Team Second Report: Air Duster Schlieren

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2025 Team Second

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Introduction

This video was created for the 2025 Team Second assignment, the fourth project in the Flow Visualization course at CU Boulder. The intent of this project was to reveal the complex flow structures that can form from a common can of compressed air.

Flow Discussion

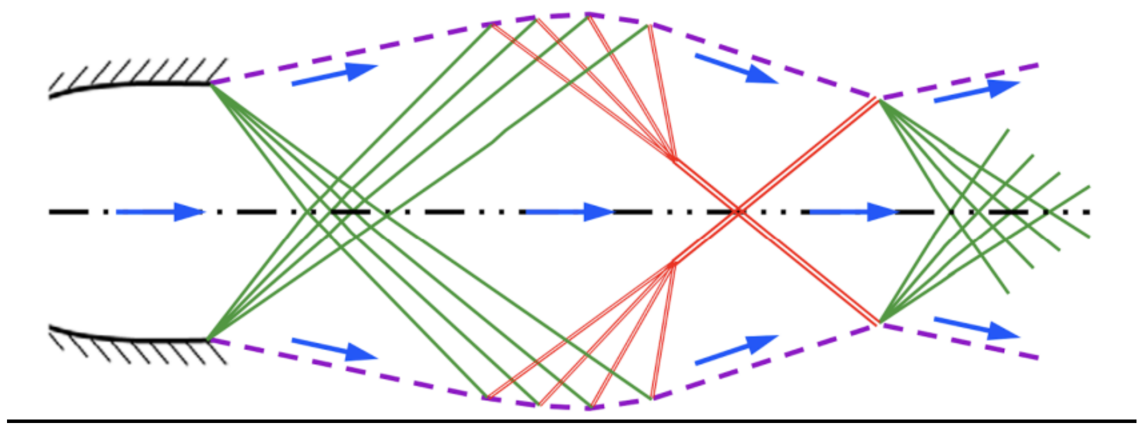

Figure 1. Periodic Expansion and Compressions in an under expanded nozzle (Zamora 2025)

This video was created using a double mirror schlieren system, specifically a z-configuration schlieren system. Supersonic flow produced from a can of compressed air is shown impinging on the flat side of a mallet. The can of compressed air contained difluoroethane gas that has a temperature of roughly 6 atm at room temperature. When this gas is expanded through the can's nozzle, it exits at supersonic speeds (Zamora 2025). In the video this is evident due to the presence of Mach diamonds in the core flow. Mach diamonds are typically seen in supersonic exhaust and are a repeating pattern of shockwaves compressing and expanding due to ambient pressure conditions (Figure 1). In the video, the resolution is not fine enough to resolve the individual compression and expansion waves, but these finer structures were revealed in photos taken by teammate Brian Terasaki. Due to the flow being supersonic, when it impinges on the flat head of the mallet, a shock is formed and spreads out on the surface. The shockwave in the video may be blurred to the limitations of the schlieren setup, or similar blurring could possibly caused by unsteadiness or fluctuations in the flow (Lamont 2004). Both the can of compressed air and the mallet were held by Brian Terasaki and it was difficult to keep them perfectly steady.

