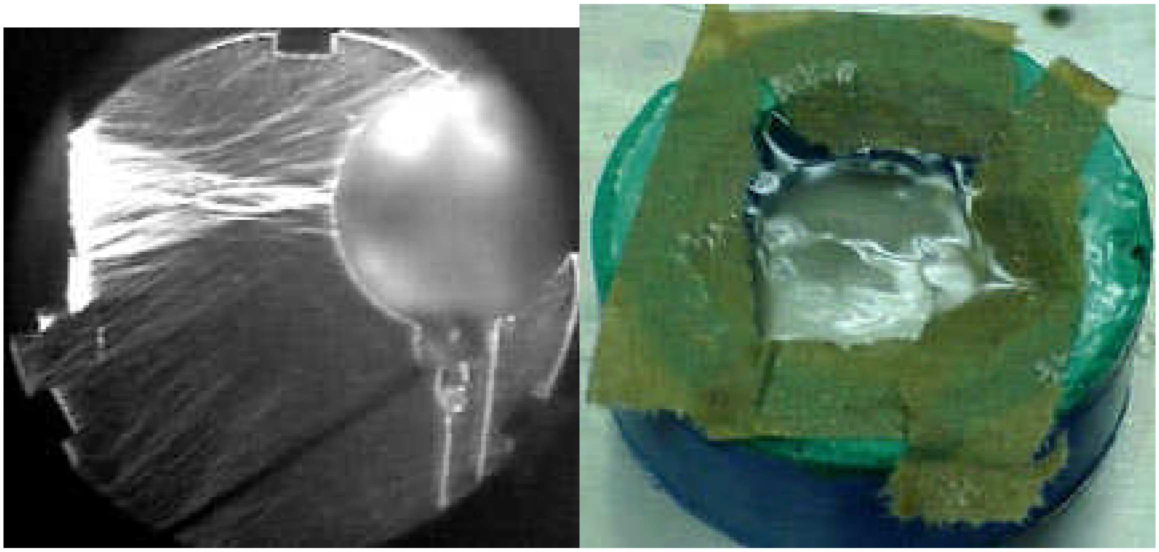
Ultrasonic Waves in Water Visualized With Schlieren Imaging

