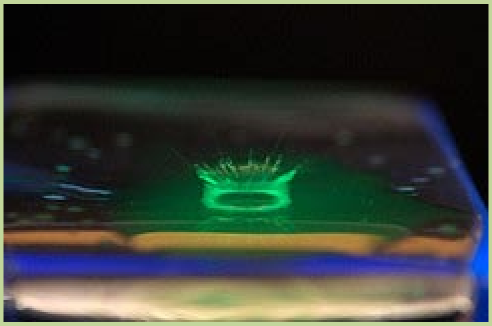
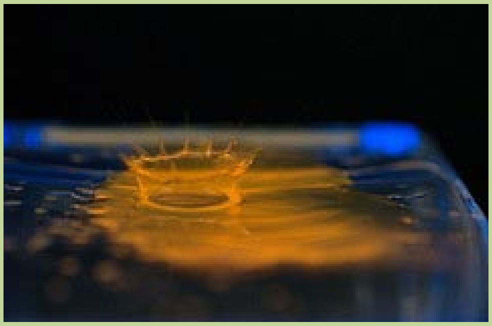
MCEN 4228/5228-010
Flow Visualization
Group Project 2 Report





Group Phi
Kane Chinnel, Richard (Chip) Fisher, and David Ramirez
Section Instructor: Jean R. Hertzberg
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Introduction

The purpose of the second group project was to observe the crown splash effect. The development of the crown splash can be divided into four steps; first is crown formation and jetting, next is rim instability and jet formation, then break-up of the jets and the formation of secondary droplets, lastly crown collapsing. Capturing the break-up of the jets and the formation of secondary droplets was team’s intent. After a substantial number of photographs, the group individually chose final images based on two basic Flow Visualization criteria: that the image illustrates interesting physics of fluid flow and is aesthetically pleasing as a work of art.

Flow Apparatus

To create the photographs, the group used store bought high-lighters, a syringe, a black light, three square vases, a two-prong lab clamp and tap water. The high-lighters were broken down and “milked” into a container full of water. The high-lighter ink was diluted with 150 mL. The syringe was loaded with the ink solution and placed into the two-prong clamp positioned approximately eleven inches above the glass vase. The black light was positioned under the square vase. The flow apparatus is the same for all four images. Figure 1 is a diagram the setup used to capture the crown splash effect.

