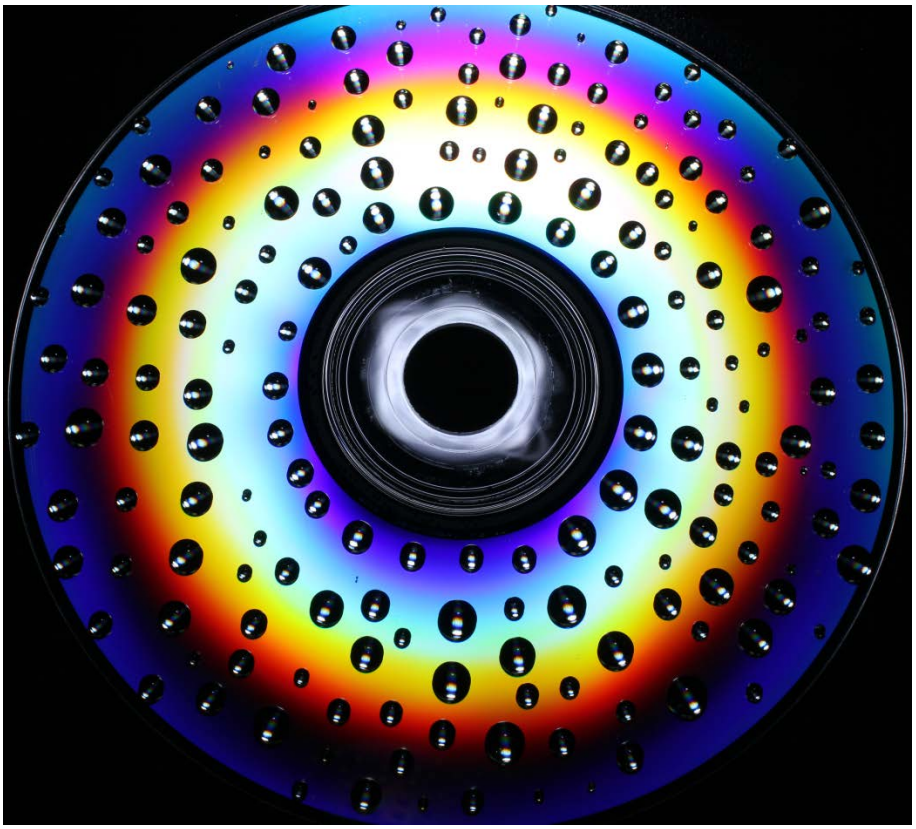

"CD Water Drops"
Danny Maguire
MCEN 5151
Team 2: Danny Maguire, Erick Pena, Stefan Schultz

Introduction

The picture captured above was taken for class MCEN 5151, Flow Visualization, offered at the University of Colorado - Boulder. This second project with a group, "Group 2 Project", is an assignment where we get to work with the same members of the class that we did in the Group 1 Project, in an effort to come up with an aesthetically pleasing image that captures particular flow visualization phenomena. The project doesn't have much limitation so the picture/video can be any number of items. Since we're working in groups the assignment allows for us to come up with a fairly complex setup that allows us to capture are chosen phenomena. The two main objectives that the image is meant to capture is that it demonstrates some flow phenomena and that it's a good, quality picture that offers some artistic relevance. For our final image, we decided to capture a series of water drops placed on a compact disc (CD) that a bright flashlight is shined on while in a dark room. The colors and complex designs that are formed on the CD are very interesting and offered a great opportunity to capture a unique image. We felt this project offered enough difficulty in both image complexity and setup, and also offered the chance to capture a really common but beautiful phenomenon. The other two members in my group were Erick Pena and Stefan Schultz. In general, the overall concept in getting this image was derived

from a YouTube video uploaded by Photo Extremist, called Psychedelic CD Light Painting Photography Tutorial[1].

