Team Second - Fall 2025

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Photo Assistance: Luke Freyhof and Xeen Meighan

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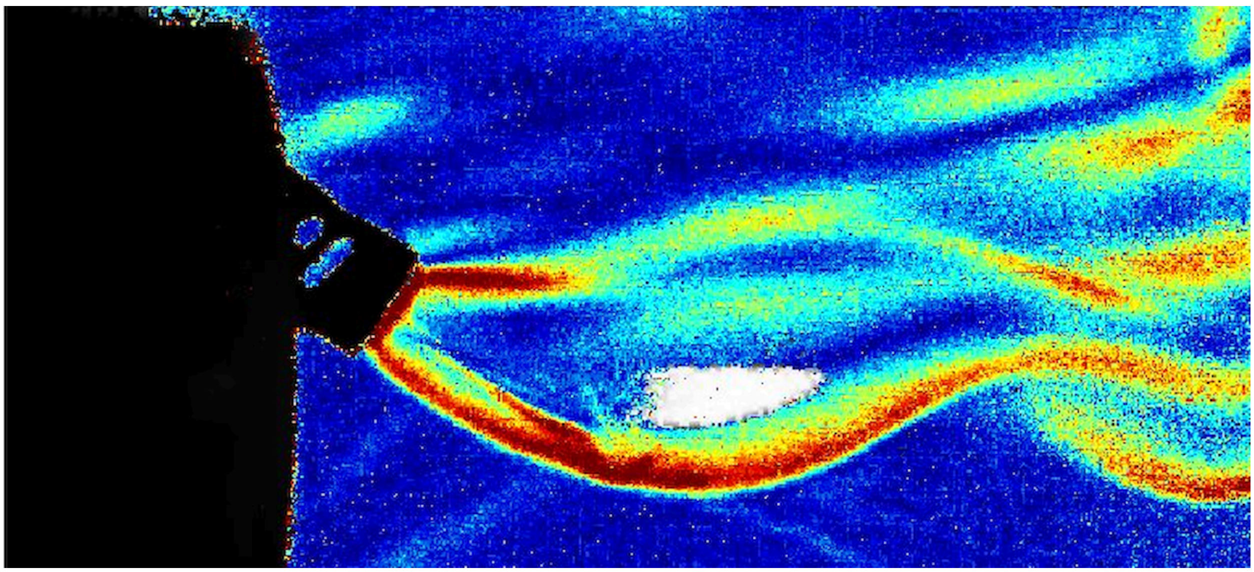

Purpose and Context

This intent behind this image was to capture Background Oriented Schlieren from a homemade schlieren setup. This was done simply by using a google image of a schlieren background and lighting a flame in front of the paper (illuminated from behind). The overall results were processed and lightened with the help of a MATLAB script from JoshTheEngineer. The final result shows the physically unseen density map and represents the pixel deflection of the flame. I would like to thank both Luke Freyhof and Xeen Meighan for their assistance in capturing this image!

Materials and Methods

The initial setup for this experiment consisted of a tripod for the camera, I background-lit schlieren image printed on paper, a hairdryer, a lighter, a black poster board, and various items used to prop up the materials. Provided below is a sketch of the apparatus that was used to capture this flow phenomena, from both the camera’s perspective and the perspective of a viewer looking down on the setup.

<table>
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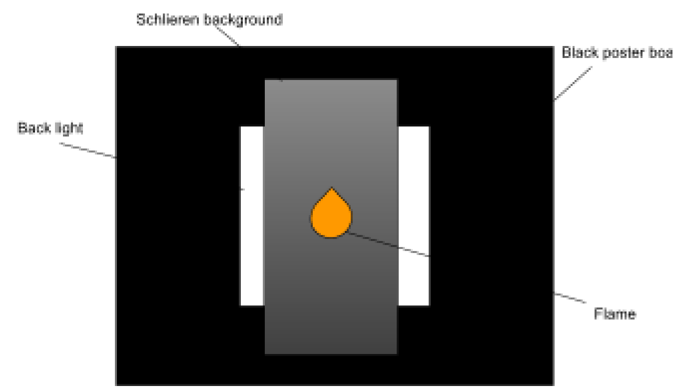
<td>
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<td>Camera POV</td>
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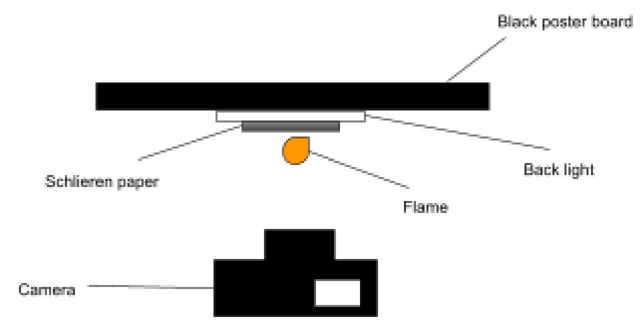
<td>
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<td>Top-down POV</td>
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Figure 1: Experiment setup

