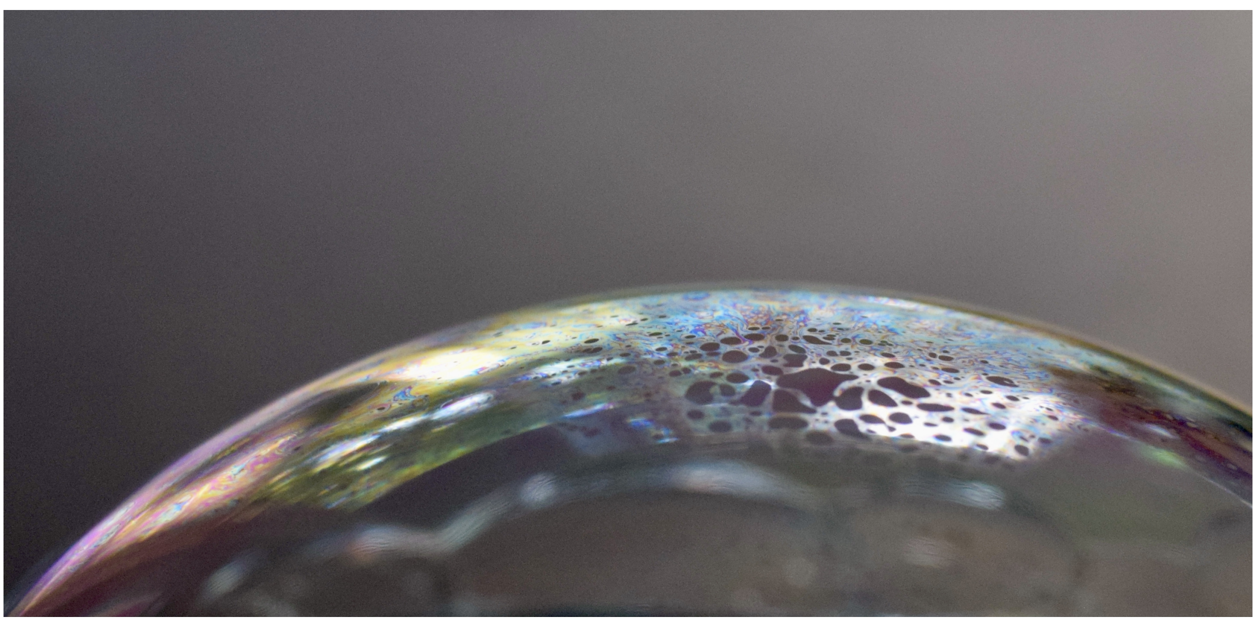
Thin Film Visualization Using Soap Bubbles

Andrew Fine

MCEN 4151 - 001
Dr. Scott Wieland
October 11, 2021
Image/Video 2 Report



1 Introduction

The purpose of this image was to capture a fluid flow phenomenon of our choosing to the best of our ability for the second project in the Flow Visualization course. The intent behind this image was to capture surface tension and thin film effects using soap bubbles. I was motivated to do this because these phenomenon are often result in very interesting colors and patterns that can be used as art. I have even seen photos of these phenomena used as wallpaper images for computers and I wanted to see how well I could match some of that art. As with my previous image assignment, the phenomenon I set out to capture could be created with simple household items like bubble solution or dish soap. This assignment was a fun opportunity to play around with bubbles in order to get the right size, camera angle and lighting conditions. It was also my first experience with a DSLR camera and I was able to learn about lens focal length, ISO settings, shutter speed and other manual settings which are usually not exposed in smartphone camera interfaces.

