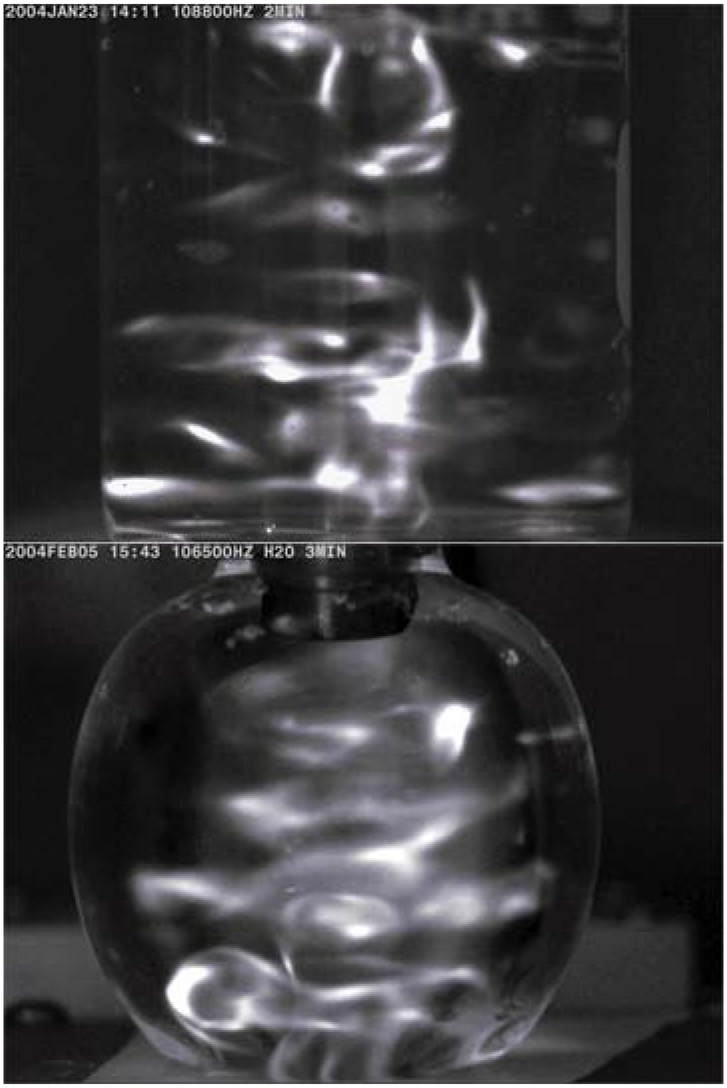
Sonoluminescence: A Galaxy of Nanostars Created in a Beaker

As part of basic and applied research on advanced instrumentation technologies, the NASA Glenn Research Center is examining applications for sonoluminescence: ultrasonically produced glowing bubbles that are hotter than the Sun. In the last decade, those outside of the ultrasonic community have become interested in understanding sonoluminescence and in using some of its more interesting properties. First discovered in the 1930s as a byproduct of early work on sonar, the phenomenon is defined as the generation of light energy from sound waves. This glow, which was originally thought to be a form of static electricity, was found to be generated in flashes of much less than a billionth of a second that result when microscopic bubbles of air collapse. The temperature generated in the collapsing bubbles is at least 4 times that of the surface of the Sun.

Theories for the cause of the glow from a collapsing bubble range from black-body radiation, plasma ionization, quantum vacuum fluctuations, or coherent optical lasing. Even as these theories are being explored, applications for the effect are taking shape, from fusion containment to thin-film deposition systems. Glenn has begun an in-house examination of sonoluminescence to develop instrumentation and measurement techniques that could ultimately use the phenomenon to enable safer, lighter, quieter, and more fuel efficient vehicles for aeronautics and space transportation and exploration.

In Glenn’s dark-room apparatus, an amplified sinusoidal signal was used to drive a high-intensity ultrasonic transducer horn probe inserted into the open top of separate glass containers filled with 50, 100, and 250 ml of distilled water. At specific input frequencies, multibubble sonoluminescence (MBSL) was generated and then photographed in preparation for the examination of the effect by Glenn’s state-of-the-art fiber-optic and thin-film sensors. The submicroscopic glowing bubbles are not visible as distinct points, but rather as a collection of corkscrew filaments, or a “galaxy” of “nanostars,” in the containers.



Left: Enhanced image of MBSL at 109 kHz in a 100-ml beaker. Exposure time, 2 min at f/2.8; field of view, 6.6 by 5.1 cm. Right: Enhanced image of MBSL at 107 kHz in a 50 ml flask. Exposure time, 3 min at f/2.8; field of view, 7.1 by 5.4 cm.

Long description of figures 1 and 2. MBSL is visible in the cylindrical beaker and spherical flask as white wispy filaments against a dark background. A dim background glow from the instrumentation reveals the beaker and flask.

The preceding images were produced with very little processing other than a brightness- or contrast-level enhancement. Resolutions of the MBSL filaments of approximately 100 µm per pixel were achieved. Longer exposure times could brighten an image, but they also blurred the image because the positions of the filaments varied irregularly around the local pressure maximums. A 3-min exposure recorded approximately 18 million cycles of the bubbles flashing. An image of the 50-ml flask, which was produced with a color charge-coupled device (CCD) imager calibrated to a standard color-rendition chart, is shown in the following figure.

Enhanced image of MBSL at 106 kHz in a 50-ml flask. Exposure time, 5 min at f/2.8; field of view, 9.5 by 6.8 cm. The colors were calibrated by a color standard.

Long description of figure 3. MBSL is visible in the spherical flask against a dark background as bluish-white wispy filaments. A reddish background glow from the instrumentation reveals the flask.

The chaotic MBSL filament structure can be observed in relation to the testing cell walls to a submillimeter resolution integrated over a long time frame (millions of cycles). This fine resolution will guide instrumentationand measurement technique development so that we can ultimately formulate an application of the effect.

Find out more about this research: http://www.grc.nasa.gov/WWW/sensors/

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