Once the camera was secured to the tripod, it was moved to about 20 inches away from the paper with the schlieren background. There was one1800-lumen, USB-powered led panel lights that was utilized to get proper lighting, placed behind the schlieren paper in order to capture the pixel distortion accurately. To aid in this process, the team decided to place a black canvas behind the tank to allow for the contrast to be seen more clearly. This was a lesson that we took from the Team First experiment and decided that it provided very clear images that were needed in post-processing. While the image capturing process was relatively simple, there was a lot more work that went into the post production of this image in order to accurately display the density effects that can’t be observed by the human eye. I will delve into these details further within this paper.

Fluid Dynamics

The main physics displayed throughout this experiment are a result of density changes within the flame that are represented by pixel distortions between two images of the flame. In the words of NASA, "Schlieren photography is similar to the shadowgraph technique and relies on the the fact that light rays are bent whenever they encounter changes in density of a fluid” [2]. In order to capture this specific image, my team needed to splice a video of this flame in front of the schlieren background. I utilized a frame in which the flame was not present, and using the MatLab code from JoshTheEngineer, I was able to compare that photo to one in which the flame was present. This allowed for the final processed image to show the density differences, represented by different colors, that were captured as a result of different pixels deflecting in multiple different directions. The resulting image shows a pattern similar to that of the original flame, which is no coincidence. The deflection of the pixels follows that of the flame due to the temperature difference, overall providing an image that accurately displays what the air around a flame looks like, given that we cannot see these temperature differences with the human eye. That is why, for this specific image, we can utilize the Grashof number to determine "non-dimensional parameter controlling the convective flow" [1]. The equation for Reynolds number is shown below:

$$Gr = \frac{g\beta\Delta T L^3}{\nu^2}$$

where g is the gravitational constant (9.81m/s^2), β is the thermal expansion coefficient of the gas (1/1500+300 K^-1), ΔT is the temperature difference between the ambient air temperature and the flame's temperature (1500 flame temperature, 300 ambient temperature), L is the characteristic length of the flame (2 inches), and ν is the kinematic viscosity of the air (4.0 * 10^-5 m^2/s). Using these values and plugging into the Grashof Number equation, we find the following value for this experiment:

$$Gr = \frac{g\beta\Delta T L^3}{\nu^2} = \frac{(9.81\frac{m}{s^2})*(\frac{1}{1800}\frac{1}{K})*(1500-300\ K)*(0.0508\ m)^3}{4.0*10^{-5}\frac{m^2}{s}} = 5.35 * 10^5$$

This high Grashof Number shows that we are experiencing flow that is driven by buoyant forces rather than dominated by viscous ones. This is true to the flow phenomena observed since the flame clearly shows that there is high convective motion rather than having little motion that is represented by strong conduction. Also, as we can see in the overall value of this number, this specific motion can be categorized as still laminar. Looking at a flame that directly comes out of a lighter, we can physically see that the flow is still laminar, justifying the results seen through numerical analysis.

Visualization Techniques

The final image was captured on a Nikon Z 6 III with a 33mm lens. The following table presents the exact properties of the final image.

Camera Settings	Value of Settings
Focal length	33 mm
Aperture	f/4
Shutter Speed	1/400 s