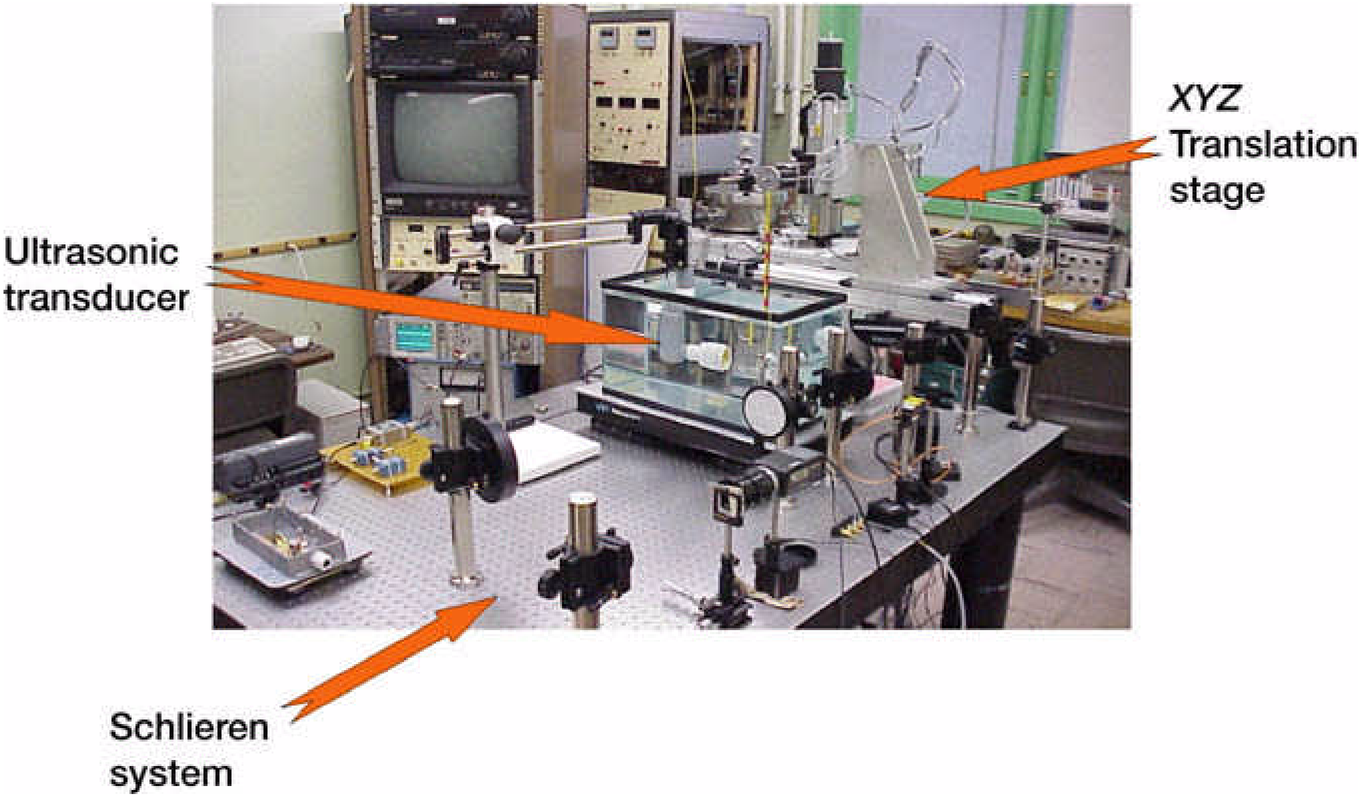
The Acoustic Liquid Manipulation project at the NASA Glenn Research Center at Lewis Field is working with high-intensity ultrasound waves to produce acoustic radiation pressure and acoustic streaming. These effects can be used to propel liquid flows to manipulate floating objects and liquid surfaces. Interest in acoustic liquid manipulation has been shown in acoustically enhanced circuit board electroplating, microelectromechanical systems (MEMS), and microgravity space experiments. The current areas of work on this project include phased-array ultrasonic beam steering, acoustic intensity measurements, and schlieren imaging of the ultrasonic waves.

The ultrasonic waves need to be imaged for a number of reasons: to verify that the transducer producing the ultrasonic waves is functioning properly (especially at low power), to visually see the shape of the transducer's output, to help reduce reflections off the walls of the tank, and to visually verify the focal point of the transducer.



Left: Schlieren image of ultrasonic waves in water deflection in an air-filled glass sphere. Right: Deformation of water surface by acoustic radiation pressure.

To visualize the ultrasonic field, we decided to use a schlieren imaging system because it is a well-established technique for visualizing density gradients. The system operates by sending a collimated beam of light through a test section. When areas of varying indices of refraction in the test section refract the collimated light, it is focused to the point where the light that was refracted by the index of refraction gradient in the test section is blocked, producing areas of varying brightness when the image is formed on a video camera.



Experimental setup in the Acoustic Liquid Manipulation Lab.

For the schlieren system, a fiber light source, which is used as a point source, is collimated with a 6-in. concave spherical mirror focused offaxis. This mirror provides an economical, large field of view but produces astigmatism and field curvature. The collimated light is projected through the ultrasonic beam being studied. Since the ultrasonic beam produces pressure gradients in the water, the water's index of refraction is changed slightly. The gradient in the water's index of refraction causes the light to stray slightly from its path. The collimated beam is then focused to a point using another 6-in. concave spherical mirror. A knife-edge is placed at the focal point of the mirror to block the rays whose path has been altered by the varying index of refraction from the ultrasonic beam. A video camera is placed after the knife-edge, allowing the ultrasonic beam to be viewed on a monitor.

In the near future, the Acoustic Liquid Manipulation project plans moving to a microelectromechanical systems scale: that is, devices on the scale of hundreds of micrometers. This will require adapting the schlieren system to a much smaller scale.

Bibliography

Hanafy, A.; Zanelli, C.I.; and McAvoy, B.R.: Quantitative Real-Time Pulsed Schlieren Imaging of Ultrasonic Waves. IEEE Ultrasonics Symposium, IEEE, New York, NY, 1991, pp. 1223–1227.

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