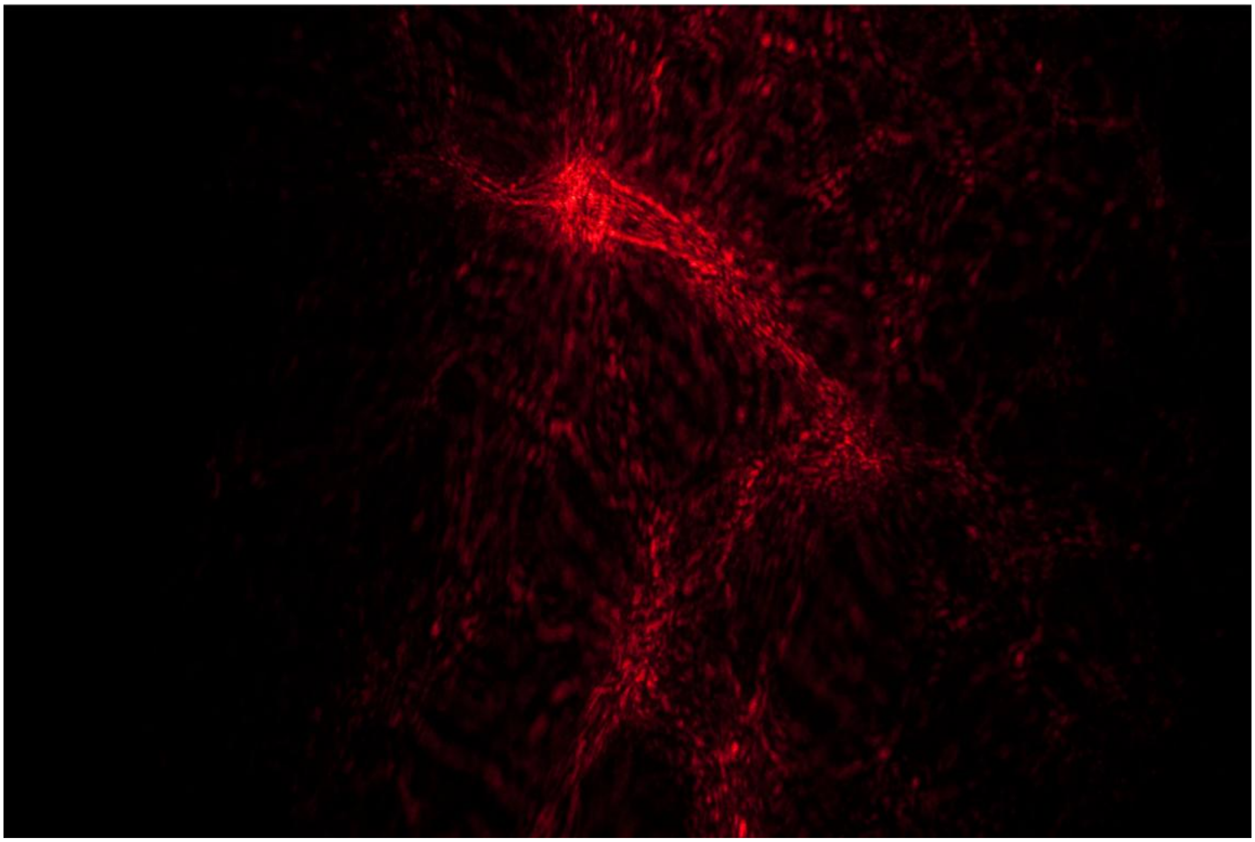
Group Project #3 Report



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5/2/12
MCEN 4151: Professor Jean Hertzberg
Flow Visualization: The Physics and Art of Fluid Flow

Students in the MCEN 4151 course were given the opportunity to work with teams in order to observe a phenomenon that may not be easily captured by a single person. Team Zeta decided to work together to explore the behavior of light in a few different experiments. In order to properly display the optics that the team observed, a digital camera was used and the final image can be seen on the cover page. The following report discusses the physics and art of that exploration of light.

