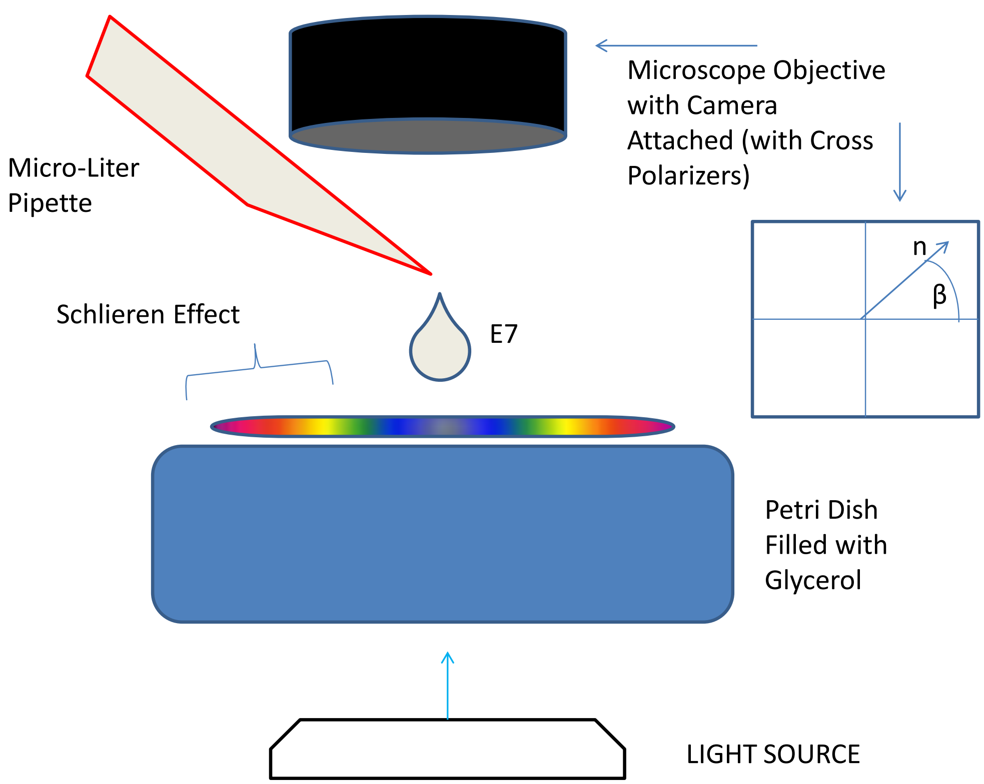
Flow Visualization Spring 2012
Benjamin Pacheco
02/13/2012

E7 Liquid Crystal over Glycerol

For the initial assignment of Get Wet, I decided to image a liquid crystal known as E7. The intent of the image was to visualize the flow of liquid crystal on some sort of medium such as glycerol. More so the flow will be reflected by how the liquid crystal will bend white light under cross polarizers. This effect of bending light in the liquid crystal is simply known as a schlieren effect. This effect is simply when certain areas of the medium visibly change color due to their different densities. In order to achieve this effect visibly in the liquid crystal I had to apply use of a particularly sensitive microscope as well as a high speed camera due to liquid crystal dispersing very quickly over the substrate. Overall, there were several images taken at multiple manual focus points due to blurriness caused by the difference between my line of sight into the microscope and the line of sight of the camera mounted several inches above my field of view. Over some amount of time I learned to then correct for the focus point difference between the two perspectives resulting in the intended image.

The experimental setup I used can be referenced in the following schematic below.



