23.IndexOfRefraction2

Monday, November 14, 2016   7:50 AM

Today: Refractive Index Methods

- Need help with final show (Dec 9) setup and cleanup, at least two people each.

Shadowgraphy:
constructive and destructive interference from disturbed parallel light

schlieren:
Selectively remove constructive or destructive interference from disturbed parallel light.
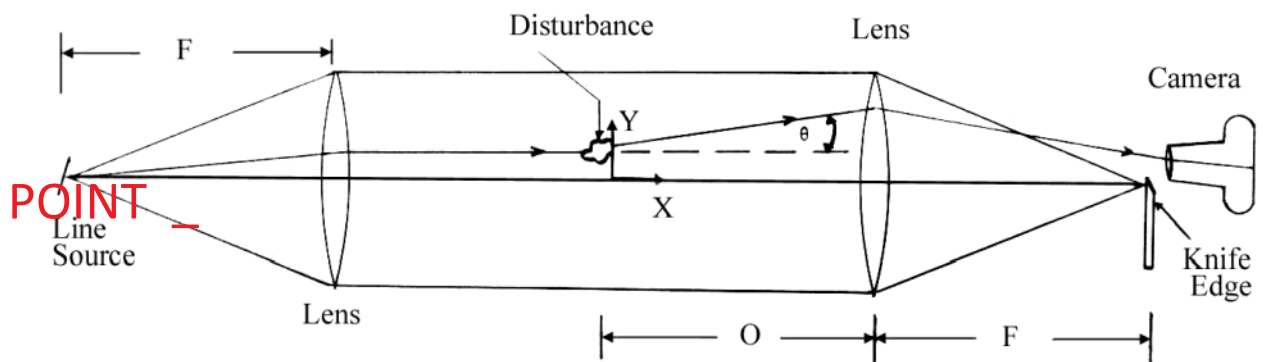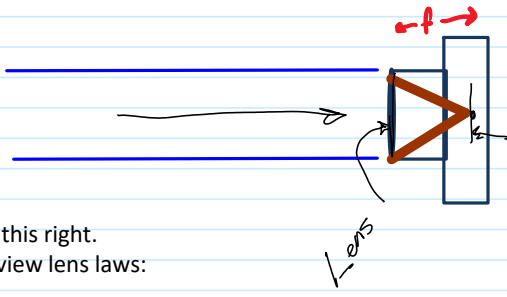Higher contrast, controlled sensitivity to gradient directions
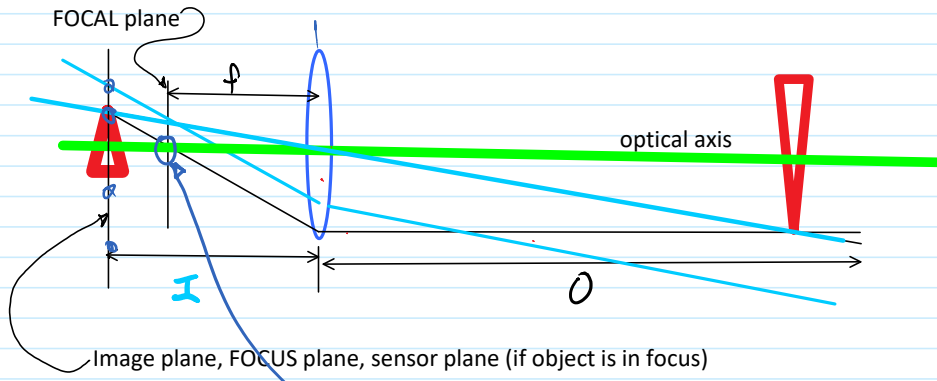

Figure 3. Schlieren System with a Small Disturbance

Minute paper: What would camera see looking at parallel light, camera lens focused at infinity?
Hint: what light sources do you know that emit parallel light? What do they look like?

$\leftarrow f \rightarrow$

lens

1/2 got this right.
Let's review lens laws:

FOCAL plane

f

optical axis

I

O

Image plane, FOCUS plane, sensor plane (if object is in focus)

