2pBAa1. Spatially and temporally resolved single bubble sonoluminescence and its entrainment in Rayleigh-Taylor jets

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Previous investigations of the temporal and spatial evolution of single bubble sonoluminescence (SBSL) have shown events to last on the order of tens to hundreds of picoseconds with spatial extents of less than 1 um. Here we present observations of the temporal and spatial evolution of laser-nucleated SBSL events in a high-pressure spherical resonator. Using high-speed imaging, we observe large, long-lived SBSL events reaching diameters of up to 50 um and lasting on the order of 30 ns. Observations of events entrained in Rayleigh-Taylor jets resulting from instabilities in the final stages of the bubbles collapses will also be presented. We observe the light emitting region entrained in these jets to reach velocities in excess of 4500 m/s and to travel up to 100 um before being extinguished. The size and duration of events, and the velocity of those entrained in Rayleigh-Taylor jets, will be compared to the maximum radius and collapse velocity of the bubbles responsible for generating them to develop a better understanding of the dynamics leading to, and the mechanisms responsible for light emissions during highly energetic collapse events. [Work supported by Impulse Devices, Inc.]
SPATIALLY AND TEMPORALLY RESOLVED SINGLE BUBBLE SONOLUMINESCENCE AND ITS ENTRAINMENT IN RAYLEIGH-TAYLOR JETS

Single-bubble sonoluminescence (SBSL) has been a topic of great interest since it was observed by Gaitan et al. [1]. Of particular interest have been the temperatures and pressures reached in the bubble’s center, which have been predicted to reach upwards of 100000K and 150GPa in some of the highest energy collapses [2]. To that end, experiments have been devised which seek to increase the energy available to collapsing bubbles by increasing their maximum radius, and by increasing the ambient pressure of the fluid in which they collapse. In order to measure the strength of these events, and to gather information about the mechanisms by which they are generated, the duration and size of events has been studied extensively. Previous observations have shown that light emissions from SBSL events typically last on the order of 30-300ps[3], and emitting regions have typical diameters of less than 3µm[4].

In this paper we present results on the light emissions from the collapse of large single bubbles in a high-pressure spherical resonator. Bubbles in experiments were nucleated at the center of the high-pressure spherical resonator (Impulse Devices, Inc.) using a pulsed Nd:YAG laser [5]. Water used in experiments was filtered to 0.2 microns and degassed by equilibration with air at 120 Torr. Experiments were carried out at room temperature and at ambient fluid pressures of 21 and 26 MPa. Collapse events were monitored using a high speed camera [SIMx8] with 8 CCD elements whose exposure and inter frame times were independently variable.

In a typical experiment, a small nucleus generated by optical breakdown [6] grows into a macroscopic bubble during the tensile phase of the pressure. Bubbles in experiments were measured through imaging to grow to a maximum radius of between 0.6 and 1.5 mm before collapsing. In order to monitor the temporal evolution of bubbles and light emitting regions during and through the final stages of collapse, images of events were taken such that frame exposure times near the point of collapse were set to 5ns and interframe times were set to 0ns. During the final stages of the bubbles collapses, bubble walls were observed to reach supersonic velocities before light emissions were observed. Light emitting regions were observed to form as bubbles neared their minimum radii and were observed to emit light for upto 30 ns before fading out. Following the formation of a light emitting region, the emission intensity from events was observed to increase over the first half of an events lifetime before reaching some maximum near the middle. The intensity of emissions would then decrease until the emitting region eventually faded out.

Emitting regions were generally observed to be spherical or ovoid in nature and were observed to reach radii on the order of roughly 30 µm. While emission regions were observed to grow slightly after formation and shrink slightly before fading out, growth and decay were typically small and emission regions were observed to remain roughly the same size throughout most of their lifetimes. As light emitting regions developed, they were also observed to move away from the center point of collapse at high velocities, before eventually slowing down as they got further away.

This movement is explained by the fact that, during collapse events Rayleigh-Taylor jets were occasionally observed to form as the result of asymmetrical collapses owing to instabilities at the bubble surface. During such collapses, sonoluminescing regions were observed to be entrained within the tips of the Rayleigh-Taylor jets and to travel with them before eventually fading out. Entrainment within a jet had no noticeable affect on the size or duration of the light emitting regions, with regions reaching approximately the same size and emitting for the same length of time while entrained. Entrainment within a jet seemed to have very little affect on the shape of the emitting region as the jet carried it. While there seems to have been some slight deformation of the light emitting region as it traveled, whether those de- formations are the result of entrainment remains to be established. During entrainment, emission regions were observed to reach velocities in excess of Mach 2 and travel with the jet up to 100 µm before fading out. Jets were observed to continue traveling after the light emission region faded out.

In conclusion, we have presented results on the development and evolution of SL regions generated by the collapse of large single bubbles at high ambient pressures. The time evolution of events has been presented which highlight the conditions present leading to the formation of the light emitting regions observed, and the development of the light emitting regions thereafter. The duration and size of events presented are up to several orders of magnitude greater than those reported from previous experiments. In addition, results from observations of events entrained within Rayleigh-Taylor jets resulting from collapse instabilities have been presented. Light emitting regions entrained in jets were observed to travel with the jet tip at velocities in excess of Mach 2 and over distances of up to 100µm. Entrainment within these jets had little apparent affect on the size, duration, and shape of events. Further investigation is required to shed more light on how these types of collapse instabilities affect light emissions resulting from the collapse of large single bubbles.
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REFERENCES