

Diffusing Wave Spectroscopy Used to Study Foams

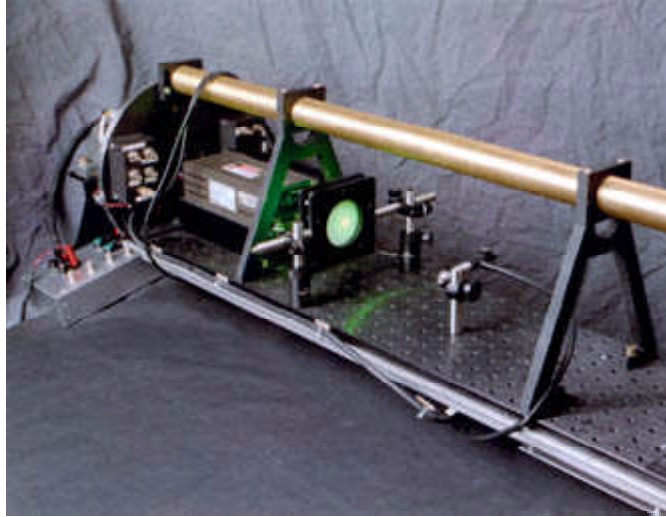
The white appearance of familiar objects—such as clouds, snow, milk, or foam—is due to the random scattering of light by the sample. As we all know, pure water is clear and easily passes a beam of light. However, tiny water droplets, such as those in a cloud, scatter light because the air and water droplet have different indexes of refraction. When many droplets, or scattering sites, are present, the incident light is scattered in random directions and the sample takes on a milky white appearance. In a glass of milk, the scattering is due to small colloidal particles. The white appearance of shaving cream, or foam, is due to the scattering of light at the water-bubble interface.

Diffusing wave spectroscopy (DWS) is a laser light-scattering technique used to noninvasively probe the particle dynamics in systems that strongly scatter light. The technique takes advantage of the diffuse nature of light, which is reflected or transmitted from samples such as foams, dense colloidal suspensions (such as paint and milk), emulsions, liquid crystals, sandpiles, and even biological tissues.

In traditional dynamic light-scattering measurements, one measures the amount of time it takes for a particle in a suspension to move a distance comparable to the wavelength of light λ ($\sim 0.5 \mu\text{m}$), such as the diffusion of colloidal particles in a solution. Or one might measure the lifetime of a density fluctuation such as those that occur in fluids near the liquid-vapor critical point. In these applications, the samples should be only weakly scattering (single-scattering) for a proper interpretation of the data. DWS extends the type of systems that can be studied by exploring systems that scatter light many, many times.

When incident light is scattered many times and in random directions, the light is said to diffuse through the sample. By using the diffuse approximation, one is able to accurately interpret the small intensity fluctuations that result from particle motion in the sample. Furthermore, because the light is scattered many times, the DWS technique is very sensitive to much smaller motions in the sample. For example, if the light is scattered 100 times (on average) before it reaches the detector, average displacements as small as $\lambda/100$ ($\sim 5 \text{ nm}$) can be detected. Thus, DWS is a powerful technique for probing motion on a molecular scale.

The NASA Glenn Research Center at Lewis Field and the University of California, Los Angeles, are using DWS to study aqueous foams. Foams are a dynamic system since they evolve with time. By using DWS in conjunction with rheology measurements, the Foam Optics and Mechanics (FOAM) flight project team expects to discover how the bubble-scale motion and structure of the foam affects its bulk rheological properties. Because these experiments will be conducted in microgravity, liquid will not drain from the foam, and we will be able to investigate the "melting transition" from dry, solidlike foams (shaving cream) to wet, liquidlike foams (bubbly water).



DWS setup for studying foams on a rotating optical breadboard. A laser illuminates the foam sample, and the scattered light is fed to the detector by a fiber-optic cable.

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