Team Third: Schlieren Flow Visualization

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Flow Visualization: The Physics and Art of Fluid Flow

The goal for the Team Third flow visualization project was to do something different and unique compared to the last two team projects. In combination with Sam Nicastro and Travis Smith we were able to set up a Schlieren Flow that would demonstrate different changes in density through light. The materials used in this project were temporarily given to us by Professor Hertzberg specifically for Schlieren Flow. There was no direct inspiration for the phenomena that was captured in this project but it was introduced to us in class and our group thought that it would be unique and interesting to pursue. Pictured below is a schematic of how the schlieren flow setup is created by Dr. Daniel Endginton-Mitchell.

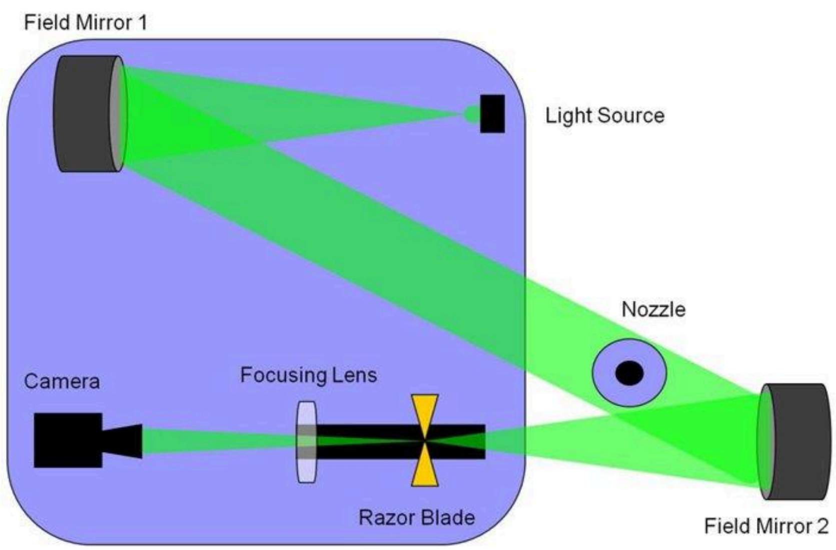

Fig. 1: Schlieren Setup Diagram

In order to create this setup, we had to set it up in a dark controlled environment, this space ended up being Travis's basement. The alignment of the mirrors and distancing the cameras to get the focus on the beam of light correct took the longest amount of time. After finally achieving the ideal setup we were then able to add in the different subjects. For my project I wanted to see the turbulence of heat waves caused by a lighter. The pressure of fuel that is being released causes a very turbulent heatwave which can be seen in the video. The concept of Schlieren Flow is very complex and can be related to a large number of equations. The equations below are some that could be used in the analysis of this flow.

$$\delta n/\delta x, \delta n/\delta y, \delta n/\delta z$$

Eqn. 1: Refractive Index Gradient Components

$$n = 1 + (K * \rho)$$

Eqn. 2: Gladstone-Dale Relation - Refractive Index and Density

$$\rho = P / (R*T)$$

Eqn. 3: Ideal Gas Law

By orienting mirrors and shining light through these mirrors we are able to image changes in refractive indexes. This is due to the change in density of the fluid, in this project it is air, and by having a greater density darker areas are produced allowing us to see this change. In order to get this imaging as perfect as possible a razor blade is utilized to focus the beam of light into the camera's sensor. Parabolic mirrors are also used in order to direct the light source into a beam rather than fully replicating the light that is shining into the mirror. The placement of these mirrors are required to be very precise at about twice the focal length of the camera being used. Below is a picture that was grabbed from the video demonstrating the ripples caused by the lighter in the Schlieren Flow experiment.

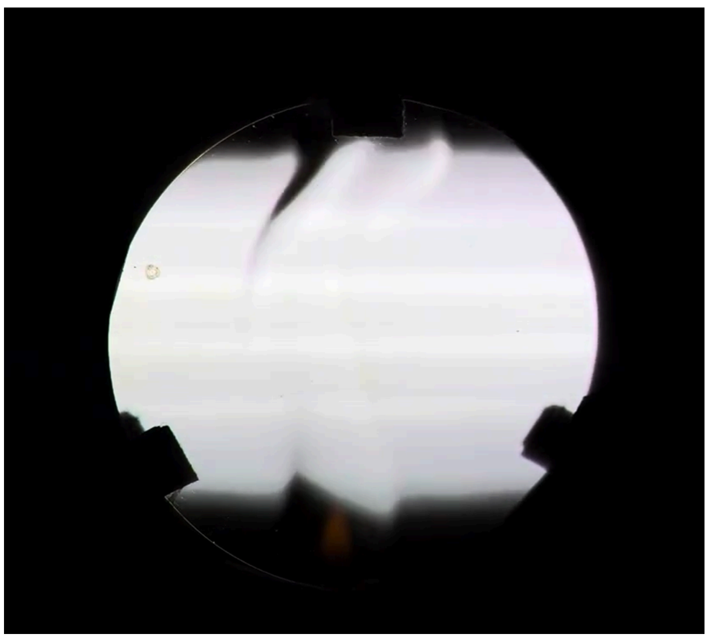

Fig. 2: Screenshot of Lighter in Schlieren

The camera used for this video was and iPhone 16 Pro with the use of Final Cut Camera. This application allows you more customization of the Apple iPhone recording mode, such as manual focus and exposure. The video was recorded in 4k resolution at 120 frames per second. The video was roughly 30 seconds long and was not recorded in slow motion to try and show the true speed of the heat waves being generated. The editing on this video was very minimal and all done in iMovie on the iPhone to preserve the quality of the video. I chose the music to be as neutral as possible because I think that the phenomena does not create a very emotional scene. Going forward I think that I would probably try to change lighting sources and the coloring of the light to possibly get a more defined look on the heat waves being produced.

Appendix:

[1] **Schematic of Schlieren System Setup.** *Dr. Daniel Edgington-Mitchell*, by Daniel Edgington-Mitchell, https://daniel.edgington-mitchell.com/how-it-works/schlieren/.