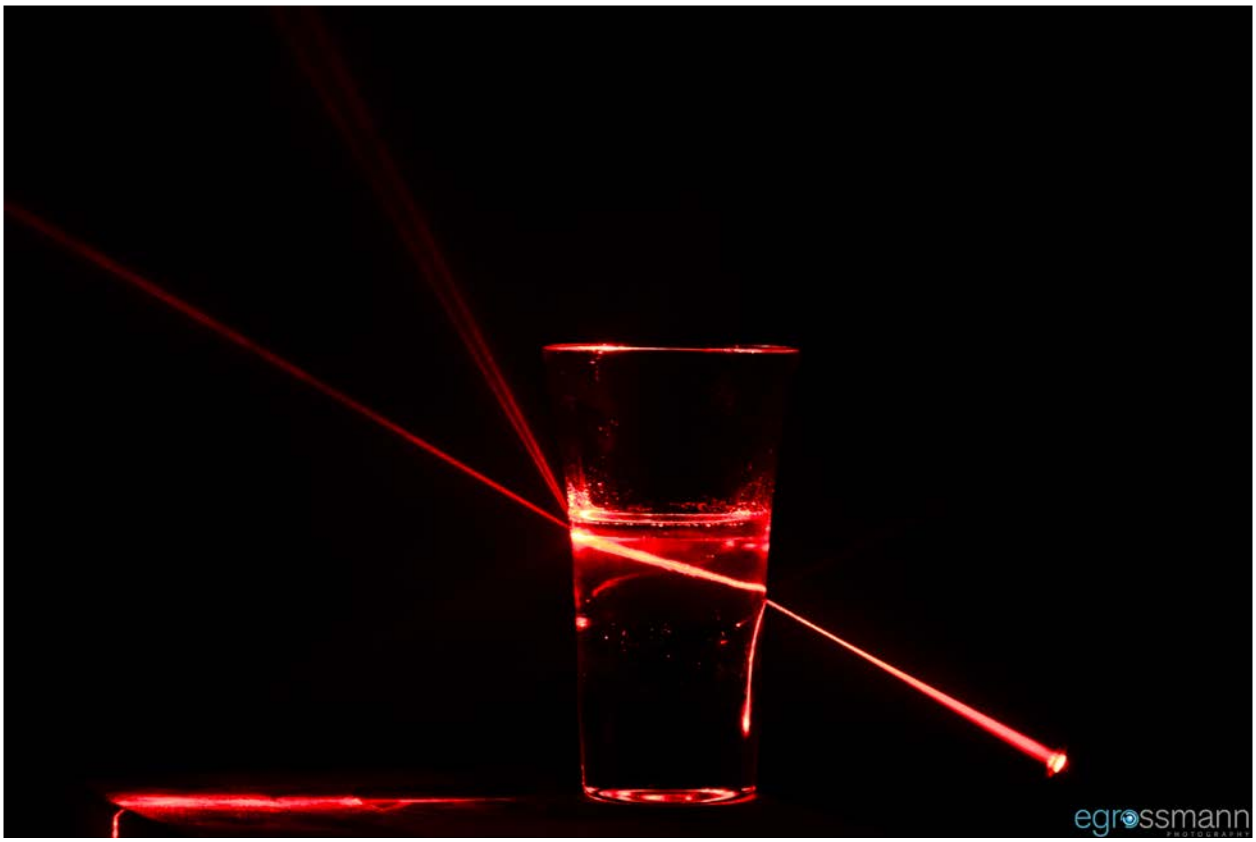
Flow Visualization
Team Project # 3

Laser Beam Refraction through a Surfactant/Fatty Acid Interface



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The main purpose of this last team project assignment was to observe the interaction between a laser beam hitting a glass filled with dish soap and oil, in a foggy medium. A fog machine was used to create the foggy medium in order to intensify the laser beam visualization. This last team # 3 project is part of a flow visualization course at the University of Colorado at Boulder. The main objective behind this assignment is the study of a fluid flow phenomenon by using different visualization techniques, and explaining the chemistry and/or physics behind its behavior.

For this particular experiment, a glass filled mostly by dish soap with an oil layer on the top was placed on top of table. A fog machine was used to create a foggy environment in order to highlight the laser beam visualization. The fog machine was placed to the left of the frame. Furthermore, the laser beam was set to impact the glass from below with an incidence angle of forty-five degrees (45°) with respect to the horizontal. Figure 1 shows the apparatus setup.