Lens Laws

1) light through center of lens is undeflected
2) light parallel to axis goes through focal *point*   ≠ focus point
3) all light entering lens at a given direction ends up at the same point in the *focal* plane (**not** *focus* plane)
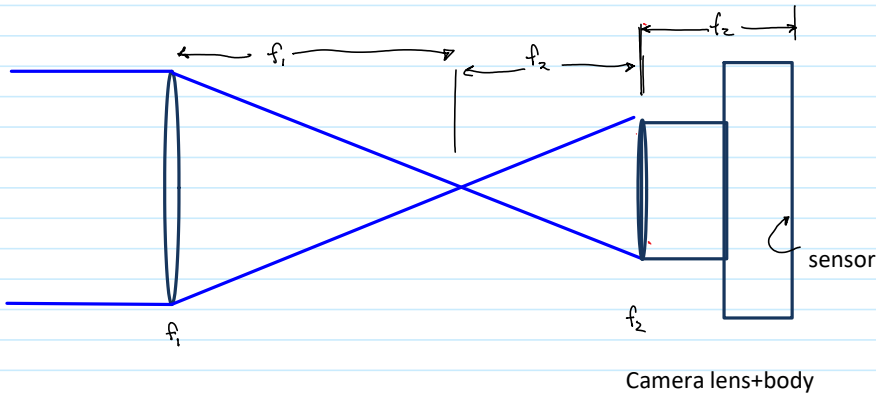
Focus equation

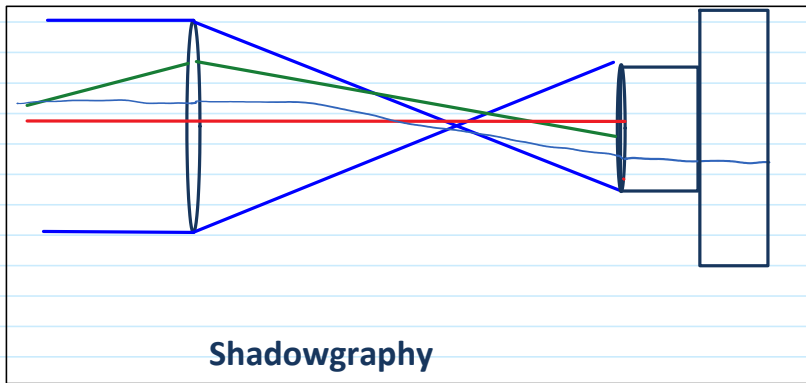$$\frac{1}{f} = \frac{1}{O} + \frac{1}{I}$$

f = focal length
O = dist. lens → object
I = dist. lens → image (sensor)

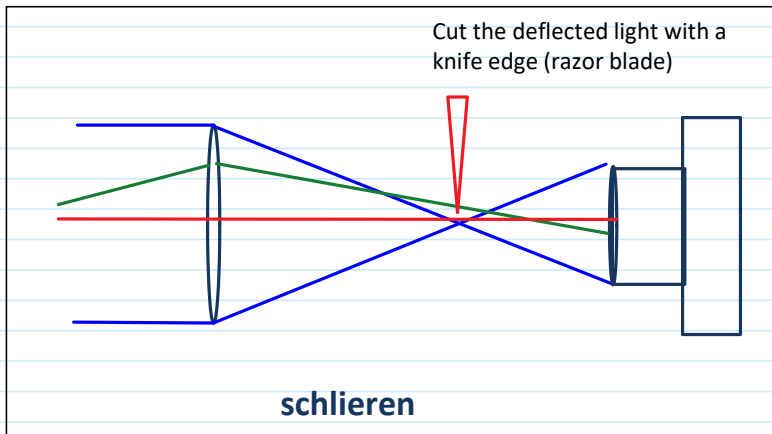Minute paper, groups: 1) Where is lens relative to sensor when focus is at infinity?

Back to schieren and shadowgraphy: What does the camera see in this case? No disturbance, no knife edge

f_1 f_2 f_2

f_1 f_2 sensor

Camera lens+body

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

Shadowgraph Equation

Shadowgraph, sensitive to 2nd derivative of η

$$\frac{\Delta I}{I} = l \int_{z_1}^{z_2} \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} \right) (\ln \eta) \, dz$$

Relative light
intensity at exit.
Light propagates
in Z direction

Integrated along line of sight. Drawback for
looking at 3-d phenomena

Ref:
1. Wolgang Merzkirch, *Flow Visualization, Second Edition*,
   2nd ed. (Academic Press, 1987).

Similar math for schlieren, is sensitive to first derivative; to gradients in temperature.
Has higher contrast, visibility; deflected light is not adding to or confusing light field.