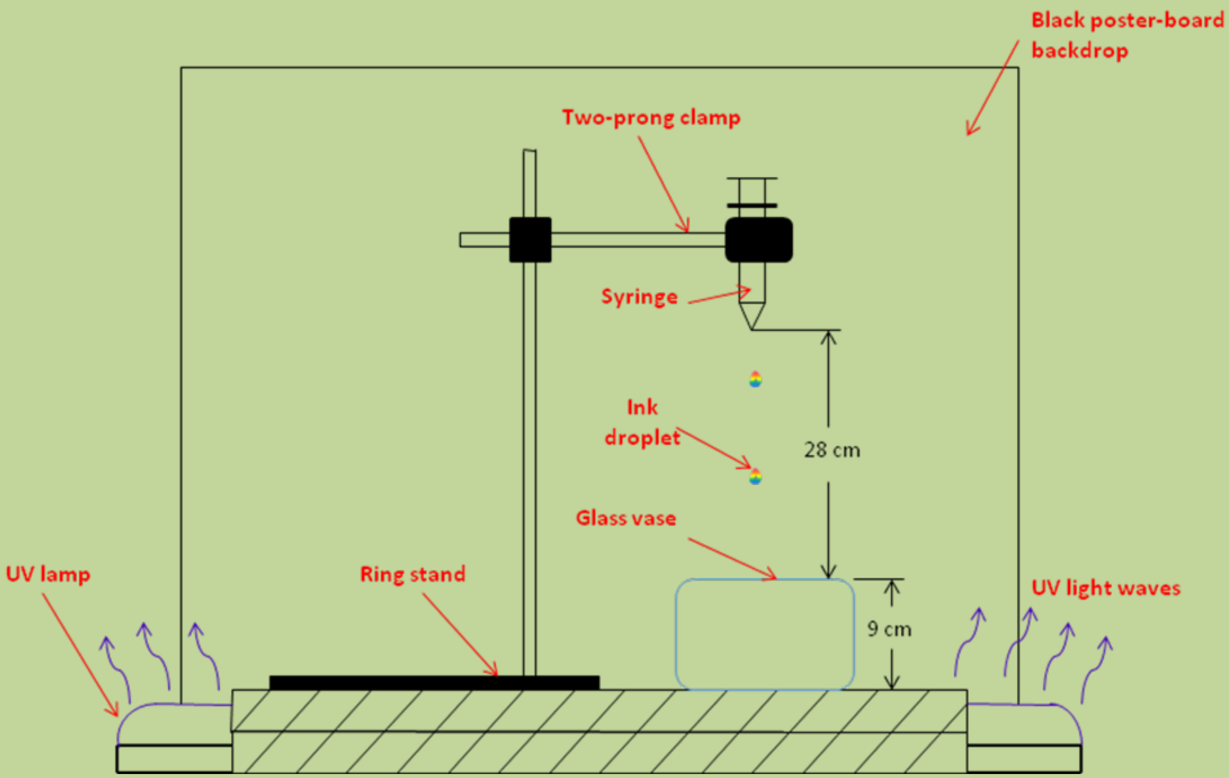

Figure 1. Diagram of experimental apparatus

Visualization Techniques and Flow Descriptions

After the impact of a small drop of fluid onto a thin film a shock wave propagates into the drop to the apex. When the shock wave reaches the contact point between the splattering drop and the thin film, an expanding wave is generated along the surface and produces a jetting flow. From this flow, a finger-like structure is formed and propagates as a crown. The crown begins with smooth cylindrical sheet-like jets shooting outward and upward[1]. The leading edges of the jets are pulled by surface tension towards the sheets[2] and grow in diameter as they send fluid from the sheet. The rim of the crown then develops a symmetry-breaking corrugation and the rim's crests sharpen into jets which pinch off to form secondary droplets. The end stages of the crown are shown in Figures 1, 2, 3, and 4: the rim of the sheet-like jets break into secondary

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[1] Deegan, R, Brunet P, Eggers J (2008) Rayleigh-Plateau instability causes the crown splash.

[2] F.E.C. Culick, J. Appl. Phys. 31, 1128 (1960).

droplets distributed along the perimeters. Moreover, the development of the sheet-like jet after the impact is driven by the opposing action of surface and inertial forces, and damped by the viscous forces[3]. The height of the ejected jets and the number of secondary droplets of the crown decrease with increased film thickness[4].

Reynolds Number

The diameter of a single drop of the mixture is approximately 4 mm with a dynamic viscosity and density approximately equal to those of water, 1.002 kg/m*s and 1000 kg/m^3, respectively. The velocity was calculated to be 2.341 m/s. The approximate Reynolds number was 9.347. Such a low Reynolds number indicates that the drops are dominated by viscous forces.

[3] Cossali GE, Coghe A, Marengo M (1997) The impact of a single drop on a wetted solid surface. Experiments in Fluids 22 463-472

[4] Gregory PH; Guthrie EJ; Bunce ME (1959) Experiments on splash dispersal of funs spores. J Gen Microbiol 20: 328

