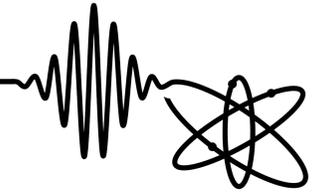


# Two-Path, Double Knife Edge Schlieren Imaging



**Maurice Woods III, Jacob Aas, Jessamyn Hutchins & Jan L. Chaloupka**  
 Department of Physics and Frontiers in Science Institute, University of Northern Colorado, CO, USA

## Abstract

The traditional arrangement for visualizing optical phenomena with the Schlieren technique is modified to include a Mach-Zender geometry. This allows for the implementation of two independent knife edges along the two paths, resulting in an enhanced combined image that is uniquely adjustable.

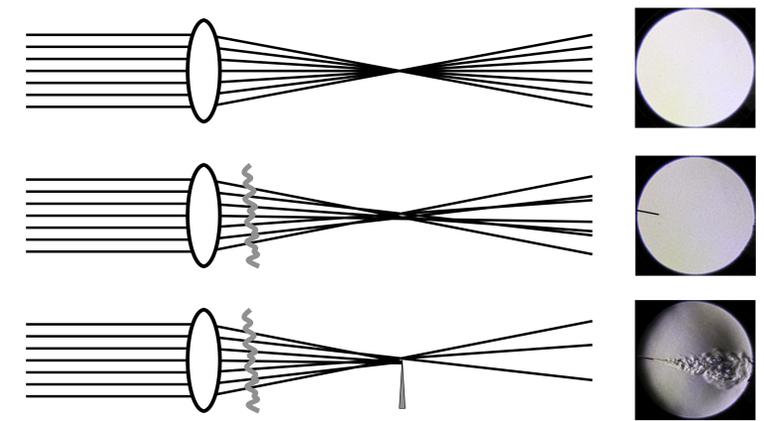
All things Schlieren: G. S. Settles, *Schlieren and Shadowgraph Techniques* (Springer 2006).  
 Other two-view systems: F. W. Barry and G. M. Edelman, "An improved schlieren apparatus," *J. Aeronaut. Sci.* 15, 364 (1948); R. B. Owen and W. K. Witherow, "Dual laser optical system and method for studying fluid flow," United States Patent #4,391,518 (1983).  
 Double image, but along perpendicular viewing directions: G. Rudinger and L. M. Somers, "A Simple Schlieren System for Two Simultaneous Views of a Gas Flow," *JSMPTF* 66, 622 (1957); V. V. Golub, A. I. Kharitonov, Iu. L. Sharov, A. M. Shulmeister, "Two-direction visualization of vortex rings emerging in the course of formation of the supersonic jet," in *Flow Visualization V* (Proceedings of the 5th International Symposium, New York, 1990), pp. 556-561.

## Future Work

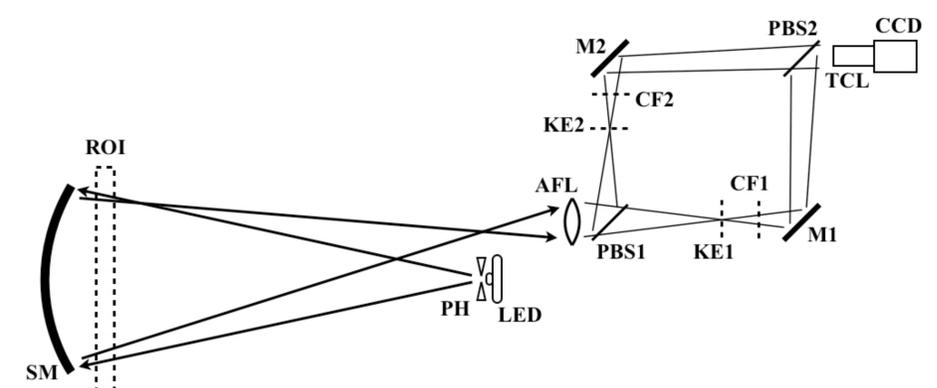
1. The current system suffers from spherical aberration, resulting in the annular/half-moon shading seen in some images. Fixing this flaw will greatly improve the image quality.
2. It should be possible to rearrange the Mach-Zender arrangement to make use of the primary focus, rather than relying on a lens to generate a secondary focus. This should improve the image quality.
3. The synthesis of combined images through the use of virtual filters is currently performed manually. We intend to write a LabView VI to automate this process.
4. An engineered source of laminar airflow will serve to better illustrate the advantages of the double knife edge system.