Variants:
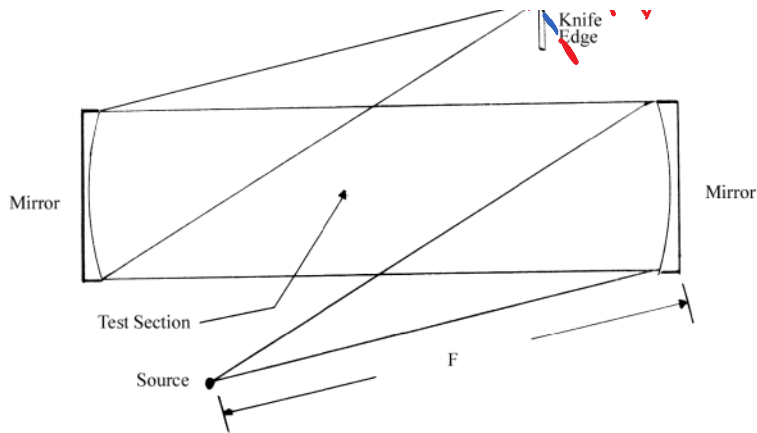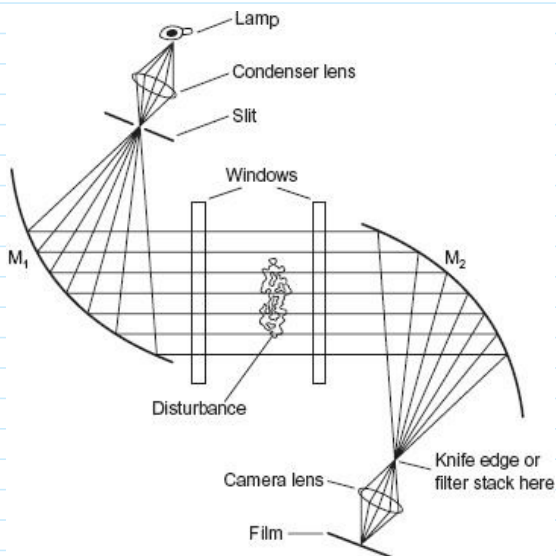
razor blade or colored transparency

Knife
Edge

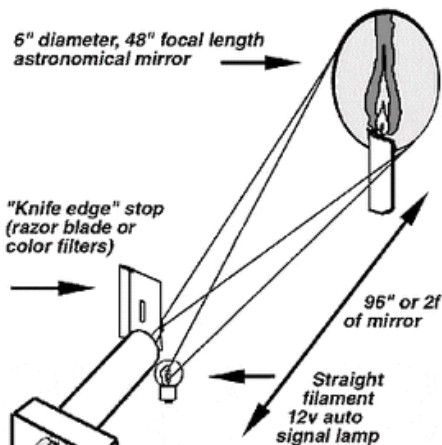Figure 7. Mirror System

Z fold with mirrors; saves space, cost. Want space between mirrors to be 3 x f

Either spherical or parabolic mirrors work.

Single mirror system

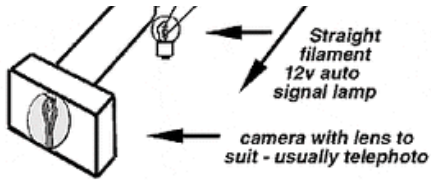Straight
filament
12v auto
signal lamp

camera with lens to
suit - usually telephoto

Pasted from
<http://www.ian.org/Schlieren/SchlierenDiagram.png>

2x Focal Length

Camera   Filter

Point Light
Source

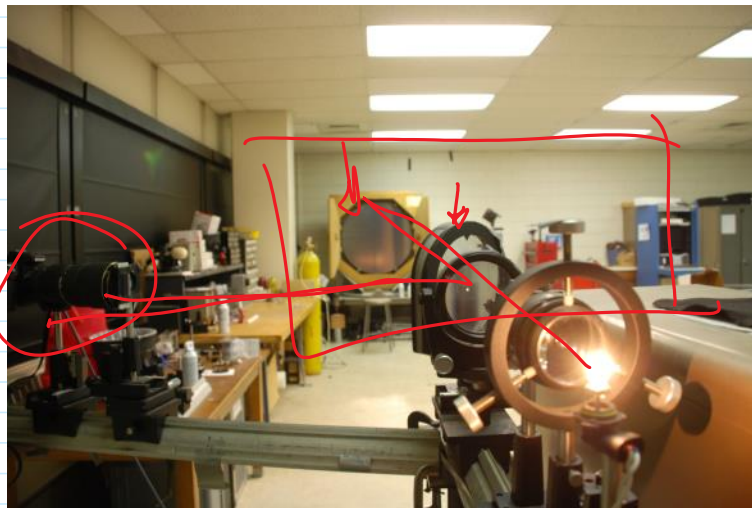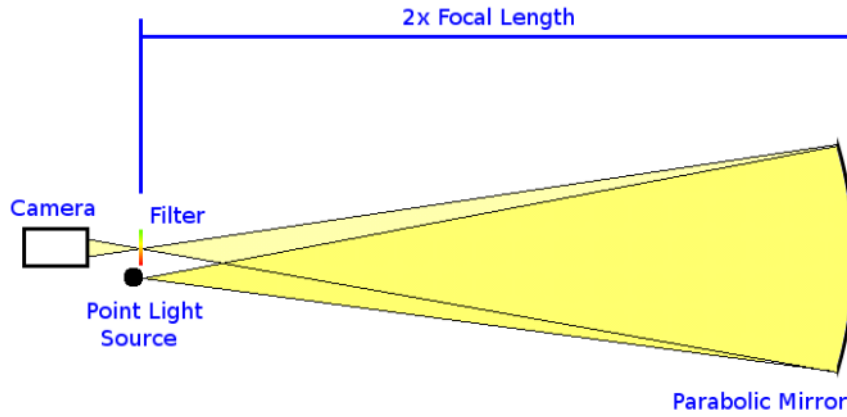Parabolic Mirror