Since the team was working with a laser, a controlled environment was necessary. The team decided to work in a room where they could cover all of the windows in blankets and seal the cracks under the door so that no light was allowed in. The laser was attached to a mini tripod (~3 in height) and placed on a stack of books on a bed, that allowed the total height of the laser to be about 4 ft off the ground. The laser was pointed toward the lamp in the ceiling (which was turned off for the experiment). The horizontal distance, d_1 was an estimated 5 ft, and the vertical distance of the laser to the ceiling, d_2, was estimated at 6 ft. These parameters would make the angle, θ_1, about 50^0. This angle was a bit finicky, and required multiple minute movements to produce. However, when the angle was correct, it would produce the pattern seen in the final image over about a 3ft by 3ft square on the wall, which was about 5 ft away from the ceiling lamp. A diagram of the experimental setup can be seen below in Figure 1.

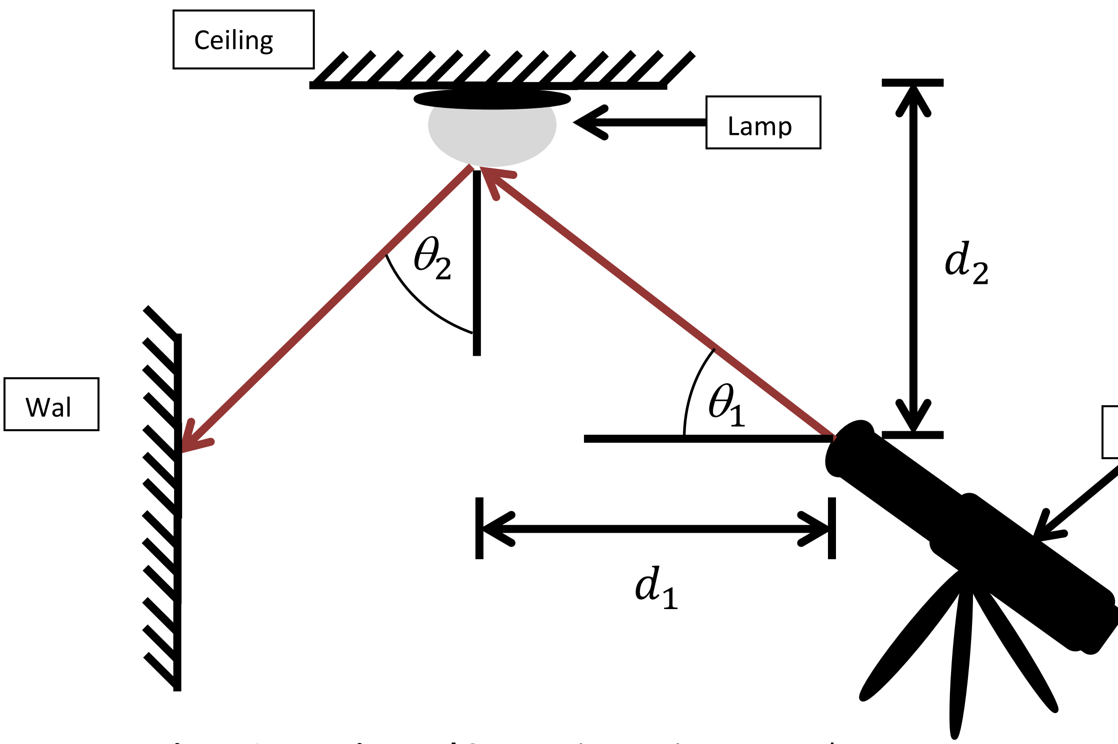


Figure 1: Experimental Setup. Diagram is not to scale.

The laser used was a class IIIb laser with a maximum power rating of less than 200 mW. The wavelength was 600 nm, and the specific model is rlf18130. It is a high powered laser with a manual focus at the tip. The beam was focused into about a 1 cm width. This allowed a high concentration of light to interact with the opal glass lamp cover. The laser was obtained through my senior design team, so no purchase was necessary. A picture of the laser is included in Appendix B.