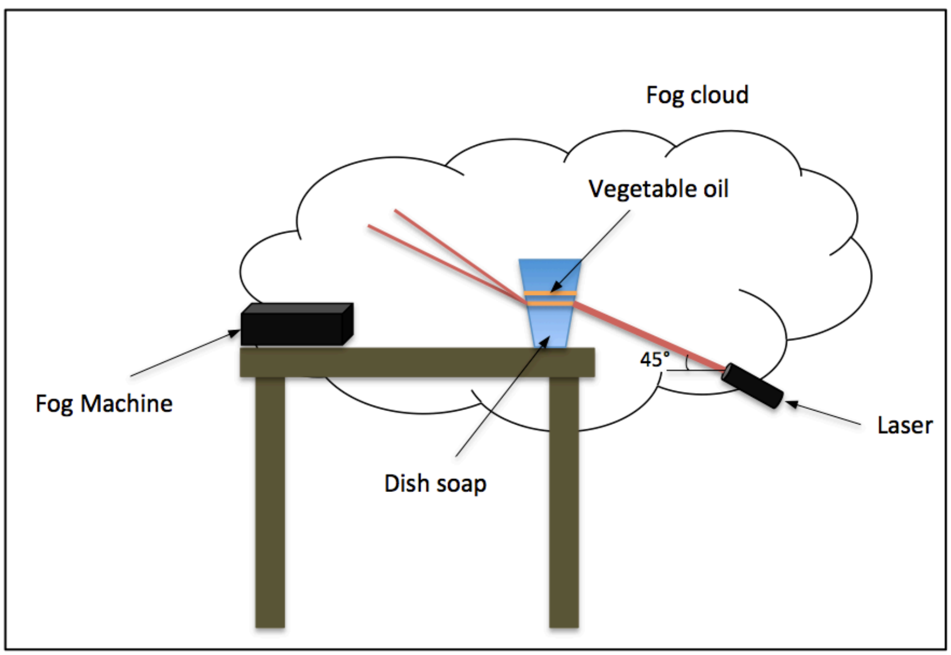

Figure 1. Experiment apparatus sketch

During the experiment, it was appreciable how the laser beam changed direction when this one impacted the glass, and later when leaving the glass (filled with dish soap and oil), as well. This bending of the laser beam when entering one or more mediums is called refraction [1]. In our case, the refraction is seen twice; therefore, it can be called double refraction. Furthermore, each medium has an index of refraction ($n_{\#}$) together with a refraction angle (θ_r). Figure 2 corroborates the latter by showing that n_1, n_2, and n_3 are the mediums corresponding indexes of refraction. On the other hand, the angle formed by the incident beam and the normal line is called the incidence angle, while the angle between the refracted beam and the normal line is called angle of refraction. In our case, the incidence angle is θ_1 and the angles of refraction are θ_2 and θ_3.

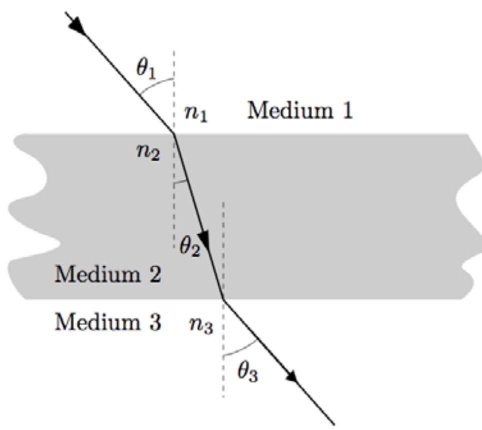

Figure 2. Double refraction

Moreover, the relationship between the incidence angle and the angle of refraction can be calculated by the following expression, better known as Snell's law of refraction [2].

$$n_i \sin\theta_i = n_r \sin\theta_r$$

Index of refraction on incident side boundary

Incidence angle (degrees)

Index of refraction on refracted boundary

Angle of refraction (degrees)

