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Team Project 1 Report

1. Introduction

This image of a laser shining through a droplet of pond water is the result of the first group project for the spring 2012 Flow Visualization course. The intent of this image was to capture microbial organisms in pond water by shining a laser through a droplet suspended at the end of a syringe, and projected onto a smooth surface. The phenomenon depicted is the magnification of the droplet's boundary and microbial content onto a smooth surface, thereby making the boundary and organisms visible to the naked eye.

2. Experimental set-up and discussion of flow

The experimental setup, shown in Figure 1, shows the magnification of the droplet onto the background. The handheld laser was directed at the droplet, which remained attached to the syringe, which was held directly upright by the stand.

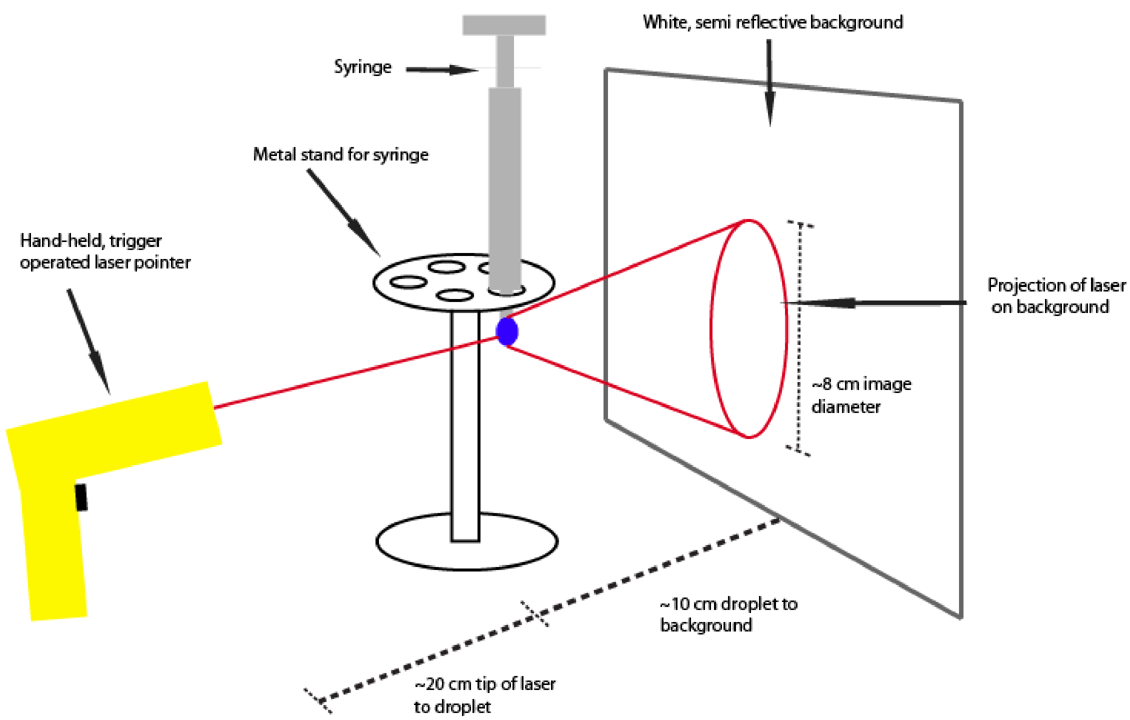

Figure 1: Experimental Setup

Within the droplet of pond water, micro bacterial organisms were visible and could be seen moving through the projected image. The droplet has an approximate diameter of 2.5mm, while the diameter of the projection was approximately 80mm in diameter, demonstrating the significant potential for magnification through the droplet. The micro bacterial organisms were not visible to the naked eye in the droplet, but were shown very clearly in the projection. Thus, the most interesting fluid effect displayed in this image is the magnification effect of a water droplet.

H. H. Myint et al discuss the utility of this phenomenon, especially related to the potential for cheap, easy and versatile magnification for science courses in developing countries [1]. In their findings, the authors note that the focal length will remain unchanged for at least two hours, so for the series of images taken with our apparatus, a constant focal length and magnification factor can be assumed [1]. The authors also recognize that a "magnification factor as high as ×50 can be made by using a metal ring with a smaller diameter of 2mm" [1], which is very close to the droplet size in our experiment. Decreasing the focal length increases the magnification, as described by the magnification relationship for a magnifying glass:

$$M = \frac{D}{f} \qquad \textit{Equation (1)}$$

where D is the distance of distinct vision, f is the focal distance, and M is the magnification.