<u>Visualization and Photographic Technique</u>

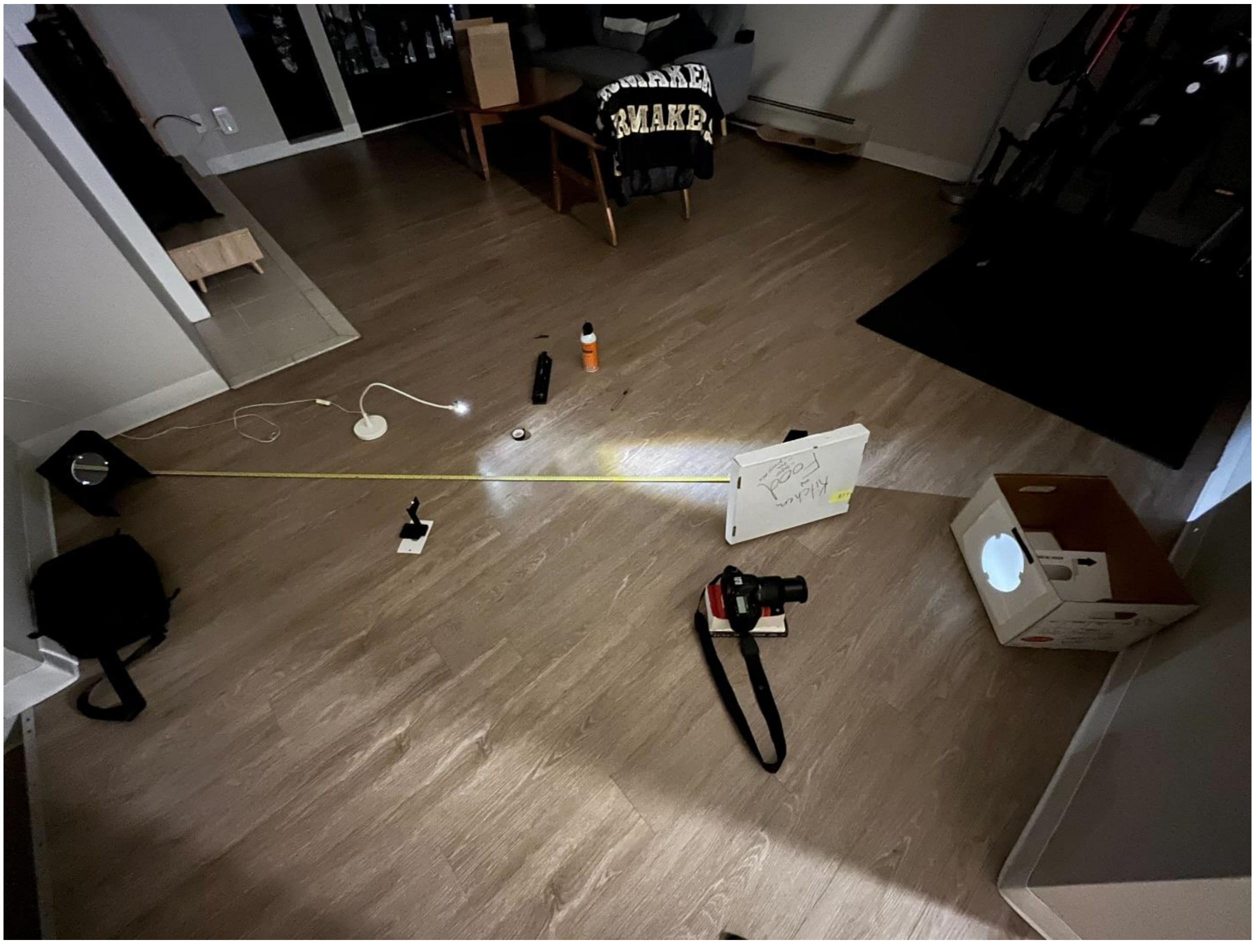

Figure 2. Example of setup used

The schlieren setup consisted of two mirrors with adjustable stands, a led desk lamp, a plastic edge, and a carboard box. The two mirrors and plastic edge were supplied by the course instructor, and the led lamp was supplied from teammate Brian Terasaki. Tape was applied to the bulb of the led lamp to both narrow and collimate its beam of light. The focal length of both mirrors was measured to be 45 inches, and a tape measure was used to position the mirrors, light source, and plastic edge at their optimal positions. The mirrors were placed at double the focal length from each other, 90 inches, and both the light source and knife edge were placed at 45 inches from their respective surfaces. The image produced by our schlieren setup was projected onto a box, with printer paper taped onto the side for a cleaner surface. The distance of this box could be freely adjusted to increase the size of the projected image, or to increase both brightness and clarity of the projected image.

The schlieren setup shows density differences in the medium being illuminated by the light source. These density differences are typically invisible to the human eye. The density differences are shown by disturbing the path of light from the source. The original light source can be approximated as a straight beam, and then is both deflected and refracted at slight angles as it travels through the flow. These disturbances are then amplified across a greater distance as they bounce between each mirror, and the plastic edge is used to block the undisturbed light. Through adjustment of the knife edge, both lighter and darker regions of light are projected that can then be interpreted as both positive and negative fluid density gradients.

The schlieren system was assembled in a study room on the bottom floor of the Dreshcer Undergraduate Engineering ITLL Building. The room was chosen as it could become adequately dark and had the required space. The camera used was a Nikon D5200 with an 18-135mm zoom lens. The focal length used for the recorded video was 32mm, f-stop was f/4.2, and ISO was 1600. The original video recorded at an image height and width of 1920 x 1080 pixels at 60 frames per second. The final video was saved at 3840 x 2160 pixels so that the effects of compression would be minimized. The original video was rotated so that the flow appeared to be going from left to right, and both cropped and zoomed to better focus on the impingement on the mallet. Both saturation and contrast of the video were enhanced to better see features that were previously not clear.

Conclusion

If this experiment were to be repeated, I believe that proper stands for both the compressed air and object the flow is impinging on would be extremely valuable. This idea could be further developed and easily improved by using a brighter light source that is a true collimated point source.

References

Zamora, Jorge Mares. "Analysis of Mach Diamond Formation on Compressed Air Nozzles." (2025).

Lamont PJ, Hunt BL. The impingement of underexpanded, axisymmetric jets on perpendicular and inclined flat plates. *Journal of Fluid Mechanics*. 1980;100(3):471-511. doi:10.1017/S0022112080001255