Gas Dynamics lab at Penn State University
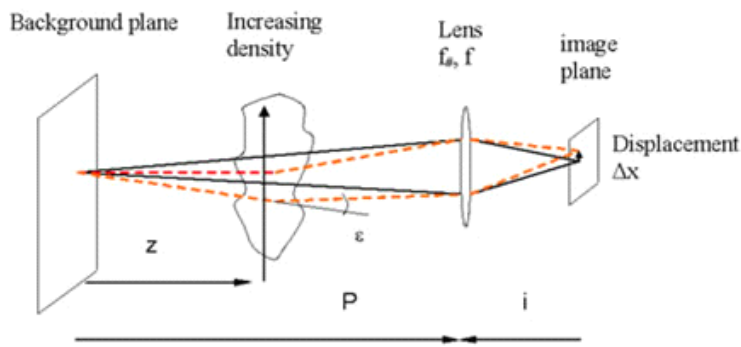Prof. Gary Settles, author of

Schlieren & Shadowgraph Techniques, Corrected. (Springer, 2001).

<file://C:\Users\hertzber\Documents\01CLASSES\FlowVis\MiscImages\Settles\SchlierenVisit\DSC_0324.AVI> My visit in March 2011

BEAM SPLITTER

BOS = Background Oriented Schlieren

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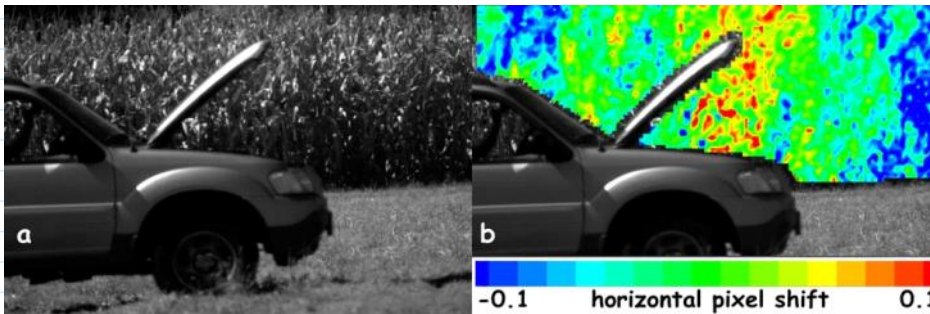

Background plane   Increasing
density

Lens
f_a, f

image
plane

http://www.mne.psu.edu/psgdl/Res-Optical.html

The thermal plume generated from a hot truck engine is visualized against a background of corn. The (a) original image is compared to one recorded 7 ms later to determine the (b) horizontal pixel shift. The contour plot of horizontal pixel shift in a BOS image is optically equivalent to a vertical knife-edge cutoff in traditional schlieren.

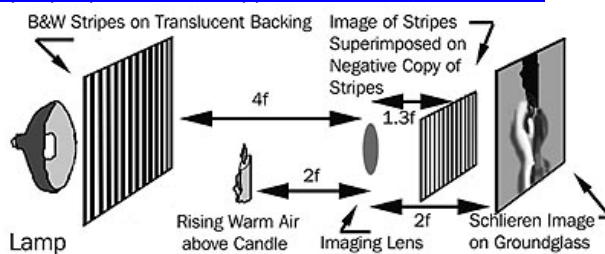Pasted from <http://www.mne.psu.edu/psgdl/Res-Optical.html>

Hargather, Michael, and Gary S. Settles. "BACKGROUND-ORIENTED SCHLIEREN VISUALIZATI ON OF HEATING AND VENTILATION FLOWS: HVAC-BOS. Paper 266." In *ISFV14 - 14th International Symposium on Flow Visualization*, 1–8. EXCO Daegu, Korea, 2010.
Hargather, Michael John, and Gary S. Settles. "Natural-background-oriented Schlieren Imaging." *Experiments in Fluids* 48, no. 1 (January 1, 2010): 59–68. doi:10.1007/s00348-009-0709-3.

Focusing schlieren

http://people.rit.edu/andpph/text-schlieren-focus.html

Now, an even simpler method, using an encoded light field:
Light Field Back-

ground Oriented Schlieren Photography (LFBOS)
http://www.cs.ubc.ca/nest/imager/tr/2011/LFBOS/