For calculating the magnification in our experiment, a spherical droplet shape is assumed, and effects on droplet shape and size at the syringe-droplet interface are considered negligible. In our experiment, the droplet diameter of 2.5mm was magnified to 80mm, a x32 magnification. The distance of distinct vision was approximately 100mm, resulting in a calculated focal length of 3.125mm.

In the image, the exposed portion of the micro bacterial organism is nearly 60mm, which in the original image corresponds to a length of 1.875mm, and its width of approximately 5mm in the magnification corresponds to an original width of .156mm, explaining why it is invisible to the naked eye. The organism captured in this image was the largest seen in the experiment: all others were significantly smaller.

Furthermore, the experiment indicated a very sensitive correlation between laser position on the drop and the location of the projection on the background. Altering the angle of the laser pointer projected the image at varying positions on the background, indicating some sort of scattering. Sassen and Liou (1979) found a strong correlation between theoretical and experimental values for scattering through spherical droplet clouds [2], indicating that theoretical calculations, such as those proposed by Mie, can predict the actual scattering caused by the droplet. The authors also note that scattering causes "the presence of optical phenomena such as cloud-bows and halos" [2], which helps account for the ripples and more transparent contours within and around the projection. Unfortunately, because no power data was recorded for the laser pointer or at the projection, exact values for scattering cannot be calculated.

3. Visualization and photographic technique

To visualize the droplet and its contents, a red laser pointer, rented from the ITLL equipment room, was shined directly at the droplet, and the image was captured from the projection of the laser on the background. The background was a white, somewhat reflective surface backed by quarter-inch plywood, making it not completely rigid, but it showed no visible deflection. The image was captured with the camera was oriented at an angle of approximately 45 degrees to the background. The image was taken in a dark room, with the only source of light being the laser pointer. No camera or other external flash was used.

The most challenging part of the photography was determining the correct exposure time in order to see the droplet contours and contents, but to avoid over saturating the image. As a result, a shutter speed of 1/100, an f-stop of 4, and an ISO setting of 800 were used, which seemed to optimize the depiction of the fluid and its contents. The distance from the object to the lens was about 25 cm, and the focal length of the lens used was 28mm. The image was shot with a Canon EOS Rebel Xsi digital camera, and had an original size of 4272 x 2848 pixels.

The Photoshop processing included cropping the original image in order to focus on droplet. The brightness was increased by 50% while the contrast was decreased to 30%. The red saturation was decreased to -38 and red lightness increased to 27. A un-sharpen mask was applied to 500% with a radius of one pixel. These effects served to make the fluid contours and contents more visible.

4. Extension and discussion of image

The image reveals the lens-like nature of a droplet and the presence of micro bacterial organisms present to the naked eye. I am not truly satisfied with the setup of the experiment, but decided to use it as it was our group's initial set-up. I would have preferred to capture a flow rather than a static fluid property. However, I do believe that the image does a good job showing the curvature of a droplet as caused by surface tension, and an especially showing the lens-like behavior of the surface by greatly magnifying the organisms. I did fulfill the intent of the experiment. A significant improvement to the setup would be a fixed mount for the laser, as holding it still made capturing good images very difficult. I think incorporating fluid flow at various velocities (still containing the organisms) and a laser would be an interesting extension to this project. I also want to thank my teammates, especially Jennie Jorgenson, for their help.

[1] H H Myint, A M Marpaung, H Kurniawan, H Hattori and K Kagawa. "Water droplet lens microscope and microphotographs." Physics Education. Pp 97-101 (2001). Retrieved 19 March 2012. Web: <http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=10&sqi=2&ved=0CHkQFjAJ&url=http%3A%2F%2Fdiyhpl.us%2F~bryan%2Fpapers2%2FWater%2520droplet%2520lens%2520microscope%2520and%2520microphotographs.pdf&ei=dTRpT6XDEaPK2AX3rqzxCA&usg=AFQjCNEAdcEUsWOmBx5rqH5oBH2skOIKaQ>.

[2] K Sassen and Kuo-Nan Liou. "Scattering of Polarized Light by Water Droplet, Mixed-Phase and Ice Crystal Clouds. Part I: Angular Scattering Patterns." Journal of the Atmospheric Sciences. Vol. 36, Pp 838-851 (1979). Retrieved 20 March 2012. Web: