

## Stereoscopic recording of droplet fragmentation

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We all have witnessed the fragmentation of liquid droplets, for example, following the impact of rain onto the soil or windshields of a moving vehicle. Droplet fragmentation is utilized in irrigation systems and sprays for cosmetics and for medical applications. A particular type of droplet fragmentation occurs when a laser beam impacts a droplet, a phenomenon of interest, for example, in laser beam dissemination into the atmosphere [1], but also important to understand in the development of UV light sources for lithography [2]. The process is inherently complex and variable, thus it may only be fully resolved with fast cameras capturing the motion in all three dimensions. This stimulated us to explore and develop an experiment that is able to resolve transient atomization events. This is accomplished with stereoscopically positioned high-speed cameras (Photron SA-X2 and SA1.1). We decided to use droplets in the millimeter range whose fragments can still be nicely resolved and whose mother droplet can be trapped in space. For the latter we have built an acoustic levitator stabilizing a droplet at its pressure antinode. There, a pulsed laser (Nd:YAG, with a wavelength of 532 nm and a pulse duration of 6 ns) is focused at the same position, and once fired it vaporizes parts of the droplet, creating a cavitation bubble inside.

The complex fragmentation dynamics is captured with a camera rig adapted from a professional video three dimensional production: Both high-speed cameras aligned at 90° observe the scene through a 50:50 beam splitter. In contrast to professional mirror rigs, we use here cameras equipped with macrolenses with a magnification of approximately 1. Both camera views are combined after suitable image processing steps (image registration, scaling, and rotation) using red and blue colors. The stereoscopic movies are available at [3], offering a three-dimensional impression. The reader needs to wear glasses with a blue and red filter for the right and left eyes, respectively.

Figure 1 depicts selected frames of one of the movies of a droplet with an initial size of  $R_d = 0.43$  mm and impacted by a laser pulse with 0.7 mJ energy. Initial and rapid material ejection is visible on the back of the droplet ( $t = 28 \mu\text{s}$ ) followed by a sheet expansion resembling the shape of a jellyfish. The sheet ejects more fragments from its rim and collapses under the action of surface tension within 1 ms.

Depending on the initial droplet size and laser energy, we have identified three regimes of fragmentation. Besides full atomization for the smallest droplets, we observed for the larger droplets partial or coarse fragmentation [4]. The intermediate regime of sheet formation is nicely captured in Fig. 1.

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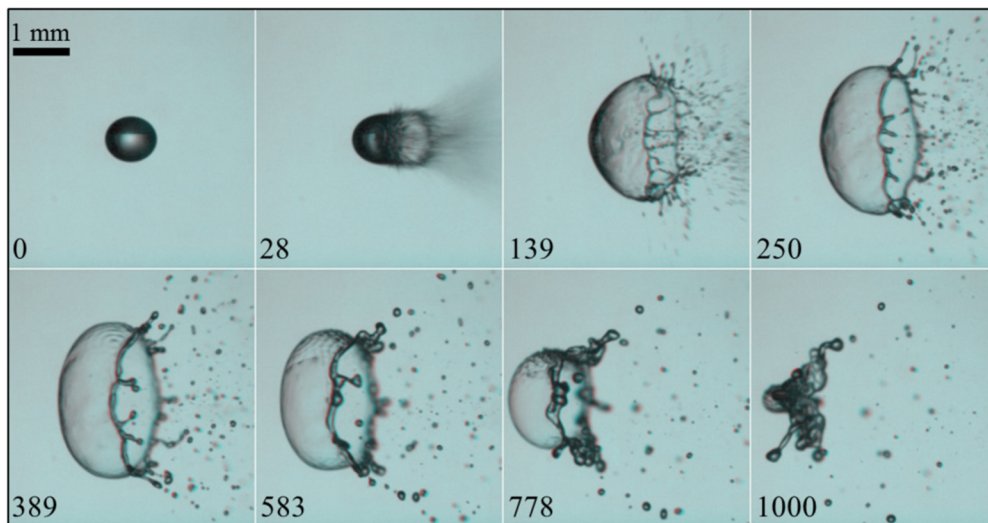


FIG. 1. Selected frames from a stereoscopic movie demonstrating droplet fragmentation. Please use blue and red glasses for the three-dimensional impression. The initial droplet diameter is  $R_d = 0.43$  mm and the time is stated in microseconds. The video associated with these images is available at <http://dx.doi.org/10.1103/APS.DFD.2015.GFM.V0029>

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