Observations of Bubbles in the Laboratory Using the LISST-100

The LISST-100 instrument has been used to observe the formation of bubbles produced by electric discharge in ionized water. The bubbles produced are of nearly uniform size for each wire current. The comparison of observed and theoretical Mie predictions of scattering shows consistency.

LISST-100

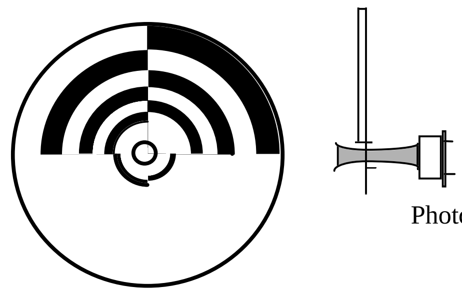
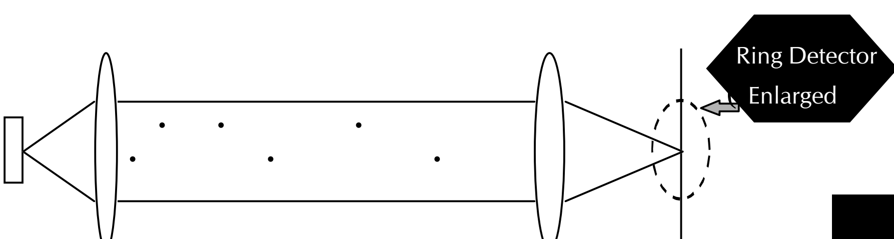


Figure 1: Operating Principle of the LISST-100.

Bubbles are the closest approximation to spheres encountered in the marine environment. They are produced most vigorously by wave breaking and are diffused by turbulence, which is also produced by shear and wave breaking processes. Due to their sphericity and homogeneity, light scattering by bubbles can be modeled exactly. Thus it is natural to ask if the particle sizing capabilities of the LISST instruments can be used to measure bubbles properly.

To test this idea, a technique commonly employed for flow visualization was used in our laboratory. In this method, a wire is immersed in the fluid and the fluid conductivity is increased by addition of sulfuric acid or salt. Bubbles are produced by passing electric current through the immersed wire.

First we describe the principle of operation of the LISST instruments in Figure 1.



As illustrated in Figure 1, a beam formed by collimating the output of a diode laser illuminates the particles. Scattering by particles is detected by a specially constructed detector consisting of 32 log-spaced rings plus a center hole which allows passage of the strong direct beam. The signature of particle size is shown in Figure 2 for two different-sized bubbles. These curves, computed using the full Mie theory for light scattering and for the ring-detector geometry of the LISST, peak at small rings for large bubbles (50 μm diameter), but at the larger rings is for small bubbles (8μm).

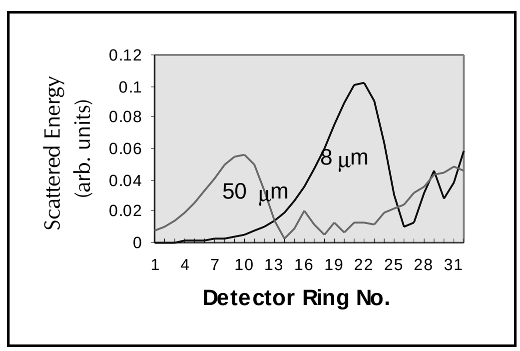


Figure 2: Signature of bubble size.

The LISST instrument records the energy distribution as sensed by the ring detector, and then mathematically inverts the energy distribution to obtain the size distribution of the particles.

For the bubble test, we employed the Horizontal Calibration Chamber that is provided with each LISST instrument for measuring the background light from the optical surfaces alone. The chamber was filled with a weak salt solution, and a stripped electrical wire was placed in front of, but beneath the large glass window visible in the photograph at the top of the previous page. Current density was varied by changing the voltage on the wires.

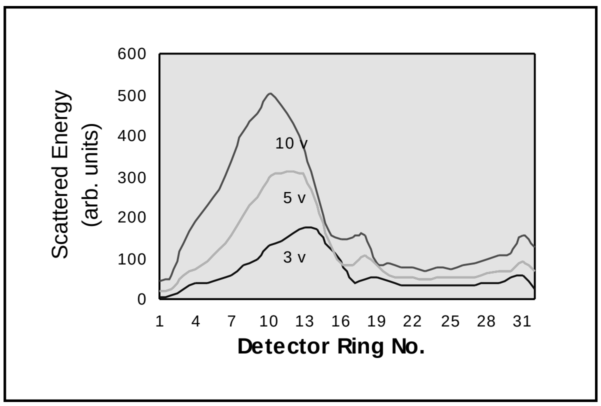


Figure 3: Scattering signatures for 3 voltages.

Figure 3 shows the scattering signature as recorded from bubbles for 3 cases: wire at 3, 5 and 10 Volts. The increase in voltage causes not only an increase in the scattered energy on the ring detectors of the instrument, which results from a greater number of bubbles being created at higher voltages, but also a leftward shift in the peak, which suggests the formation of larger bubbles. The mathematical inversion of these energy distributions produces the size distributions shown in Figure 4. As the magnitude of scattering in Figure 3 varies with wire voltage, so does the concentration of bubbles. The shift in the peak of the scattering energy distribution is reflected in a shift in the size of the bubbles.

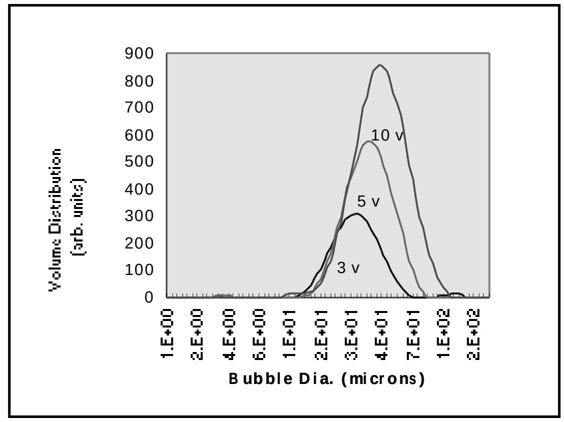


Figure 4: Bubble size distribution recovered from data of Figure 3.

These are narrow distributions, so it is natural to examine how close the measured energy distributions are to theoretical predictions. This we show in Figure 5.

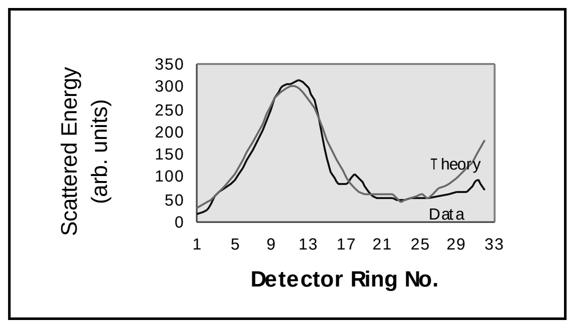


Figure 5: Comparison of theoretical fit to bubble scattering, vs. data from bubbles, wire at 5 volts.

The agreement between the predictions of Mie theory and measurements must be viewed as a satisfactory test of the suitability of the LISST for bubble measurements. The instrument was not modified in anyway for these tests, so identical results can be expected in the field.

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