A new portable, large field of view, schlieren camera system can be used to image air density gradients.

Density gradients in air—produced by plumes of hot or cold air, fumes from volatile organic compounds, or jets of compressed air—cause the refraction of light. The refracted light patterns can be observed using the classic schlieren (literally meaning ‘streak’) technique. Schlieren photography images the flow of fluids of varying density; however, although it was invented over a century ago and is an essential tool in flow visualization, few schlieren instruments are commercially available.

Classic schlieren instruments typically use a parabolic mirror to collimate light (make rays parallel) from a point-like light source, and a second mirror to refocus the light onto a knife edge. The region under test is positioned between the mirrors, where the transmitted light rays are parallel. Density gradients bend the light rays, thereby altering the amount of light blocked by the knife edge. Several aspects in the design of these instruments limit the field of view that can be achieved as well as their portability. Specifically, the field of view is limited by the size of the parabolic mirrors, which can be extremely expensive for large mirrors. In addition, the mirrors must be separated by long distances (usually ten times the mirror diameter), precise alignment of the mirrors and the knife edge is necessary, and isolation of the mirrors from external vibrations is usually required.

We have designed an innovative schlieren camera system that is based on existing technology, but is more portable. The focusing schlieren technique provides larger fields of view than are possible with the classic instruments. With this technique, air density gradients are detected by observing the apparent distortions in a background grid placed behind the test area. A lens focuses an image of this pattern onto a cutoff filter with a complementary pattern. Refraction of light by air density gradients in the test area alters the amount of light transmitted through the cutoff filter, which serves the same function as the knife edge in classic systems. The test area is imaged by a sensor that is placed behind the cutoff grid, with the lens aperture opened wide to minimize the depth of field, thereby blurring the grid lines in the cutoff filter.

The ability to selectively focus on a shallow zone is advantageous for many applications. The maximum field of view of focusing schlieren systems is much larger than classic schlieren systems of comparable cost. A focusing schlieren system capable of imaging test areas as large as 2 × 3m has been built.

The large field of view makes it ideal for photographing airflows and fumes of interest in the air conditioning, heating, cooling, ventilation, and architectural design industries.

Rather than using a background screen with a fixed pattern, our new schliereenscope projects the pattern onto a retroreflective background screen using a source grid that is identical to the cutoff grid. The grids can be focused at different screen distances, giving the system increased flexibility. For applications that do not require high speed, video and images

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are recorded by a digital single-lens reflex (SLR) camera. For high-speed applications requiring short exposures, the test area is illuminated by a pulsed flash lamp and images are captured by a scientific CCD camera.

Our schlierenscope can view test areas as large as $1.5 \times 1.0 \text{m}$ and has been used to capture striking schlieren images of heat rising from cookers, air sinking around ice, gasoline fumes, Mach diamonds, and turbulence in air jets as well as shock waves around supersonic projectiles. Figure 1 shows a schlieren image captured using our instrument of a supersonic projectile penetrating a target, clearly showing the complex array of shock waves and air flow associated with the event.

Compared with classic schlieren systems, our schlierenoscope is more portable, requires simpler assembly, and is easier to use. All of the instrument’s critical components are mounted on a small platform and the system is focused using a few simple controls. Although the system requires a background screen, its alignment is not critical. The system is sufficiently small and rugged to be shipped and to be set up in remote locations by one person. The camera can be made ready for use within about 15 minutes by a non-expert with only a small amount of training. We are currently working with NASA to develop a high-speed version of our system, as well as developing other instrument models that are even more portable.

**Author Information**

**Drew L’Esperance**

MetroLaser Incorporated

Laguna Hills, CA

Drew L’Esperance received his PhD in physical chemistry from the University of California, Riverside. He has been a senior scientist at MetroLaser since 2001.

**References**