Kane Chinnel

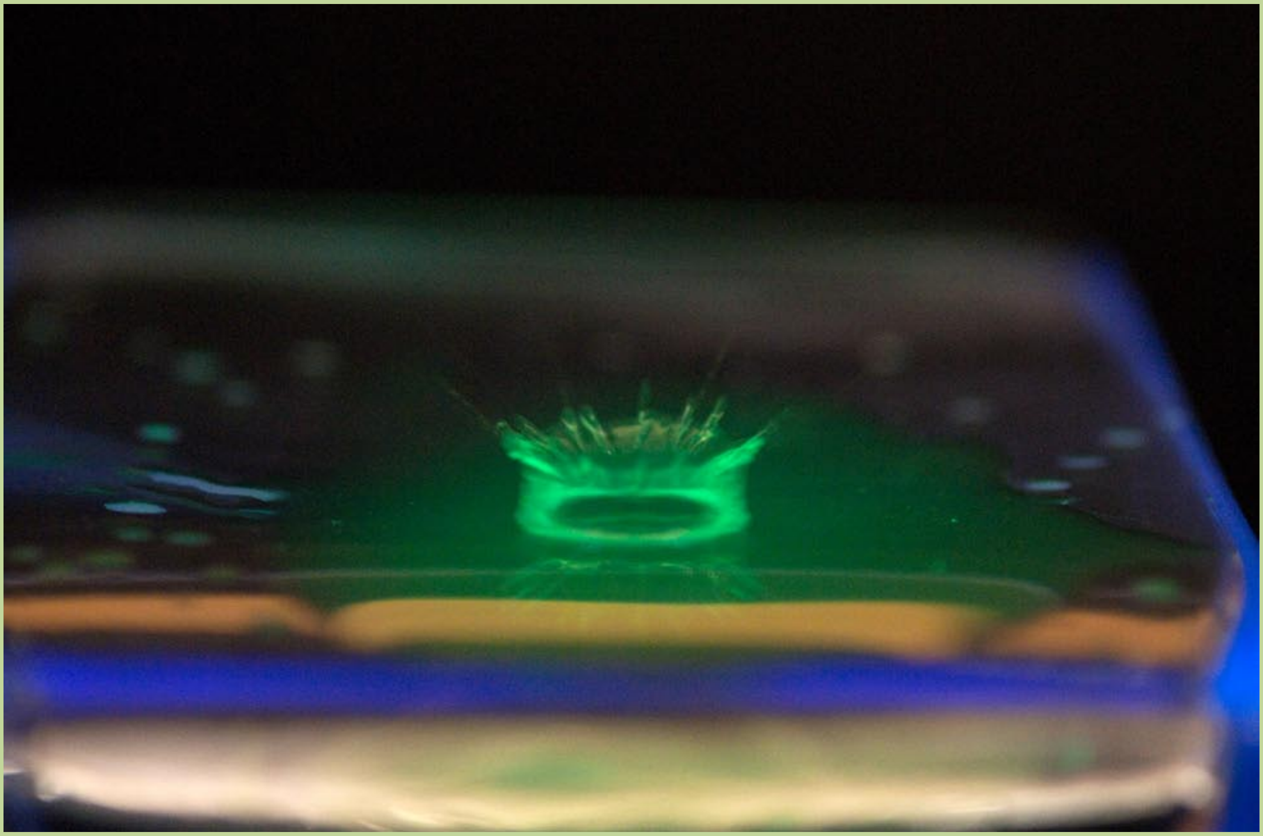

Figure 2: Chinnel unedited photograph

The group focused on capturing the crown effect of a fluorescent fluid on top on a black light. We mainly focused on the interaction between the interface of the solid and the fluid, at the moment the collision exhibits restitution. In this phenomenon, the low Reynolds number indicates that the flow is dominated by surface tension and viscous forces. The image was captured using a very short shutter speed with high camera ISO sensitivity.

I chose the final based on the sharp contrast between the physics, colors, and the reflection exhibited on the lower part of the photograph. Photoshop was used to enhance the flow and display, in detail, the concentration gradients. A high pass filter was overlaid on top of the original image, and set to 36.8.3 pixels. Afterwards, picture cropping brought the raw image down to a manageable size. The original image size is 4288 x 2848 pixels down to 2066 x 1999 pixels. Curves option was used to create a deeper, more vivid contrast between the fluorescent color and the dark background. Other than the high pass filter, curves, and picture cropping, no other photo enhancements were done in Adobe Photoshop.