The lamp is the main source of interest in this experiment, because it creates the pattern seen in the final image. The light travels through an opal glass lamp cover at such an angle that the laser is projected onto the wall. The curvature of the lamp creates a surface that reflects the laser light almost uniformly over a certain area. Figure 2, seen below, qualitatively shown the minimum and maximum reflective angles for the lamp.

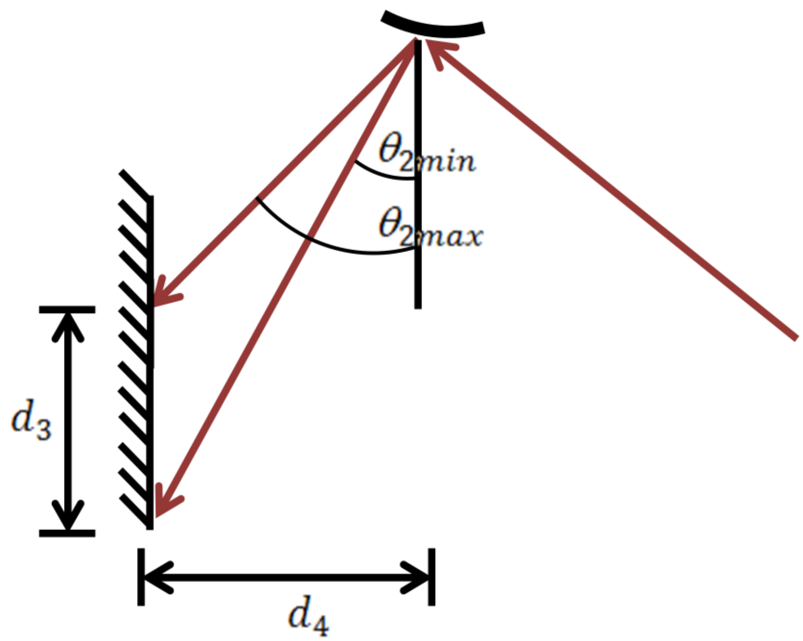


Figure 2: Minimum and Maximum Angle of Reflection. Diagram is not to scale.

Since d_4 is about 8ft, the image height, d_3, was about 1.5ft, and the vertical distance from the lamp to the start of the image was about 4ft, therefore θ_2 was between 56^0 and 63^0. The angles inside the glass could be calculated using the initial angle perpendicular to the surface (90 - θ_1), the index of refraction for the opal glass and air, 1.45 and 1, respectively, and Snell's law in equation 1, below [1].

$$n_1 sin\theta_1 = n_2 sin\theta_2 \qquad (1)$$

From this equation, it can be calculated that the light ray enters at 40^0, and is refracted to about 57^0 in the glass. However, it is not quite this simple. Opal glass is known to diffract light in different patterns. Glass is an amorphous solid, which means that there is no definitive atom arrangement. It is produced by melting different inorganic materials and cooling it without allowing crystallization. Opal glass, in specific, is a white glass which is composed of SiO_2, Al_2O_3, Na_2O, and CaO, listed in order of high to low weight percentage composition, along with a few extra compounds that form less than 1% of the material [2]. These compounds form together to make an amorphous material that diffracts light into the pattern seen in the final image.