And the same expression applies when calculating multiple layers or mediums. In our experiment, the mediums can be identified as air, glass, glycerol/oil (common substance found in liquid soaps), glass and air once again. Since our experiment presents many challenges regarding the calculation of all the angles of refraction due to a lack of data, a simplification is going to be made in order to show Snell's law of refraction. Therefore, by assuming only two mediums, air and glycerol, which indexes of refraction are 1.00029[1] and 1.4731[2] respectively; and knowing that the incidence angle is forty-five degrees (45°), the angle of refraction can be estimated to be 28.69°. Furthermore, another concept that is essential to understand the phenomenon seen is the critical angle (θ_c), which is the angle at which the incident beam will be reflected entirely [3]. Therefore, by looking at the image, it is noticeable how at the end of the glass the light splits into two separate beams after travelling through two different mediums. A possible explanation to such behavior is that the light is bouncing between the two mediums until the light reaches the end of the glass, analogous to the concept behind fiber optics. Here is when the critical angle comes into play, by making the refracted beam, coming from the first medium, bounce between the oil and the dish soap creating a total internal reflection [3] (fig. 3). Therefore, the laser beam propagates till the end of the glass where it splits into two rays due to the internal reflection and the two different liquids properties.

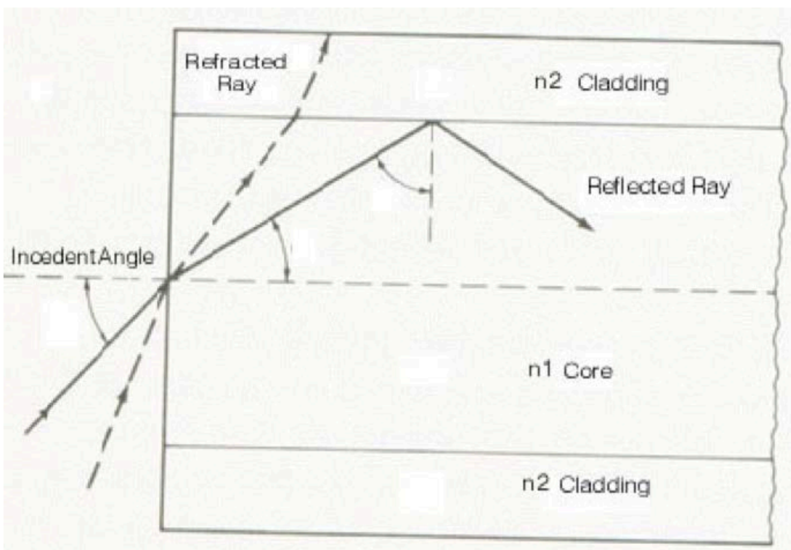

Figure 3. Total internal reflection

Photographic technique

As previously said, the picture was taken under a foggy and dark environment in order to see the laser beam. The camera used for this assignment was a Canon EOS Rebel T2i. The ISO was set to be 200 to increment the sensor sensitivity due to the low aperture used (f/8). The reason behind the low aperture was the fact that the laser was too bright, and the purpose was to capture a dim and sharp beam. In addition, the focal length was 75 mm. On other hand, due to the lack of light and range of colors, the post- processing of the

[1] http://hypertextbook.com/facts/2005/MayaBarsky.shtml

[2] http://hypertextbook.com/facts/2005/ShirleyDeng.shtml

image was somewhat impossible. However, the temperature color was decreased from the original image that was too red.

Table 1. Image specs

Date and Time	April 22, 2012
Camera	Canon EOS Rebel T2i
Aperture	f/8
Shutter Speed	1/6 sec
ISO	200
Focal Length	75mm
Location	Boulder, CO

Finally, the reason behind choosing the laser beam interaction with dish soap and oil for this last team project assignment was because of the physics behind the phenomenon. Particularly, I did not know anything about laser beams and how they interact in different mediums previously to this assignment. The image really shows the refraction of light phenomenon together with what might be the concept behind fiber optics. What I really like about this picture is the different mediums use to propagate light, showing at the end a very interesting show of beams splitting. Although the explanation given in this report can be considered a basic explanation, it helps introduce the main concepts behind refraction and reflection of light.

References

[1] Venable, D. D., Batra, A. P., Hubsch, T., Walton, D., & Kamal, M. (n.d.). *Refraction*. Retrieved from http://physics1.howard.edu/undergraduate/Labs/GenLab2/10_Refraction.pdf

[2] *Reflection and refraction*. (n.d.). Retrieved from http://www.cpo.com/home/Portals/2/Media/post_sale_content/PHY2/samples/phy2_inv_chap17.pdf

[3] Kwan, S. (2002). *Principles of optical fibers*. San Jose State University, Retrieved from http://www.sjsu.edu/faculty/selvaduray/page/papers/mate115/simonkwan.pdf