2 Discussion of Flow Phenomenon

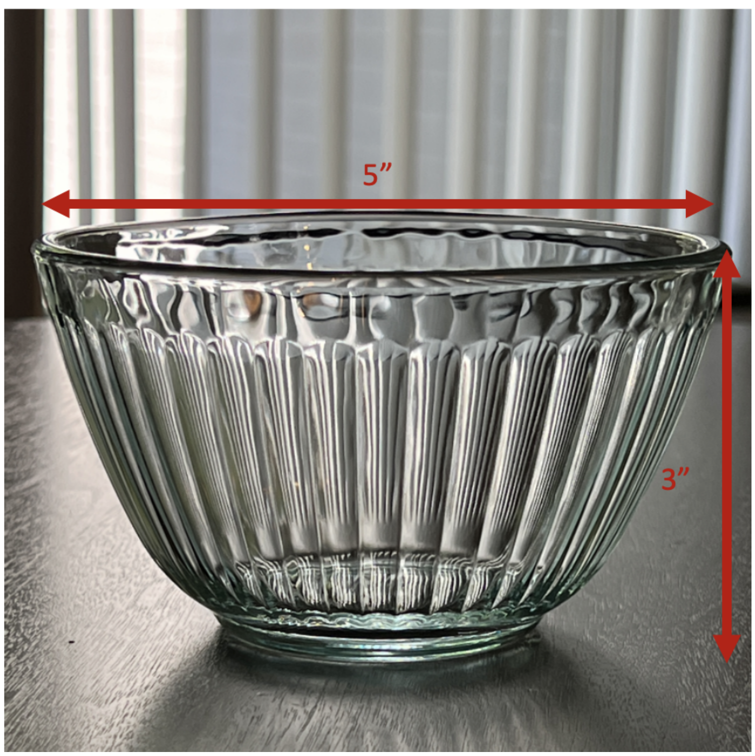


Figure 1: Diagram of general setup

The general flow apparatus used in this image is a simple bowl filled with any kind of soap solution and a straw used to agitate the solution and form bubbles. In my specific setup I used a glass bowl with a diameter of $5 inches$, and height of $3 inches$. The straw used to agitate the soap solution was a green silicone reusable straw.

The first fluid flow phenomenon involved in my image submission was surface tension. Surface tension is a fundamental force involved with fluid flows and can be observed in many classical forms such as water droplets, air bubbles, and of course soap bubbles. Surface tension is a result of the electrostatic forces between the fluid molecules, and combined with the pressure difference between the air inside and outside of the bubble give the bubble its shape. The equation governing the relationship between surface tension, pressure, and bubble radius in thin films is known as the Young-Laplace Equation [3]:

$$P_i - P_o = \Delta P = \frac{4\gamma}{r} \tag{1}$$

Where $\gamma = surface\ tension$, $r = bubble\ radius$, $P_i = internal\ pressure$, and $P_o = external\ pressure$ [2].

The second phenomenon involved in my image submission was Thin Film Interference (TFI). This is the phenomenon that creates the colors seen on the surface of the bubble and make photos of bubbles much more interesting. In thin films light waves that are incident on the outer and inner surfaces interact upon reflection and create constructive or destructive interference. This is because the light that is reflected from the inner surface undergoes a phase change relative to the light reflected from the outer surface. The magnitude of this phase change is dependent on the film thickness and the index of refraction of the film [1].

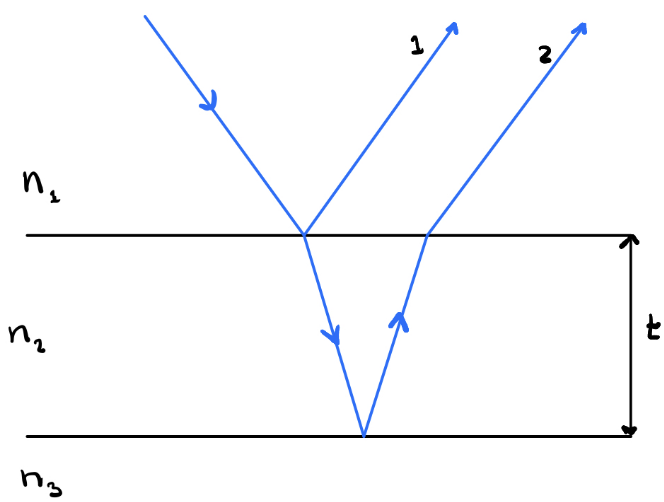


Figure 2: Diagram of Thin Film Interference

Destructive interference is given by the equation $2t = \frac{\lambda_n}{2}$, and constructive interference is given by the equation $2t = \lambda_n$. Therefore, where and when the film is thinner, you will observe destructive interference which will manifest as a darker spot on the surface of the bubble [1].

3 Producing the Phenomenon

Producing the surface phenomenon captured in my image submission required several different steps. First, the setup needed to be in a room with lots of natural light streaming in. This created the rainbow like colors on the surface of the bubbles. I made sure to open the blinds in the living room of the apartment where I intended to create the bubbles. Next I cleared a table and laid out black construction paper to create a plain backdrop since I would be capturing the photos from overhead. Finally I filled a glass bowl with the soapy solution.