Setup

The overall setup of this particular project is fairly simple and straight forward. We placed a CD on a countertop and placed small beads of water, using an eye dropper, on the bottom surface of the CD. As seen in the final image the water beads were distributed throughout the entire surface of the CD. The pattern of the water beads wasn't specific or ordered in any particular way, although as mentioned in numerous comments on the D2L discussion board, there is a characteristic of symmetry that's captured in the final image that was never intended. A black velvet cloth was placed below the CD in order to get a dark, black background when taking the pictures. A small LED flashlight was used to shine the light on the CD and get the unique, bright colors that are found on the final image. The flashlight was held between 8-12" away from the CD in moved up and down vertically over the time the picture was being taken. The flashlight was moved at a fairly steady rate, and within about a 4 second timeframe (the exposure time used for final image) the flashlight would be moved up and down about a total of 4 times. It was noted that depending on where the flashlight was held vertically above the CD, the colors would be drastically different, as seen in the final image. A tripod and camera was setup roughly 6" away from the CD at roughly a 15° angle from the vertical, and was used to take the long exposure images. We took the pictures in a small, dark bathroom that resulted in the black backdrop and ideal conditions for this photo technique. One of the more difficult aspects in taking these pictures was making sure the water beads were in focus. There were multiple times that we'd take the picture and it'd look great on the LCD camera screen, but when downloaded onto my computer the drops weren't nearly as clean and crisp as initially thought. Due to this inconsistency we had repeated trial and error steps in order to produce a well-focused image as seen in the final image. A sketch of this setup is shown below in Figure 1.

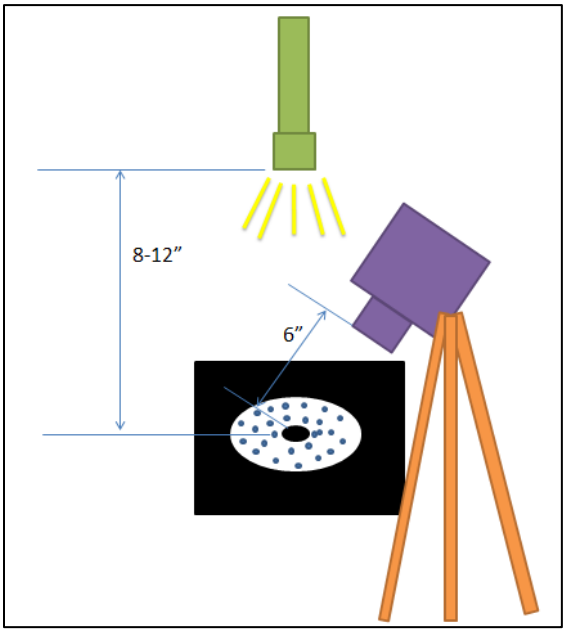

Figure 1: Group 2 Setup

Phenomena

The main phenomenon that is captured within the final image is surface tension and light interference/diffraction/reflection. The light interference/diffraction/reflection that's taking place on the CD is similar to what our group saw in first group project when we experimented with soap film in which we saw an array of colors when shining direct light on the soap. Depending on the angle the light is hitting the CD a range of colors are produced to the observer. In this case the light is held straight above the CD, center around the central hole, so the light patterns are a concentric around that area. The diffractive grating surface of the CD is exposed to the white light and due to interference and reflection the light is spread at various angles represented as different colors/wavelengths[2]. Figure 2 below shows how the light hits the diffractive surface and bounces back at different wavelengths, along with what a common diffractive surface looks like.

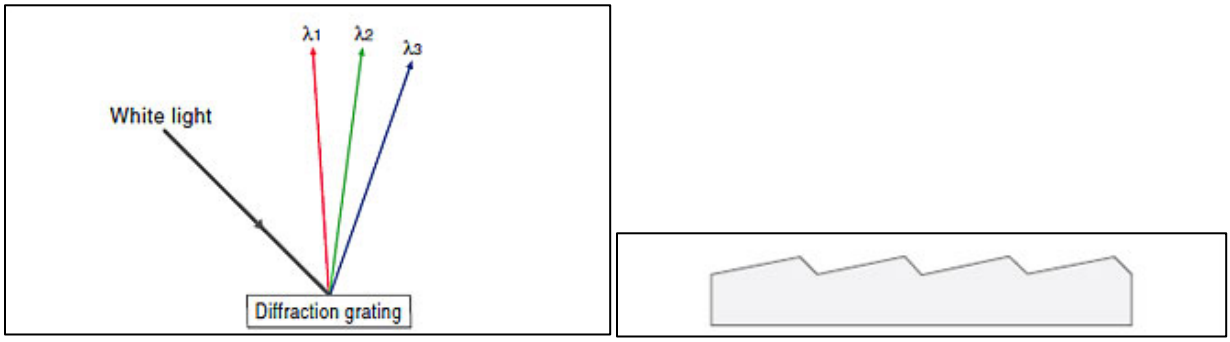

Figure 2: Scattering of Light Due to Diffractive Pattern & Common Diffractive Pattern Surface[2]

Although the surface tension phenomena isn't as obvious from the angle the final image is taken, it is an important phenomenon that's taking place and one that really creates the captivating final image of the water drops sitting atop the CD surface. The basic principle of surface tension in this particular setup is that each of the water drops, and the water molecules that make them up, are held together by cohesive forces forming a lens-like water drop on the CD surface. These cohesive forces are pulling each of the outer surface molecules inward in an attempt to have the smallest possible surface area[3]. The cohesive forces on the water molecules that are within the water drop are zero since the molecule is surrounded by other molecules pushing at equal magnitudes netting a total force of zero. The surface tension force (Fs) acts along the surface of the water bead where it makes contact with the surface of the CD. There is also a gravity force (Fw) that is the resultant of the water drop mass on the surface of the CD. These forces and how they interact on the water drop are shown below in Figure 3 as a free body diagram.

