A. DAVIDHAZY, RIT = Rochester Institute of Technology, offers engineering and BS through PhD in Imaging Science.

Last minute project: Toys video

SHADOWGRAPH

Growth of vortices on an accelerated plate. Spark shadowgraphs show the history of a 3-inch square plate in air, accelerated from rest to 24 ft/s. The sharp edge of the plate is initially opposite the front of a source of preequipped 1/4 inch apart. The motion is initially vertical, and the flow is visualized by painting a narrow band of benzene across the center of the balsa-wood plate, so that when the plate accelerates benzene vapor is drawn into the vortex sheet. The difference in density between the vapor and the air makes the path of the boundaries visible. Care was taken to ensure that the undulations observed in the vortex sheet were not caused by vibrations of the model. Pencé 296.
Mach 1.1, full size T-38 in flight, 1993. L. Weinstein, NASA 
example of Background Oriented Schlieren (BOS). Correlate patterned 
background from image to get schlieren

How it works:

\[ n = \frac{c_{\text{vacuum}}}{c_{\text{material}}} \]

\( n \) = index of refraction
Light is deflected towards more dense medium

Collimated Light

\[
\frac{dn}{dy} < 0 \quad \frac{dn}{dy} > 0
\]

Figure 1. Disturbance in Collimated Beam

\[ \frac{1}{n_1} = \frac{1}{n_2} \]

curve of disturbed line

http://web.mit.edu/Edgerton/www/schlieren5.html

\[ \theta_1 \quad \theta_2 \]

Snell's Law

Air

Water

\[ \lambda \text{ is shorter} \]

Beam is slowed, turns into, i.e towards the denser medium

like a caustic sunlight

DARK BRIGHT

Water

http://web.mit.edu/Edgerton/www/schlieren5.html

Figure 2. The Refractive Index Gradient

Figure 3. Schlieren System with a Small Disturbance
Minute paper: What would camera see looking at parallel light, camera lens focused at infinity?

And in this case? No disturbance, no knife edge.

Now, deflect some of those light rays. Would add light in some areas, reduce it on others.

→ Shadowgraphy

Cut the deflected light with a knife edge (razor blade)

→ schlieren

By Foucault, 1859

schlieren: German noun, Not a name

\[
\frac{\Delta T}{T} = L \int_{\bar{z}} \left( \frac{x^2}{k_x^2} + \frac{y^2}{k_y^2} \right) (\ln \eta) \, d\bar{z}
\]

Shadowgraph, sensitive to 2nd derivative of \( \eta \)


Relative light intensity at exit. Light propagates in \( Z \) integrated along line of sight. Drawback for looking at 3-d phenomena.
propagates in $Z$ direction

Looking at 3-d phenomena

Similar math for schlieren, is sensitive to first derivative; to gradients in temperature.

Variants:

Z fold with mirrors; saves space. Want space between mirrors to be 3 x f
Gas Dynamics lab at Penn State University
Prof. Gary Settles, author of

_Schlieren & Shadowgraph Techniques, Corrected._
(Springer, 2001).

[file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\MiscImages\Settles\SchlierenVisit\DSC_0324.AVI] My visit in March

BOS = Background Oriented Schlieren

Uses patterned background instead of mirror, any random lighting. View of background will be distorted by field. Take two images and do cross correlation, like PIV.