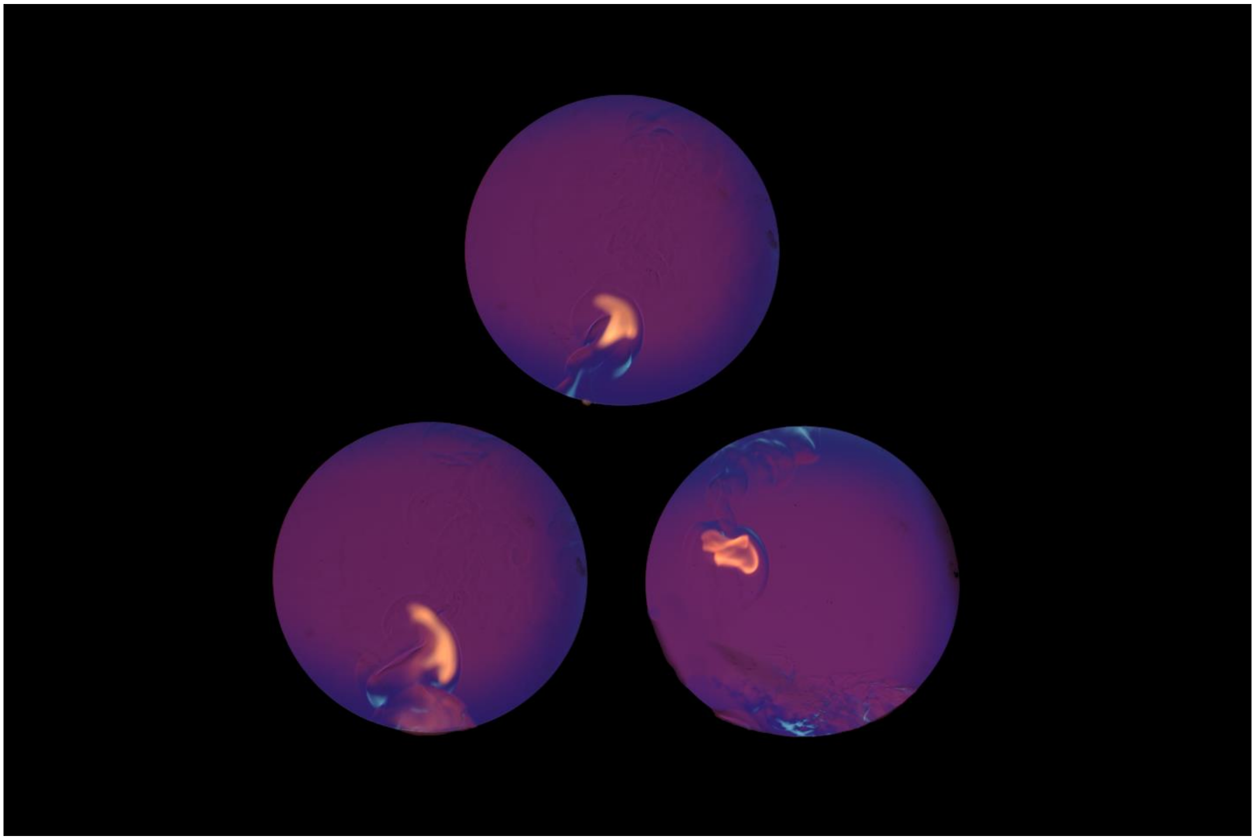
Owen Brown

Team Third Report

December 2018



This image was a collaboration with Chris Davidoffh. 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] [2].

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 filter then acts to cut off the light which trajectory was altered by the combustion, making the contrast intensify and color change. The only difference for practical purposes between shadowgraphy and schlieren, is the filter 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 8 ft, is then the camera is then place roughly two focal distances away, with approximately half of the light eliminated by a concentric light filter. It is simple and effective for creating a pseudo-parallel light pattern, that is idea for imaging this scattering effect.