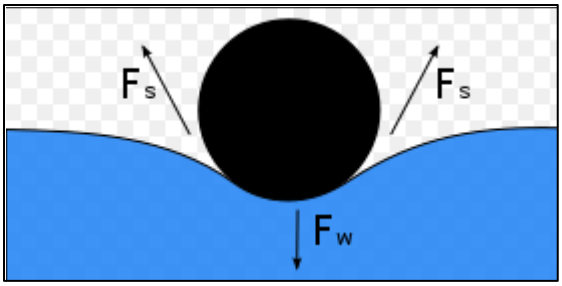

Figure 3: Free Body Diagram of Water Bead on CD Surface[4]

One other aspect that I believe is an important concept regarding the surface tension of the water on the CD is the contact angle that is formed between the two. This angle is directly related to the strengths of both the cohesive and adhesive forces, the higher the contact angle the greater the ratio between the cohesive forces versus the adhesive force[3]. In my final image it's difficult to measure this contact angle since the photo is taken from a top-down angle. Fortunately our group took hundreds of pictures at a series of different angles so I was able to pull information from another photo that's at a relatively useful angle to measure the contact angle. As shown in Figure 4 below, the relative angle of the water to the CD surface is 80°.

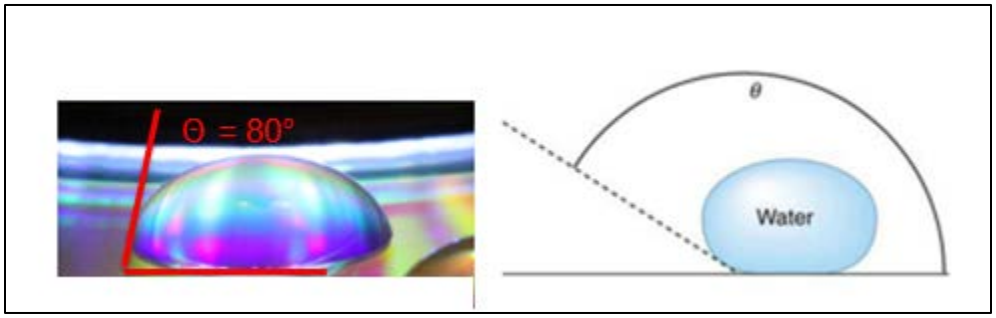

Figure 4: Contact Angle of Water Drop on CD Surface[3]

In order to really put this in perspective, and understand how the cohesive and adhesive forces compare to other conditions, we'd have to compare how this angle relates with how water sits on other surfaces.

Visualization Technique

The main visualization technique used in this image is using the light of the flashlight to hit the CD and create an array of colors while also reflecting off the beads of water to create a mesmerizing image. We mainly focused on capturing the bright and vibrant colors that are formed, and the various designs that are formed on the surface of the CD. As discussed earlier, this particular technique is called light painting photography. In most of these photos it's fairly obvious where the flashlight, or light, is hitting the object/camera over the exposure time but in my particular image it's not as obvious. The solid colors created on the CD look fairly static, but the small amount of white light swirl in the center of the CD is where this "Light Painting" is a little more obvious. Depending on how the flashlight was held and moved above the CD, how far it was from the CD, and the exposure time that was used on the camera it

would result in a collection of different images. As shown in Figure 5, where the flashlight is randomly moved above the CD over a long exposure, the design created on the CD is drastically different than what the final image looks like.

