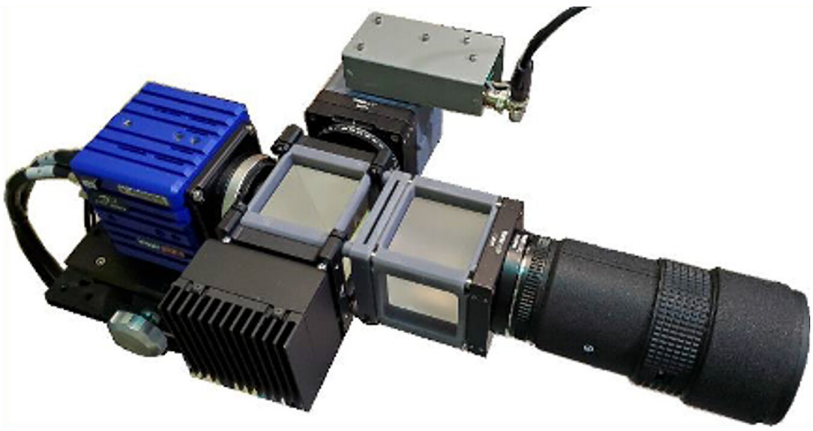


National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Instrumentation

Assembly for Simplified Hi-Res Flow Visualization

Self-aligned, single grid projection focusing schlieren imaging system

Researchers at NASA's Langley Research Center have developed a simple, compact, easy-to-use projection focusing schlieren imaging system optical assembly that leverages a light source, a single physical grid element, and polarization optics to enable hi-res flow visualization. The assembly can simply be mounted in front of a camera to enable focusing schlieren imaging capability. The assembly was designed to drastically reduce the complexity and time required to align a focusing schlieren imaging experiment.

Conventional focusing schlieren imaging systems and projection-based analogs require cumbersome grid alignment and peripheral resources to function (e.g., separate source and cutoff grids, projectors, specialized software). NASA's system leverages a single physical grid as both the source and cutoff grid, so the system is self-aligned, compact, does not require specialized software, and costs less than other projection-based alternatives.

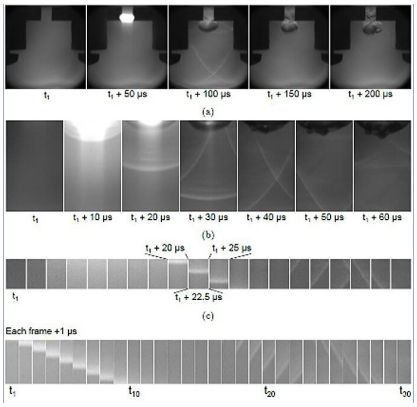
BENEFITS

- Easy to use: The single grid design is inherently self-aligned (i.e., precludes the need for fabrication of a source-matched cutoff grid) and the sensitivity is easy to adjust which simplifies set-up saving time (i.e., hours to days) and expands potential user base to those outside of experts in optical diagnostics instrumentation.
- Compact: The optical assembly is small enough to be mounted like a lens in front of a camera enabling efficient use of space (or room for additional instruments) in cramped experimental environments such as wind tunnels.
- Vibration insensitive: The self-aligning nature of the instrument prevents grid misalignment issues common to currently employed focusing schlieren instruments
- High-speed imaging capable: Demonstrated framing rates up to 1 MHZ (dependent on camera and light source used)
- Modular: System components can be optimized for a given environment, experiment, or cost as the design and method is capable of employing a wide array of light sources, cameras, polarizing prisms, and retroreflective materials.

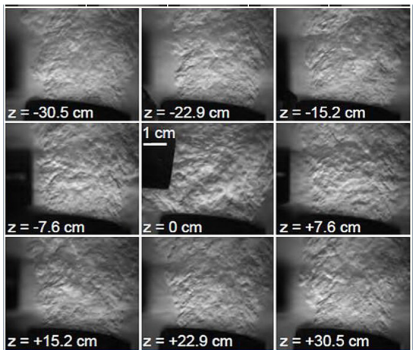
THE TECHNOLOGY

NASA's single grid, self-aligned focusing schlieren optical assembly is attached to a commercial-off-the-shelf camera. It directs light from the light source through a condenser lens and linear polarizer towards a polarizing beam-splitter where the linear, vertically-polarized component of light is reflected onto the optical axis of the instrument. The light passes through a Ronchi ruling grid, a polarizing prism, and a quarter-wave plate prior to projection from the assembly as right-circularly polarized light. The grid-patterned light (having passed through the Ronchi grid) is directed past the density object onto a retroreflective background that serves as the source grid. Upon reflection off the retroreflective background, the polarization state of light is mirrored. It passes the density object a second time and is then reimaged by the system. Upon encountering the polarizing prism the second time, the light is refracted resulting in a slight offset. This refracted light passes through the Ronchi ruling grid, now serving as the cutoff grid, for a second time before being imaged by the camera.

Both small- and large-scale experimental set ups have been evaluated and shown to be capable of fields-of-view of 10 and 300 millimeters respectively. Observed depths of field were found to be comparable to existing systems. Light sources, polarizing prisms, retroreflective materials and lenses can be customized to suit a particular experiment. For example, with a high speed camera and laser light source, the system has collected flow images at a rate of 1MHz.



Raw high-speed images of the shock wave and thermal plume from a spark, imaged at (a) 20 kHz, (b) 100 kHz, (c) 400 kHz, and (d) 1 MHz.



Flow images of two heat guns. The vertical gun is fixed at focus plane (z = 0 cm and the horizontal gun is traversed along the optical axis in front of and behind the focus plane.

APPLICATIONS

The technology has several potential applications:

- Aerospace: Flow visualization, aerodynamics and fluid dynamics R&D
- Thermal Management: instrument to visualize or monitor heat transfer from sensitive electronic devices (e.g., to diagnose thermal issues or determine efficacy of thermal management solutions)
- Medical: Instrument for contamination control (e.g., mask efficacy, clean room air flows) and diagnostic imaging of air flows or fluid flows
- Manufacturing: Instrument to visualize gas flow or thermal flow imaging for additive manufacturing or semiconductor manufacturing processes
- Ventilation: Instrument to visualize air flow from ventilation systems
- Education: Instrument for primary, secondary, undergraduate or graduate laboratory experiments.

PUBLICATIONS

Patent No: 11,650,151

"Compact, self-aligned focusing schlieren system" (June 14, 2021) by inventors Brett F. Bathel and Joshua M. Weisberger in Optics Letters: https://doi.org/10.1364/OL.428011
"Development of a Self-Aligned Compact Focusing Schlieren System for NASA Test Facilities" (December 29, 2021) presentation at AIAA SCITECH 2022 Forum by inventors Brett F. Bathel and Joshua M. Weisberger: https://arc.aiaa.org/doi/abs/10.2514/6.2022-0560

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