Chip Fisher

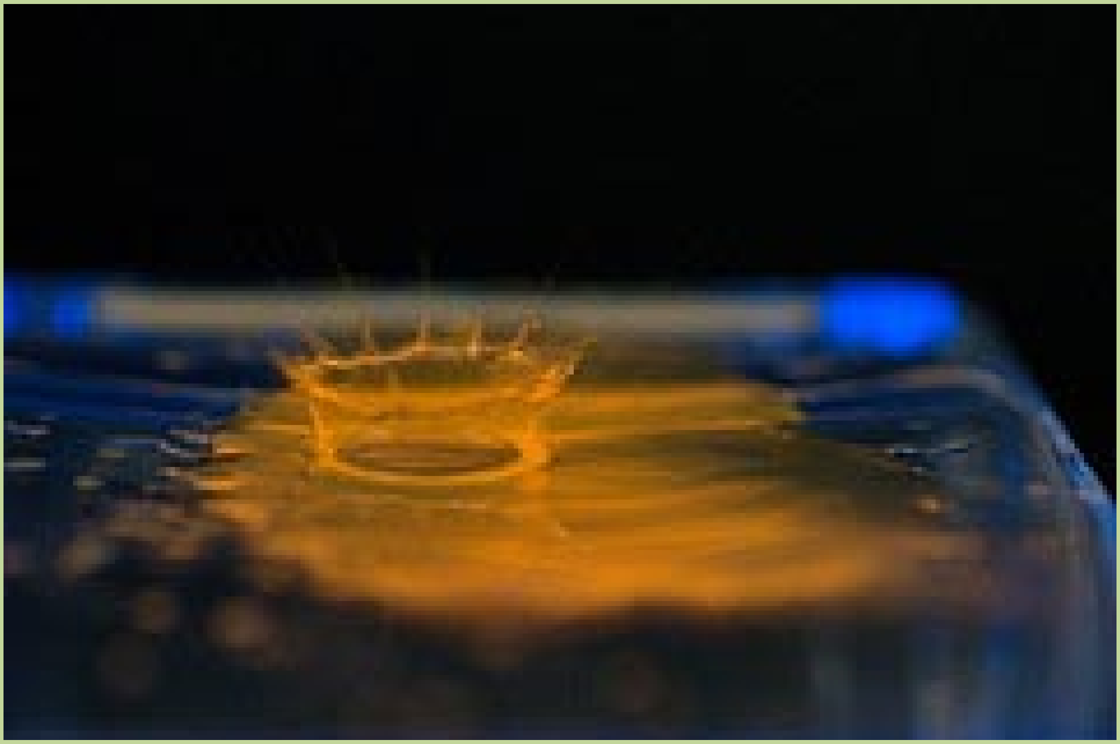

Figure 4: Fisher unedited photograph

Fisher's final image of the crown effect in fluorescent orange highlighter ink is 3686 x 1395 pixels and edited in Adobe Photoshop CS4 to improve the sharpness of the crown's edges and increase contrast between light and dark regions. To improve the sharpness of the crown, the raw image was overlaid with a background copy and then a High Pass Filter was run on the overlaid copy at 100 pixels. Unfortunately, this method also increases the pixilation, or "noise," of the image but overall improves the image's aesthetic and scientific quality. Finally, the contrast between light and dark regions of the image was increased using the Curves function; this helped reduce the noise generated by the High Pass Filter and really made the fluorescent colors stand out.

To me, this image reveals a spectacular fluid phenomenon that cannot be captured with the naked eye. While taking photographs with the apparatus this group built, I was not able to actually see the crown happening on the glass vase. Only through the use of photography is one able to see this unusual and magnificent fluid behavior. The image captures the climax of all the force and pressure interactions right as the crown sheet produces secondary droplets and finger-like jets, which is the most fascinating and aesthetically pleasing point of this effect. My intention of capturing the crown splash effect was fulfilled. However, in retrospect, I would have used a different lighting scheme that allowed for faster shutter speeds to reduce the motion blur in this image.