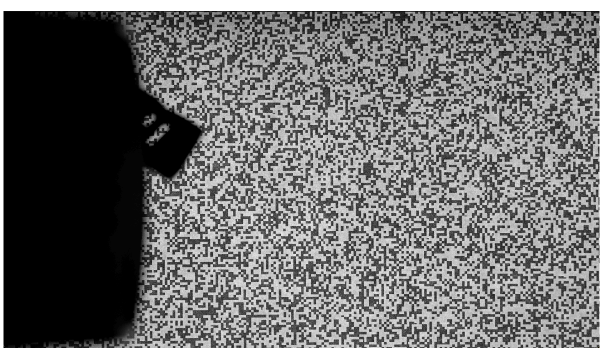
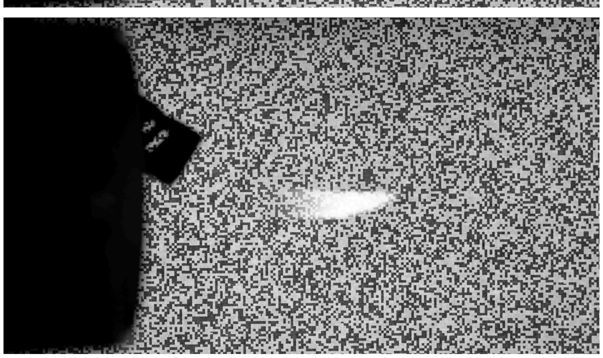
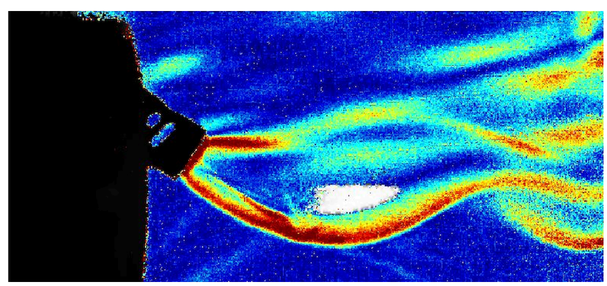
ISO	800
Size	1004×569 pixels

Figure 2: Image Properties

As stated previously, the lens was about 20 inches from the location of the flow. Given that the focal length was 50 mm, the field of view for this image turned out to be 21.81 inches in width and 26.22 inches in height.

The lighting that was chosen was relatively low, so an increase in the ISO provided the additional needed lighting to capture such a contrasting phenomenon. The settings utilized were not explicitly thought through since a majority of the final image captured relied on post-processing. So trying to capture enough video to create an interesting schlieren effect was the main goal of the image capturing portion of this assignment.

The post-processing that was completed for this image, including cropping the image to a more suitable size and adjusting the shadows and highlights via the RGB curve in Darktable. The two images below show the before and after of what post-processing was done. The original image was very over-exposed, so I tried my best to bring out the blues of the water and limit the bright white color that was present in the photo.

Original Images	**Final Image**
 	

2792×1572 pixels	1004×569 pixels

Figure 3: Original and Edited images

As for the actual image processing technique, it began with converting the .MOV files to AVI files to utilize within the MatLab program provided through the pdf instructions from JoshTheEngineer. We then sliced all of the frames within an 8 second video clip using ImageJ, saving all of the clipped video images as .TIF files that could be accurately processed within the software. Utilizing the GUI provided through Matlab, I was able to compare two images to each other: one without the flame in the image and one with the flame. This allowed for the program to accurately depict the pixels where the image was distorted. Once these two images were compared within the program, the color distribution was selected to show the temperature and density differences seen within the flame. I decided to use the original colors within the program as I felt that it appeared similar to the temperature gradient maps that you see on the weather channel, a similar phenomenon that is fairly comparable to this experiment that was performed.

Conclusion

The final image that we captured and processed shows the beauty that lies within the unknown and unseen. The fact that we were able to capture an image of something that is not seen with the human eye and process it in a manner in which you can see the different densities really shows how fascinating and useful software can be in the world of fluid photography. I think this image beautifully displays the effect that simple density differences have on ordinary flow. If I were to recreate this image, I would try to capture a video of the schlieren effect when it comes to a ping-pong ball floating above the hot air within a hairdryer. I would also like to experiment with different camera settings to see how much of an effect the initial image settings have on the final image (after post-processing is complete). Overall, I believe this image displays the intended phenomenon from a different perspective than was initially decided upon, resulting in an interesting representation of schlieren flow.

References

[1] Kleinhenz, Julie, et al. “Pressure modeling of upward flame spread and burning rates over solids in partial gravity.” *Combustion and Flame*, vol. 154, no. 4, Sept. 2008, pp. 637–643, https://doi.org/10.1016/j.combustflame.2008.05.023.

[2] “Schlieren Flow Visualization.” *NASA*, NASA, www.grc.nasa.gov/www/k-12/airplane/tunvschlrn.html. Accessed 3 Nov. 2025.

[3] “Www.Scantips.Com.” *Camera Field of View Details and Calculator (FoV)*, www.scantips.com/lights/fieldofview.html#top2. Accessed 28 Sept. 2025.

[4] *YouTube*, YouTube, www.youtube.com/watch?v=VCUN59x0LF4. Accessed 3 Nov. 2025.