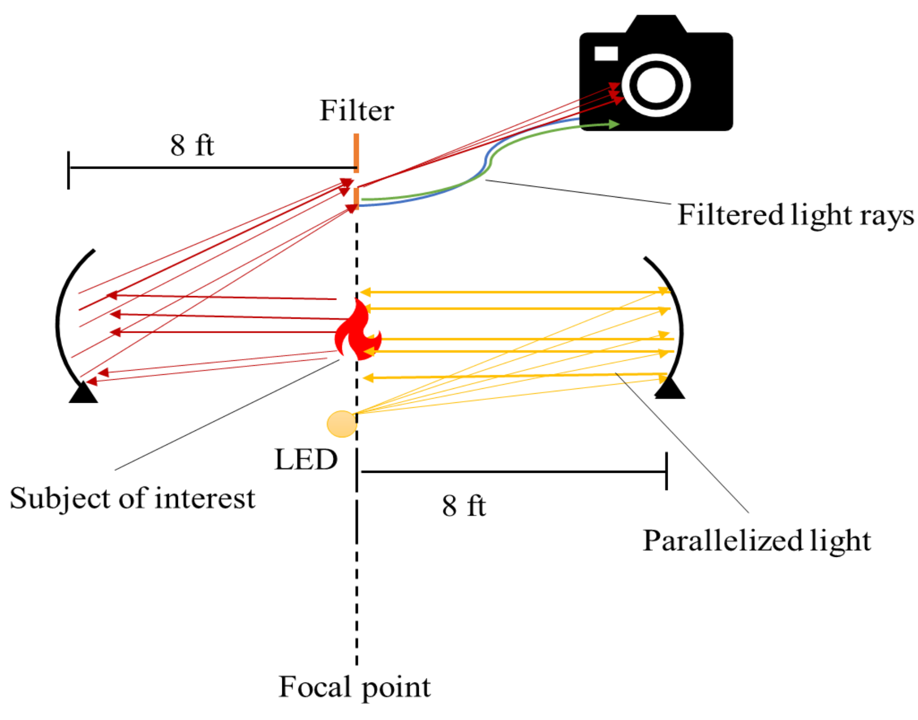


Figure 1: Schematic showing the general set up

The flow captured is identical to the rising buoyant flumes described in my *team second* 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.

As seen in Figure 2(a)(b)(c) the 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 4690x3124 px. The only post-processing was the stitching and cropping of the three images. I really wanted to add contrast to the piece, but photoshop was unforgiving with its intricate tools.

The difference in color inside of the flow is from the light rays taking different paths to reach the camera lens. With some of the light rays being ‘caught’ by the filter at the focal point of the second mirror causing changes in color.