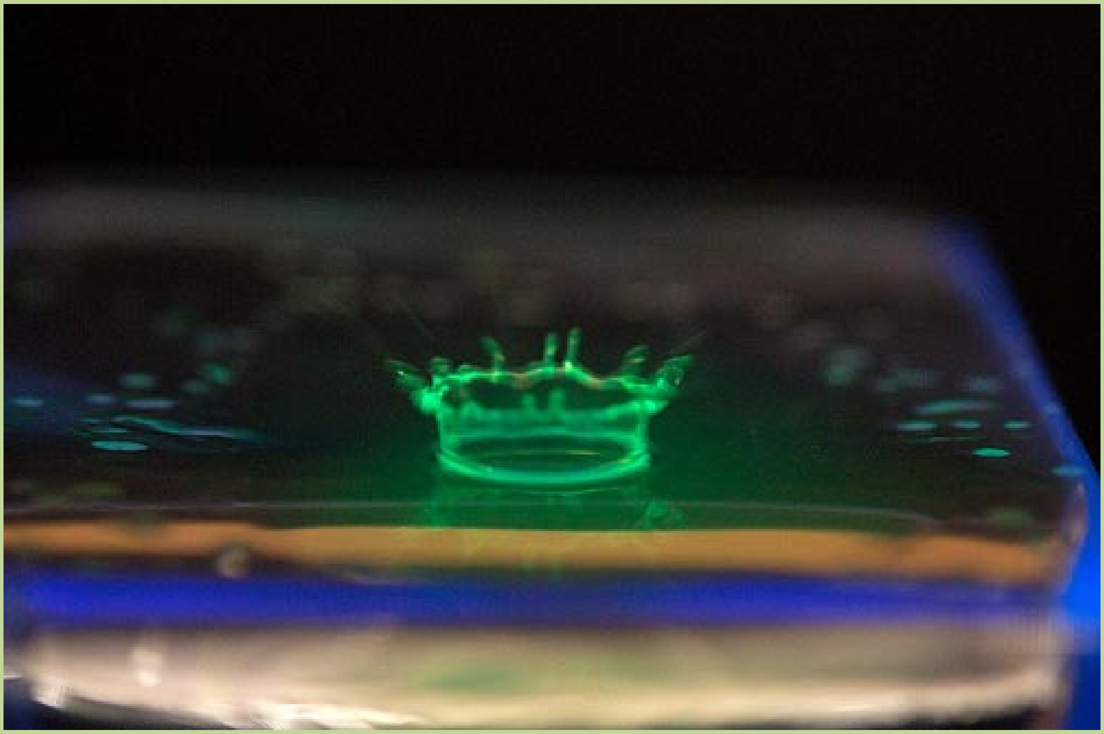

Figure 5: Ramirez unedited photograph

The final image was selected because of the contrast in color as well as the interesting physics that are revealed. The solution has a low Reynolds Number (9.34) which means the solution is dominated by surface tension and dynamic viscosity. It appears that the Rayleigh-Plateau instability is the cause of the crown splash[5]. Curves was one photographic technique used improve image quality as well as clone stamp and the cropping tool. A duplicate layer was added in Photoshop and then a high pass filter was placed over the duplicate layer. The background layer was then added on top of the copy layer and they were merged together. The goal of the duplicate layer and the high pass filter was to bring out small details in the image.

[5] Deegan, R, Brunet P, Eggers J (2008) Rayleigh-Plateau instability causes the crown splash.

The image came out blurry none the less. The final image has pixel dimensions of X: 3708 and Y: 1497.

Using the macro lens was a double edged sword with this photo. The lens was able to capture the small details of the flow but was focused in the wrong place, which resulted in a blurry image. The general outline of the jets and cylindrical sheet are evident but not crisp. The fluid physics are evident as well, but again they are not perfect. The crown splash is not visible to the naked eye but was visible using the macro lens, it seems that the image was a bit of a gamble. I was not happy with the blurriness of the image.

Photographic Technique

A Nikon D300 12.3 mega-pixel digital SLR camera with a 105 mm macro lens was used to capture the images. The camera and lens combination provided the best resolution for the images the group intended to capture. The camera was also chosen based on availability, functionality, and the requirements for the project. The field of view shown in the RAW file picture is approximately 50mm X 50mm. The distance from the table to the lens is roughly 30 cm, but it is difficult to tell due to the macro lens used. While taking pictures of the apparatus, the distance provided enough of a safety zone to keep the camera equipment clean, as well as the operator. No flash was used during shooting. Using Adobe Photoshop's "EXIF" metadata option, the camera data is provided in the table below.

Table 1: Photographic data

Make:	Nikon
Model:	D300
Date Time:	4/1/2009 19:00
Shutter Speed:	1/200 sec
Exposure Program:	Aperture priority
F-Stop:	f/3.5
Aperture Value:	f/3.5
Max Aperture Value:	f/3.3
ISO Speed Ratings:	1600
Focal Length:	105 mm
Lens:	105.0 mm f/2.8
Flash :	Did not fire
	No Strobe return detection (0)
	Unknown flash mode (0)
	Flash function present
	No red-eye reduction
Metering Mode:	Pattern

References

1. De Ruijter M, Charlot M, Voué M, De Coninck J (2000) Experimental evidence of several time scales in drop spreading. Lanmuir 16:2363-2368

2. De Ruijter M, De Coninck H, Oshanin G (1999) Droplet spreading: partial wetting regime revisited. Langmuir 15:2209-2216

3. Cossali GE, Coghe A, Marengo M (1997) The impact of a single drop on a wetted solid surface. Exp Fluids 22:463-472

4. Heslot F, Fraysse N, Cazabat AM (1989) Molecular layering in the spreading of wetting liquid drops. Nature 338:640-642