instabilities of a transient bubble over hundreds of acoustic cycles.

EXPERIMENT

A light-scattering system is used to measure the instantaneous bubble motion. The output of the detector goes into a fast digitizer (LC9384L) with 8 MB memory. The high speed and long memory allow capture of approximately 8 ms of data at 4 ns/pt. For our system, which operates at approximately 30 kHz, we can capture approximately 240 consecutive acoustic cycles of data.

Figure 1 shows consecutive cycles of the afterbounces of a bubble in the ‘dancing’ region of parameter space, below the luminescence threshold. Note the transient signals that occur during the second and third afterbounce. We believe these signals represent light focusing from a non-radial (parametrically unstable) bubble. In this figure, the instabilities appear to be linked to the previous cycle, although not all data sets show such a strong correlation over consecutive acoustic cycles.

Figure 2 shows how the bubble responds when subjected to a rapid increase in drive pressure amplitude. The bubble, initially below the luminescence threshold, is rapidly brought above the threshold, and responds by growing to larger radii and collapsing at a later time in each cycle. We used this pressure changing technique to show that the bubble undergoes a fundamental change between the non-sonoluminescing and sonoluminescing state (3).

FIGURE 1. The cycle-to-cycle afterbounces of a bubble below the luminescence threshold show prominent signals (near 8.8 and 10.5 μs, respectively) that apparently result from parametric instabilities. The radial response of the bubble should not show these variations, but non-radial oscillations may produce light-focusing, or caustics, which could produce these signals.
Finally, figure 3 shows the effects of rapidly increasing the drive pressure amplitude beyond the extinction threshold. In this figure, subsequent cycles of the bubble's motion are plotted below the previous cycle. The drive pressure is increased around the 30th acoustic cycle. Near the 78th acoustic cycle, the data shows a transitory signal similar to the parametric instability signals in Fig. 2(b). In this case, however, the signal occurs near the main collapse of the bubble. The bubble is not observed beyond this time, and apparently self-destructs. This data is in qualitative agreement with the analysis of Hilgenfeldt, et al. which claims that the extinction threshold is due to a rapid instability (4).

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REFERENCES