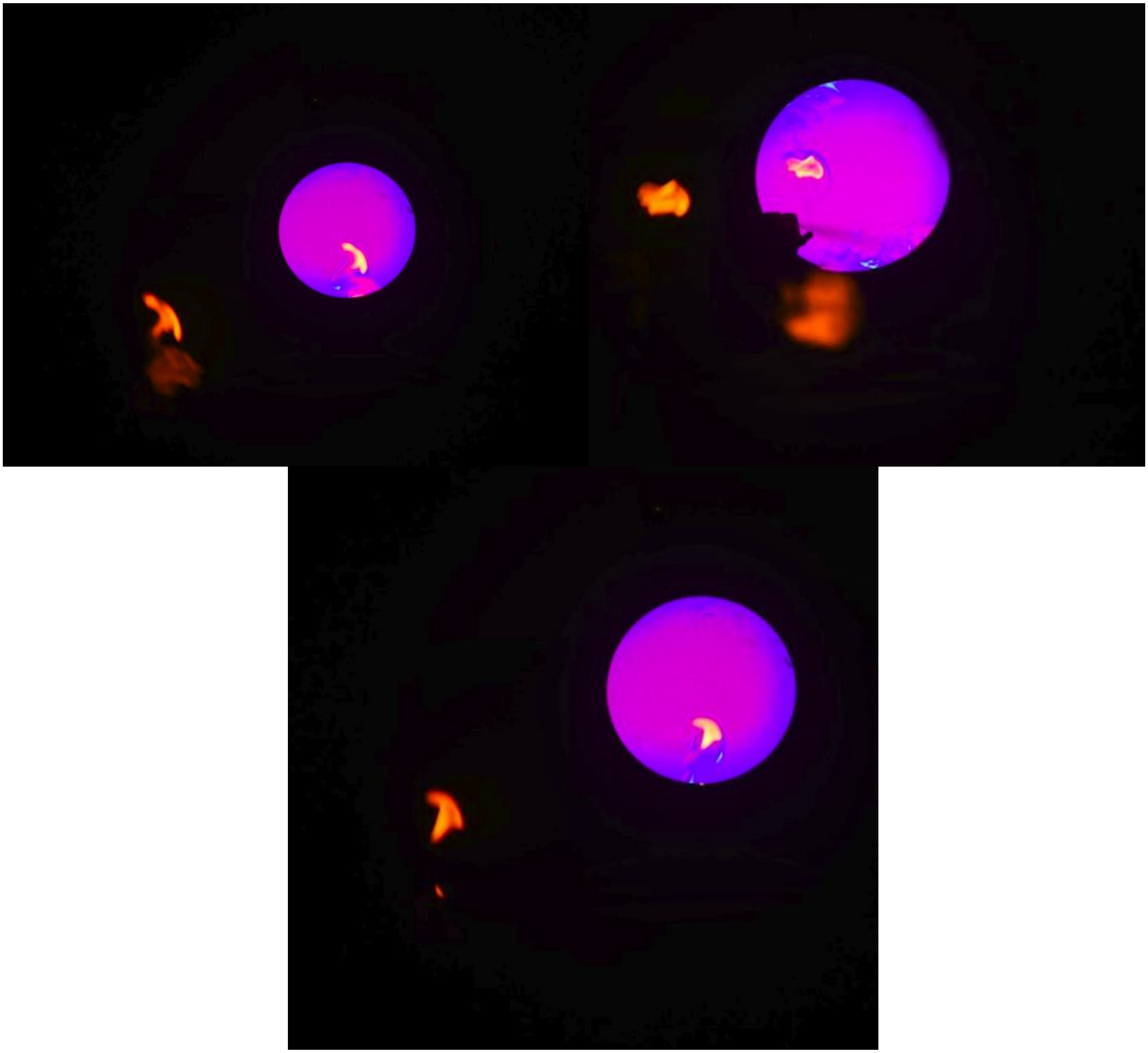


Figure 2: Original three images, capturing unique combustion events from a light with schlieren light processing

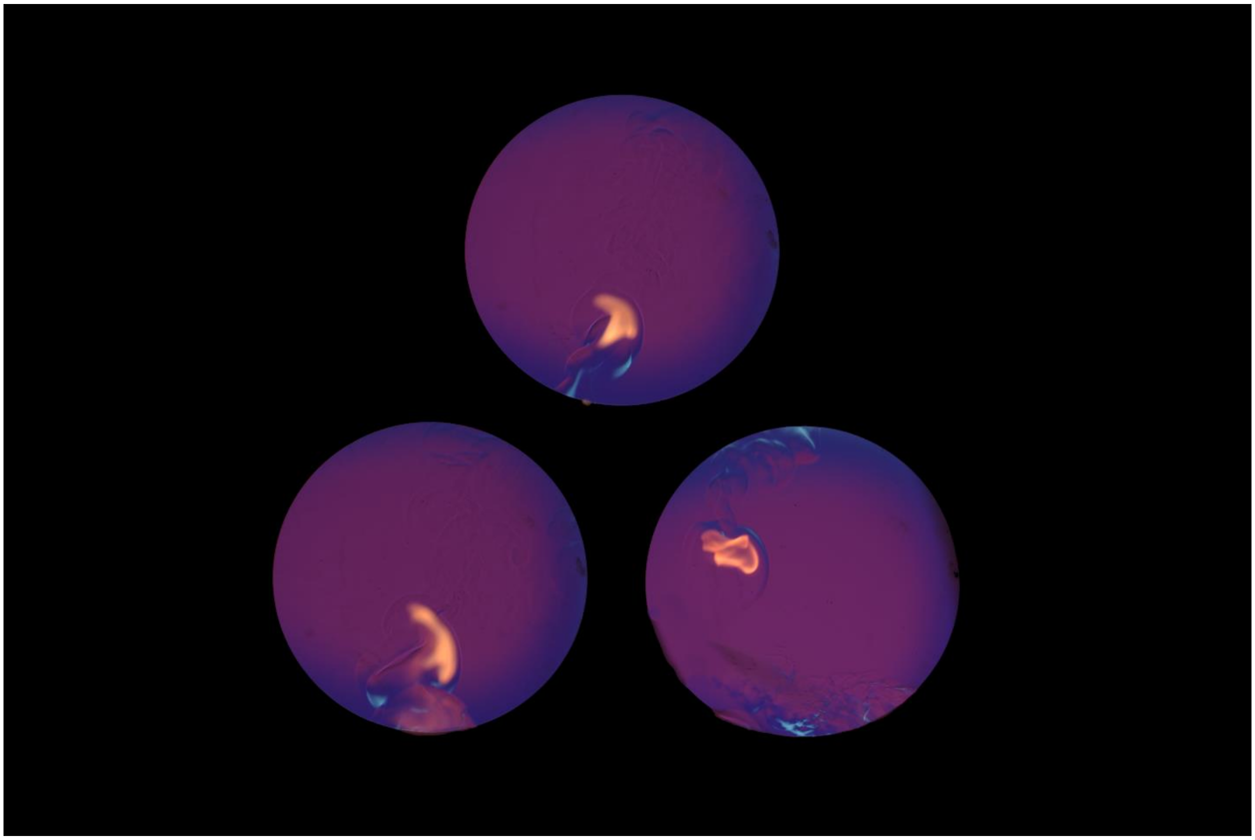


Figure 2: Final image

This final image was by far my favorite from the course. As the previous few projects exceeded my expectations, with its contrast and clarity, this project projected an idea I had had throughout the semester that I was not able to fully grasp with the last two. This was the team's second attempt at creating a schlieren-type image, and we were able to make some really nice contrast with the filtered lighting. In the future it would be interesting to see how the images of more complex combustion events look under these schlieren techniques.

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 Second Report*.

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