Figure 5: Flashlight Moved Randomly Above CD

Photographic Technique

The main purpose of this setup was to get the most colorful and unique designs on the CD as possible. The settings of the camera became an important aspect when taking the picture. The manual mode was selected on our DSLR Canon T2i camera in order to adjust the aperture, exposure and ISO setting while using the manual focus setting on the lens itself to get the image in focus. Numerous angles, physical distances, zoom distances and camera settings (aperture, shutter speed, ISO) were experimented with in order to come up with the best image. The table below is a breakdown of the final settings that were used for the final image. The combination of an aperture setting of F14, an exposure time of 4 seconds and an ISO setting of 100 (chosen automatically) allowed for a clear, well focused image in the space I was working with. Since the final image captures the entire CD surface I didn't have to zoom in as much, so the 18 mm zoom was used. The image was cropped down laterally to a pixel size of 3832 x 3456 in order to center the main focus of the image, the CD and the unique design that the water drops create on it. The image was in a .jpg format initially but was brought into GIMP and cropped down to a more ideal size. None of the colors were altered or changed within the image. The final image was exported as a .tif image. Both the original and final images are shown in Figure 6 below.

Table 1: Camera Settings

Setting Description	Setting Value
Aperture	F14
Shutter Speed	4
ISO	100
Zoom/Focal Length	18mm
Original Pixel Size	5184 x 3456
Cropped Pixel Size	3832 x 3456

Object/Image Size in Original Photo	4.5” x 4.5”

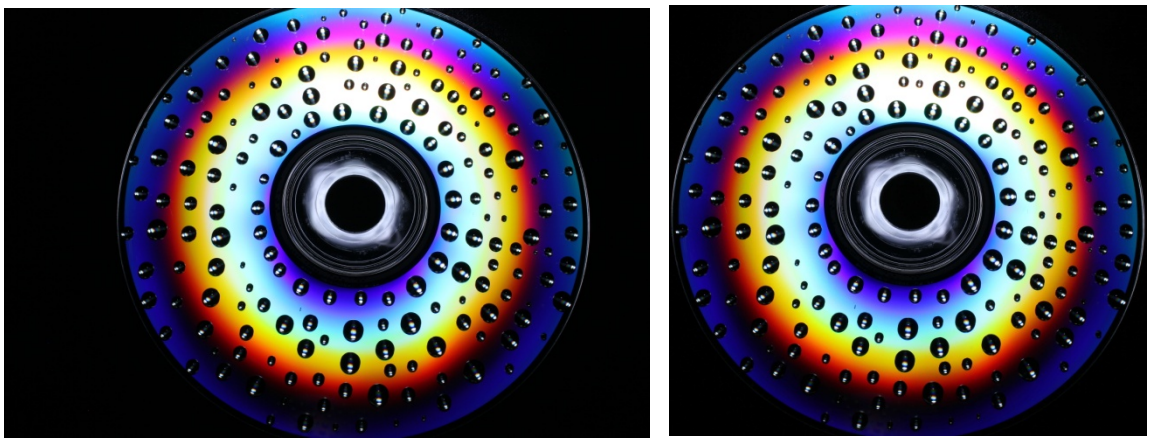

Figure 6: Original and Final Image

Conclusion

I thought the image really captures the basic properties of what makes light painting photos so fascinating. The image really brings out some interesting colors along with having a unique design on the CD’s surface. I really like the symmetry that is formed around the center of the CD and the effects of the water beads that have unique light patterns and shadows that are created from the light hitting them. In all honesty this image turned out better than I had hoped and I don’t think there is much I would’ve changed or altered in either the setup or post processing. The only effect I wish I could’ve captured a little better was the actual surface tension that’s taking place on the CD. Since we’re essentially looking straight down it doesn’t give the viewer much of a perspective of the water beads and how they sit on the CD surface. Although in order to capture that phenomenon a little better, I would lose the unique and complex that’s found in the final image. Another thing I would look into further would be capturing this phenomenon on video, to really concentrate on all the various colors and designs that are found when maneuvering the flashlight around the top of the CD. Overall, I really enjoyed working with my group and producing a very high quality image that captured the CD light painting and surface tension phenomena extremely well.

References:

[1] Sharboneau, Evan. *Psychedelic CD Light Painting Photography Tutorial*. March 15th, 2011. Retrieved at https://www.youtube.com/watch?v=ZvkOh_qvu3M

[2] *The Structure of Spectrophotometer.* Shimadzu Retrieved at http://www.shimadzu.com/an/uv/support/fundamentals/structure.html

[3] OpenStax College. *Cohesion and Adhesion in Liquids: Surface Tension and Capillary Action.* Febuary 20th, 2014. Retrieved at https://cnx.org/contents/eef12ab9-588f-4922-9314-ac1cb25831f5@5/Cohesion-and-Adhesion-in-Liqui

[4] *Surface Tension.* Retrieved November 10th, 2015. Retrieved from https://en.wikipedia.org/wiki/Surface_tension