Schematic 1

Initially, I started by finding a liquid crystal that could clearly illustrate the schlieren effect as well as a beautiful and scientifically interesting image. Finally, I went with the liquid crystal E7 and glycerol technique. The schematic was relatively simple; I used a bright/dark field type microscope and connected the advanced SPOT High Speed Camera. Once the microscope setup was complete and all necessary components were set to make it function correctly I then applied a reasonable light setting on the light source so it would not heat/boil my liquid crystal. After this was accomplished I found a small petri dish roughly 2 inches in diameter and filled it to the brim with glycerol. Next I simply used the pipette set at 1mL to extract the E7 from its container. The last step was to carefully add the smallest possible drops directly to the surface of the glycerol. Once I did this, I immediately starting taking pictures of the drop slowly dissipating across the surface of the glycerol. The magnification I decided to use was 20x because it completely allowed me to image most all the colors and patterns created by the liquid crystal.

Calculations for the actual physics of the individual nanoparticles themselves are rather complicated and require multiple layers of quantum mechanics as well as a copious amount of boundary conditions. Due to this reason when studying a liquid crystal there are easier steps to be taken to measure the liquid crystal a whole and use the optical properties of light to simplify the actual flows occurring. For this reason the calculation of transmission of wavelengths of light can be used to measure the actual thickness of the liquid crystal at a given color (wavelength).

$$T = \sin(2\beta)^2 * \sin(\delta/2)^2$$ [1]

Where phase perturbation is $\delta = \frac{2\pi * \Delta n * d}{\lambda}$, where Δn is the index of refraction of E7 which is approximately equal to 0.2, d is the thickness of the liquid crystal at that point and λ is the wavelength. β will also equal the angle of the director n in the cross polarizers which in this case is 45. For example one can now see that the violet (λ = 400) was transmitted at near 100 percent so we can then put this value in for T and solve for d which comes out to be roughly 10µm thick. Then with this we can compare the light and dark spots on the pattern of the liquid crystal to determine how the nanoparticles orientation relates to the thickness. This can be done by previously knowing the liquid crystal is nematic and the dark spots are particles horizontally aligned where as the brightest spots are particles oriented in a 45˚ angle counter clockwise from that horizontal.

The crucial part of visualization was the lighting and how it went through the E7 then through the cross polarizers to reach the camera. The cross polarizers were very crucial because they describe how the molecules are oriented by the bright and dark spots on the sample. More so if the cross polarizers were not put into the microscope objective there would be no distinguishing effects or patterns seen being made by the liquid crystal. The cross polarizers are also crucial for determining the transmission and other important values. The setup was to have one light source coming from beneath the liquid crystal sample then goes through the polarizers; and for my purpose the cross polarizers were ordered so they both were perpendicular at all times to each other in the same plane as can be seen in the schematic above.

---

[1] S Chandrasekhar, *Liquid Crystals* (Cambridge [England]; New York, NY, USA: Cambridge University Press, 1992).

Flow Visualization Spring 2012
Benjamin Pacheco
02/13/2012

The size of the image was taken in a field of view that was roughly 1 cm away at around >1mm wide. The very small micro sized area was magnified by the lenses in the microscope by 20x. The fluid flow process was rather quick and required the High Speed Capabilities of the SPOT 14.1 Color Mosaic Diagnostic Instruments camera. The camera was then adjusted by the computer program SPOT that directly adjusted the image settings in real time. Overall, the exposure time used for the final image was 3.4522ms with a gain of 2 and a gamma of 1. Under these settings a proper image was taken with optimal contrast, colors and brightness so one could visibly see what is happening in the liquid crystal.

Overall, my image was ideal for showing the optical properties of liquid crystals and how that can determine the fluid flow. The image was also able to reveal the schlieren effect quite clearly. This liquid crystal, E7 is also very good at revealing the fluid physics behind liquid crystal order based on thickness and can be easily manipulated to get values for thickness and direction based on colors and their brightness. My intent was fulfilled but I would like to improve on the aspects of quantum mechanical calculations and boundary conditions in order to get a near perfectly ordered pattern in the liquid crystal. Also, in the future I would like to explore some more complicated systems of liquid crystals by applying electromagnetic fields to get a more fluid like flow and order in the alignment of the nanoparticles within a given liquid crystal.

References:

Chandrasekhar, S. *Liquid Crystals*. Cambridge [England]; New York, NY, USA: Cambridge University Press, 1992.