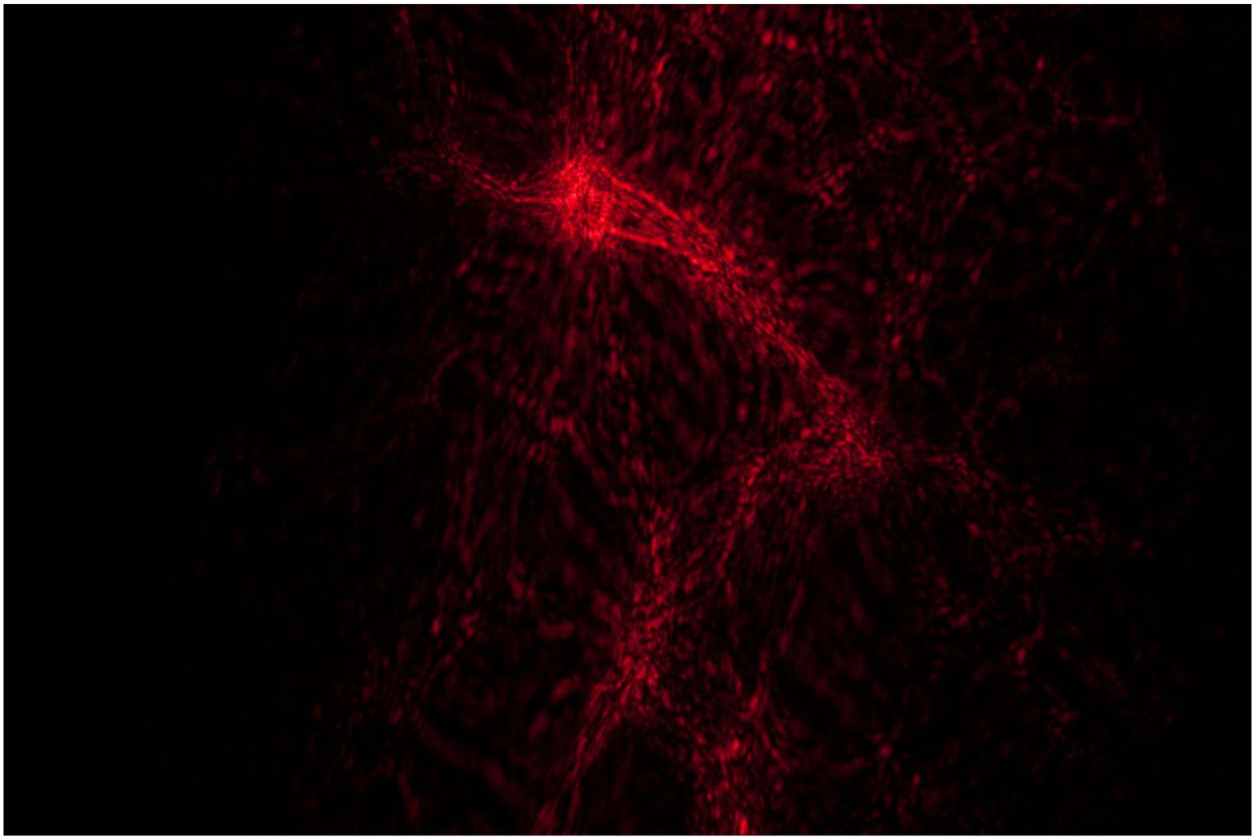
The image was captured with a Canon EOS Digital Rebel XT. The image was shot in RAW mode, in order to get the highest quality image possible. The lens was an 18.0 – 135.0 mm EFS lens with a 41.0 mm focal length. The original and final image dimensions were 3456 x 2304 pixels, which covered an area of about 2 ft wide and 1.5 ft high. The object was about 5 ft in front of the camera, and the camera was about 4 ft off the ground, which was about the center of the object height. The camera sat on a tripod about 20^0 off of perpendicular to the wall. All camera settings were manipulated in order to let the correct amount of light into the camera, without compromising quality. The F-Stop was set at f/8, and the ISO at 200. The shutter speed was .3 s long. The settings were a bit difficult to manipulate, as the experiment had to be conducted in the dark. However, the amount of light in the final image is appropriate for the phenomenon I attempted to represent. The only photo processing done was a few minor adjustments to bring out the contrast and darken the dark sections further. This was all done in Adobe Lightroom 4.

Overall, I was happy with the final image produced. It shows an interesting pattern with abstract characteristics. If I were to do this experiment over, I would spend more time optimizing the camera settings in order to get a clearer image. The idea could be further explored by using different pieces of glass instead of just the single opal glass lamp cover, as well as aiming the laser at different parts of the same lamp cover.

Sources

[1] *Tengu*. Web. 02 May 2012. <http://www.canit.se/~tengu/ior.html>.
[2] "Glass - An Overview." *Glass - An Overview*. Web. 02 May 2012.
http://www.azom.com/article.aspx?ArticleID=1021

Appendix A – Original Image



Appendix B – Laser