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Team Second Report

11/11/2018

This image was a collaboration with Chris Davidoff, and Casey Munsch. Using a spherical mirror, single-point LED, and a few optical tricks, the inhomogeneities of combustion products of a lit match can be seen. Our team was able to image the invisible, using schlieren photography techniques.

These schlieren techniques are a practical tool for a broad range of scientific visualizations, from aerosols in the kitchen to supersonic oblique shock waves about a bullet. This technique dates back to some of the earliest scientific work in optics. The first paper of observing these invisible flows was published in 1793 by Jean Paul Marat, a French revolutionist, who captured rising thermal plums off of objects using a single mirror shadowgraph system [1].

The technique uses the principles of index of refraction to isolate regions of bended light. In this case we used a match and grill lighter to initiate a plume of hot air rising across the mirror. The difference in densities, between the hot combustion products and air, alter the path of the light rays reflected off of the mirror. The razor then acts to cut off half of the light, making the contrast intensify. The only difference for practical purposes between shadowgraphy and schlieren, is the razor or knife edge blocking half of the emitting light rays.

As seen in figure 1 below, the light source shines directly onto a spherical mirror, with a measure focal distance of 3 ft, the camera is then place roughly two focal distances away, with approximately half of the light eliminated by a razor blade. It is simple and effective for creating a pseudo-parallel light pattern, that is idea for imaging this scattering effect.

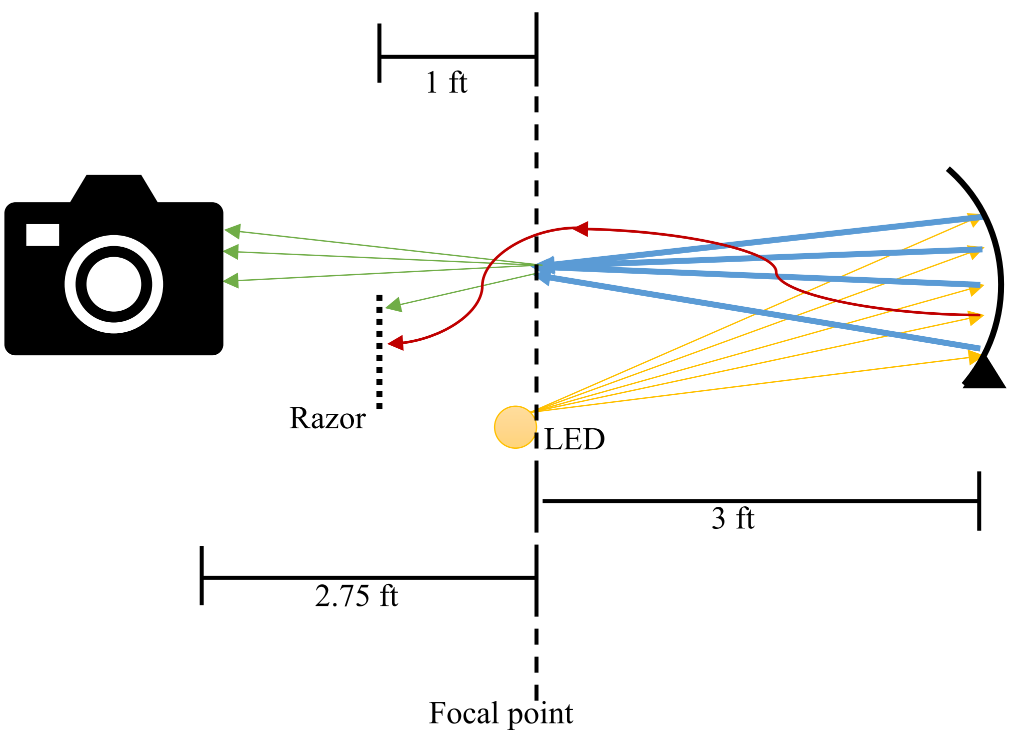

Figure 1: Schematic showing the general set up

The flow captured is identical to the rising buoyant flumes described in my *team first* report[2]:

The plume is broken into two regions, the laminar zone and the turbulent zone. Entering the frame of the film is the thin laminar sheet flow that is smooth, until it is perturbed mid-way transitioning to a turbulent mix of chaotic motion. This instability is known as the Kelvin Helmholtz instability, which is mixing the unseen air with the smoke. The Richarson number can be a good indicator for how unstable the interaction will be. It is expressed as,

$$Ri = \frac{\frac{g}{\rho}\nabla\rho}{(\nabla u)^2}$$

where $\nabla\rho$ *is the change in density across the fluids,* g *is gravity, and* ∇u *is the velocity across the interaction. The critical Ri = 0.25, which any number less is dynamically unstable[3].*

Because of the low speed, these are easy to reproduce and capture. Between the first and second project, how the group chose to capture them is the only major change.

The shot was captured by Chris Davidoff, on his Nikon D850. This camera used a prime-lens set-up with a 55mm f/1.4 and a fixed tripod. The focus is placed directly on the observable light. The pixel density was a whopping 8288x5520, after converting from the .raw format.

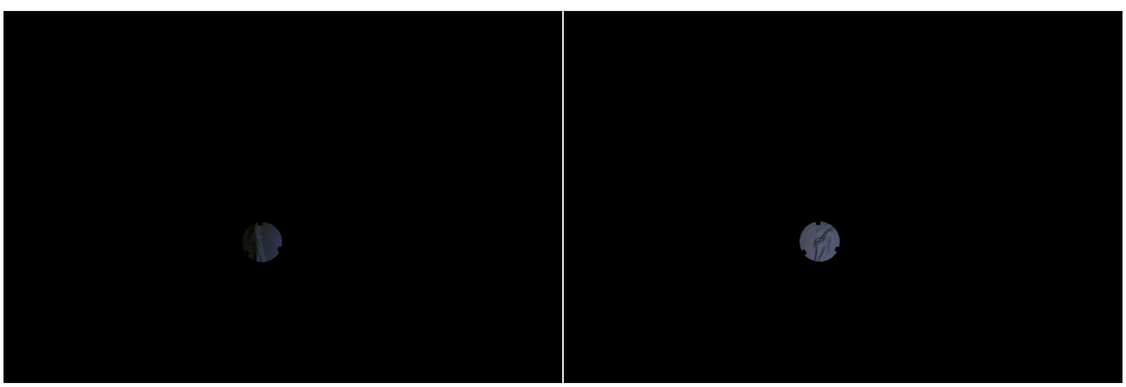

Figure 2(a)(b): Unedited version

As seen in Figure 2(a)(b) he prime lenses has an extremely wide field of view. Neither during the capturing process or after the image was taken was a digital zoom applied, these images are just so large that the pixel density is able to be maintained after cropping, to a final size of . The only post-processing was the stitching and cropping of the two images. I really wanted to add contrast to the piece, but photoshop was unforgiving with its intricate tools.

Figure 3: Final image

The image far exceeded my expectations, with its contrast and clarity. This was the team's first attempt at creating a schlieren-type image, and while in practice some of the techniques were not executed correctly. We are hoping to revisit these imaging techniques for the third and final team project, using larger mirrors with a more precise setup. I look forward to seeing those result.

Citations

[1] Settles, G. S. (2001). *Schlieren and Shadowgraph Techniques: Visualizing Phenomena in Transparent Media*. New York, NY: Springer-Verlag Berlin Heidelberg.

[2] Brown, O. G., Flowvis.org (2018), *Team First Report*.

[3] Kundu, P. K., Cohen, I. M., Hu, H. H., & Ayyaswamy, P. S. (2010). *Fluid mechanics*(4th ed.). Amsterdam: Academic Press.