## Traditional Schlieren Imaging

Schlieren imaging is used to generate high-contrast images of otherwise invisible optical phase disturbances. Changes in temperature or pressure, for example, lead to local variations in the optical index of refraction. By placing a knife edge in the focal plane of an imaging system, small deviations in the path of the light source result in selective blocking of portions of the image. In the traditional single knife edge system, the resulting image is sensitive to deviations only along the direction perpendicular to the knife edge orientation.



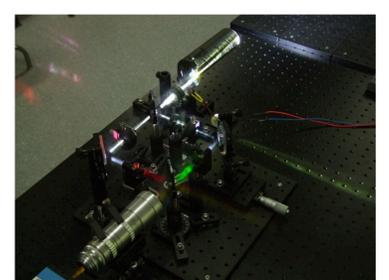
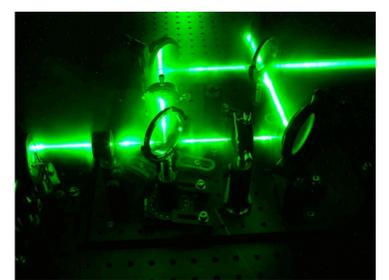
## Double Knife Edge Experimental Arrangement



The experimental arrangement utilizing a two-path, double knife edge system: light from a white LED source (LED) passes through a 150µm pinhole (PH) positioned 2f from a 10" f/4.5 spherical mirror (SM). After passing through the region of interest (ROI) and reflecting off of the mirror, the converging light is directed past the source, coming to a focus adjacent to the pinhole. An aspheric focusing lens (AFL) brings the beam to a secondary focus within the Mach-Zender arrangement: two pellicle beam splitters (PBS) and two mirrors (M). A knife edge (KE) and color filter (CF) is placed in each path, allowing for independent tuning of both parts of the combined image, viewed with a telephoto camera lens (TCL) coupled to a CCD camera (CCD).

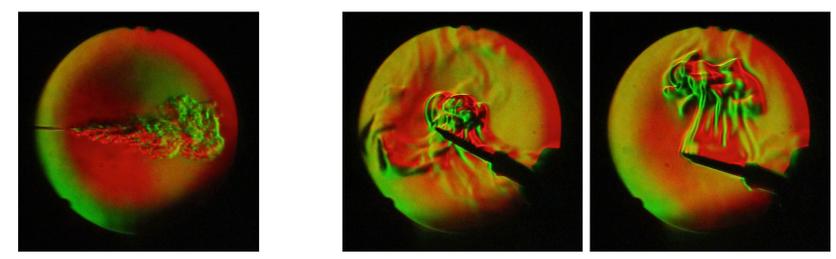
## Mach-Zender Geometry

The two beam paths in the Mach-Zender arrangement can be readily aligned with the help of a laser.



The white light from the LED passes through both arms of the apparatus, complete with red and green color filters.

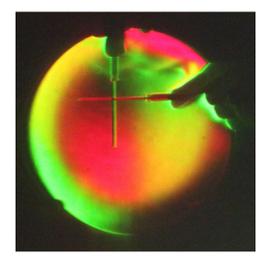
## Combined Image Results



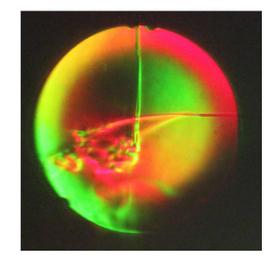
Air flow from a compressed air can is imaged with the two-path, double knife edge system.

Heat flow from a soldering iron shows intricate patterns.

Diffraction from two ball drivers shows how light, deviated along the vertical and horizontal directions, is tagged with different colors.



Laminar air flow along orthogonal directions shows similar behavior.



## Double and Synthesized Images

By intentionally misaligning the beam paths, and removing the color filters, two simultaneous images can be captured of the same event with a single camera. Since the knife edges in the two paths are arranged along orthogonal directions, highlighted features in each image can vary significantly. A combined image can then be created by computer, with full user control of each virtual color filter. Sample double images and synthesized combined images are shown below.