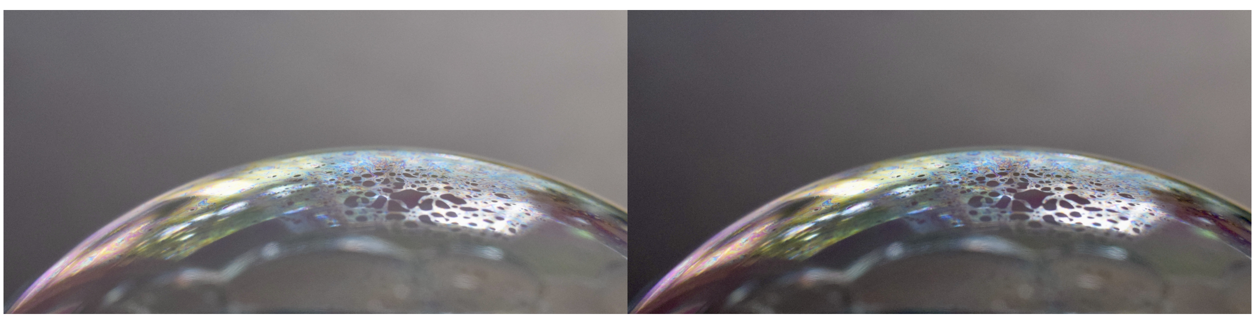
The first attempt at creating these bubbles involved using a dedicated bubble solution acquired from Amazon. This solution was supposedly designed to blow bubbles. However, the bubbles I was able to create by blowing through a straw didn't last very long so I decided to switch to household dish soap. The bubbles from the dish soap seemed to be more resistant to popping which gave me more time to get a satisfactory camera angles, settings, and focus. I did not measure the amount of soap or water. As long as bubbles are forming when the solution is agitated this setup is most likely repeatable by eyeballing the amounts of soap and water.

The process of agitating the solution also had an effect of the type bubbles I was able to create. For the purposes of this assignment larger bubbles were more desirable because they gave the camera something to focus on and really showed off the surface effects described in previous sections. After quite a bit of trial and error I found that creating many smaller bubbles and then creating the larger bubble worked the best. I did this by first blowing through straw under the surface to agitate the water and soap solution which created the "bed" of smaller bubbles. Then I brought the end of the straw above the surface of the solution and this resulted in one large bubble forming as I kept forcing air into it. Once I had a good technique, it was easy to continue doing this until I had capture enough interesting images.

4 Visualization Technique & Equipment

The photographic equipment used to capture this photo was a Nikon D3300 Digital Single Lens Reflex (DSLR) camera equipped with an optical viewfinder. This optical viewfinder allows the photographer to look through the Nikkor 18 - 55mm lens. The final image width - after cropping - was 2923×1421 pixels. IN order to achieve the shallow depth of field seen in my image, I used a lens focal length of 34mm which gives this photo a ”macro” look. I also utilized an ISO setting of 800 with an aperture setting of $f/7.1$, and a shutter speed of 1/80s. These three parameters combine to give the exposure settings.

The post-processing required for this image was relatively light as the camera settings did most of the work. The TFI seen on the surface of the bubble was in focus and camera was able to achieve a bokeh effect where the background and other less interesting elements of the photo had a slight blur, meaning they were out of focus. I had the goal of simply making the colors on the surface of the bubble stand out more. To that end, I used the available photo editing tools in Apple’s own Photos application on my Mac. I used the Edit > Color > Options menu, and increased Saturation to 0.05 and Vibrance to 0.03. Under Edit >Light > Options I increased Brilliance to 0.32, Black Point to 0.74, Contrast to 0.10, and Shadows to 0.11. I decreased Exposure to -0.04, Highlights to -0.10, and Brightness to -0.16. These changes had the effect of making the photo darker in the areas that were out of focus and making the colors more vibrant and visible.



(a) Before post-processing

(b) After post-processing

Figure 3: Before and after post-processing

5 Conclusions

The way I was able to achieve a good focus on the surface of a soap bubble and capture TFI meant that this photo was a success for me. This aspect successfully capture the fluid physics involved and allowed the viewer to see the interference patters on the surface of a thin film. However, I would still say that this photo is not quite ”wallpaper worthy”. I would like to develop this idea further and increase my skills with post processing because the areas of the photo that were out of focus still seemed a little bit grainy. I think creating a pure black background and trying some different exposure settings on the camera could remedy this. Another way I could take the capture of TFI further would be to get video or slow motion video of the colors changing and moving on the surface. This would be a result of the film slowly evaporating and becoming thinner until it is only a few molecules thick.

References

[1] ”Thin Film Interference” Accessed October 10, 2021.
https://courses.lumenlearning.com/physics/chapter/27-7-thin-film-interference/

[2] ”Surface Tension and Bubbles” Accessed October 9, 2021.
http://hyperphysics.phy-astr.gsu.edu/hbase/surten2.html

[3] ”Properties of Bubbles” Accessed October 9, 2021.
http://www1.phys.vt.edu/bubble/properties-of-bubbles.html