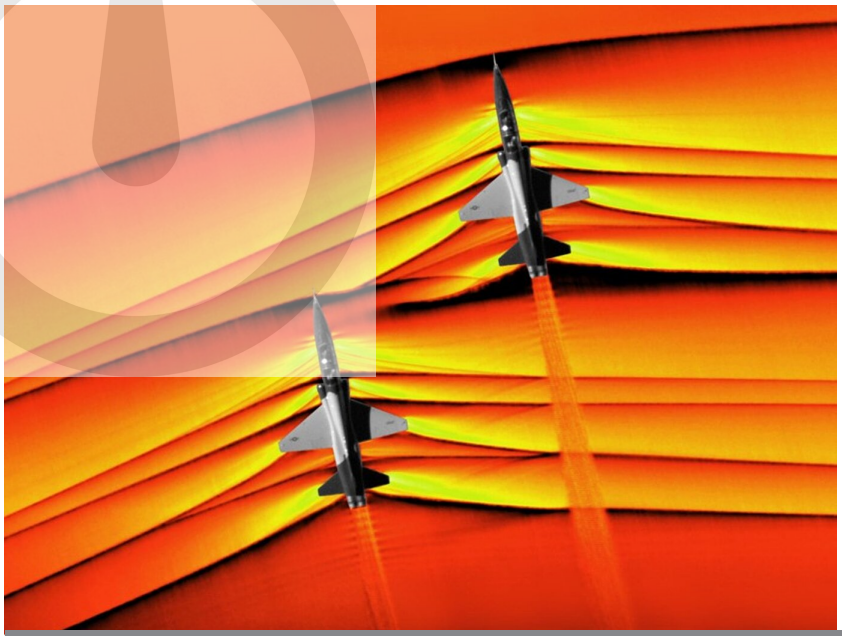
Visualization of (e.g., mask systems, clean room air flows) and diagnostic imaging of air flows or fluid flows



National Aeronautics and Space Administration

TECHNOLOGY SOLUTION

Instrumentation

Digital Projection Focusing Schlieren System

LCD-integrated optical assembly for image-based flow visualization

Researchers at NASA have developed a compact LCD-integrated optical assembly that enables a research camera to (simultaneously) collect focusing schlieren and other image-based measurement data (e.g., particle tracking velocimetry (PTV), particle imaging velocimetry (PIV), temperature pr pressure sensitive paint measurements (TSP, PSP), or photogrammetry). The assembly was designed to enhance the capabilities of NASA's patented self-aligned, single grid projection focusing schlieren imaging system described in LAR-TOPS-348, and reduce the complexity and time required to perform multiple image-based measurement experiments. Typically, multiple imaging systems are required to collect focusing schlieren and other image-based measurement data. Additionally, conventional focusing schlieren imaging systems are only sensitive to a single density gradient. NASA's digital single-grid system leverages a programmable LCD as the grid enabling on-the-fly grid adjustments (or grid deactivation) to enable an unprecedented amount of experimental flexibility for image-based measurements.

BENEFITS

- Easy to use: The single grid design is inherently self-aligned 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.
- Multi-functional: The LCD element is programmable and can be changed on the fly to enable simple changes to density gradient sensitivity and simultaneous collection of multiple image-based measurements.
- Off-Axis imaging capability: The LCD grid can be rotated within the assembly enabling flexibility in the region of interest imag ed which is useful in wind tunnels where windows may be upstream or downstream of the object of interest.
- Compact: The optical assembly is small enough to be mounted like a lens in front of a camera for efficient use of space in cramped experimental environments such as wind tunnels.
- Vibration insensitive: The self-aligning nature of the instrument prevents grid misalignment issues

APPLICATIONS

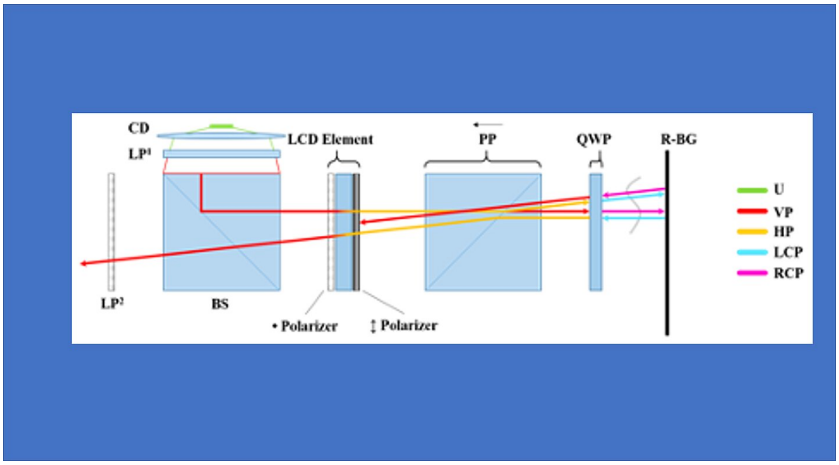
The technology has several potential applications:

- Aerospace: Flow visualization, aerodynamics and fluid dynamics R&D
- Manufacturing: Instrument to visualize gas flow or thermal flow imaging for additive manufacturing or semiconductor manufacturing processes

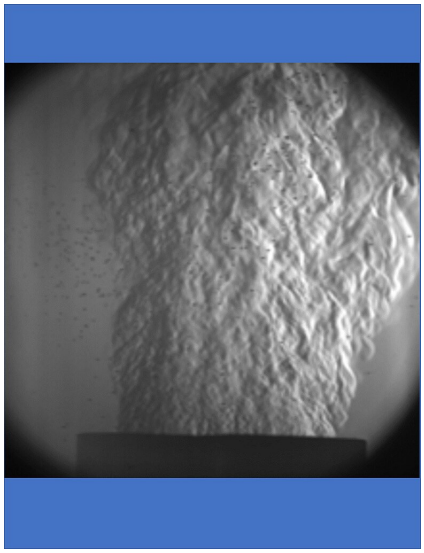
THE TECHNOLOGY

NASA's digital projection focusing schlieren system is attached to a commercial-off-the-shelf camera. For focusing schlieren measurements, it directs light from the light source through a condenser lens and linear polarizer towards a beam-splitter where linear, vertically-polarized component of light is reflected onto the optical axis of the instrument. The light passes through the patterned LCD element, a polarizing prism, and a quarter-wave plate prior to projection from the assembly as left- or right-circularly polarized light. The grid-patterned light (having passed through the LCD element) is directed past the density object onto a retroreflective background (RBG) that serves as the source grid. Upon reflection off the RBG, 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 slightly offset. This refracted light passes through the LCD element, now serving as the cutoff grid, for a second time before being imaged by the camera.

The LCD element can be programmed to display a variety of grid patterns to enable sensitivity to different density gradients. the color properties of the LCD can be leveraged in combination with multiple colored light sources to enable simultaneous multi-color, multi-technique data collection.



Simplified design of a compact, self-aligned digital projection focusing schlieren system. Colored lines represent different forms of light.



Simultaneous imaging system concept. On the left, particles and flow are visible when LCD grid-altered light is sampled. On the right only particles are visible when LCD-unaltered light is sampled.

PUBLICATIONS

Patent Pending

"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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LAR-19947-1, LAR-TOPS-349

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