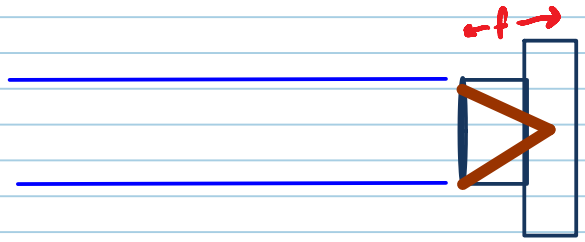
18.IndexOfRefraction2

Wednesday, April 21, 2010
8:50 AM

Still need help with setup and cleanup, at least two more people each. Will re-send doodle poll.

Minute paper: What would camera see looking at parallel light, camera lens focused at infinity?



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

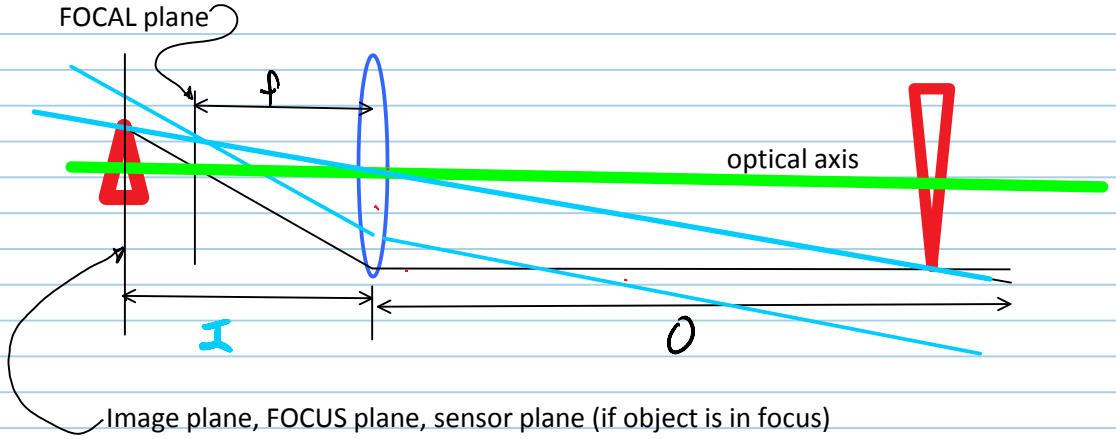


Image plane, FOCUS plane, sensor plane (if object is in focus)

Lens Laws

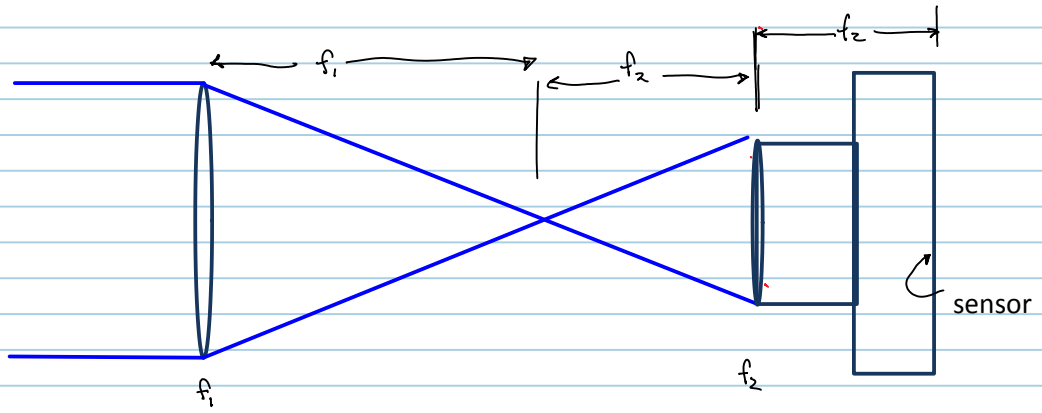
1) light through center of lens is undeflected
2) light parallel to axis goes through focal *point*
3) all light entering lens at a given direction ends up at the same point in the *focal* plane (**not** *focus* plane)

Focus equation

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

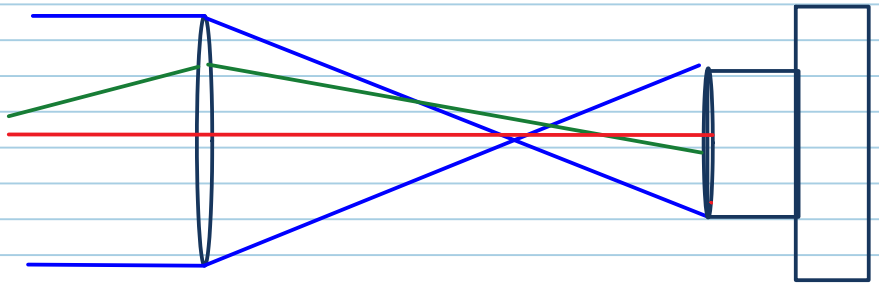
Minute paper, groups: 1) Where is lens relative to sensor when focus is at infinity?

2) What does the camera see in this case? No disturbance, no knife edge



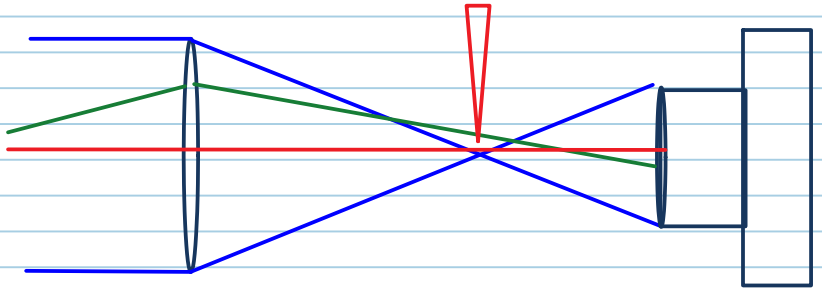
Camera lens+body

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.

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

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:

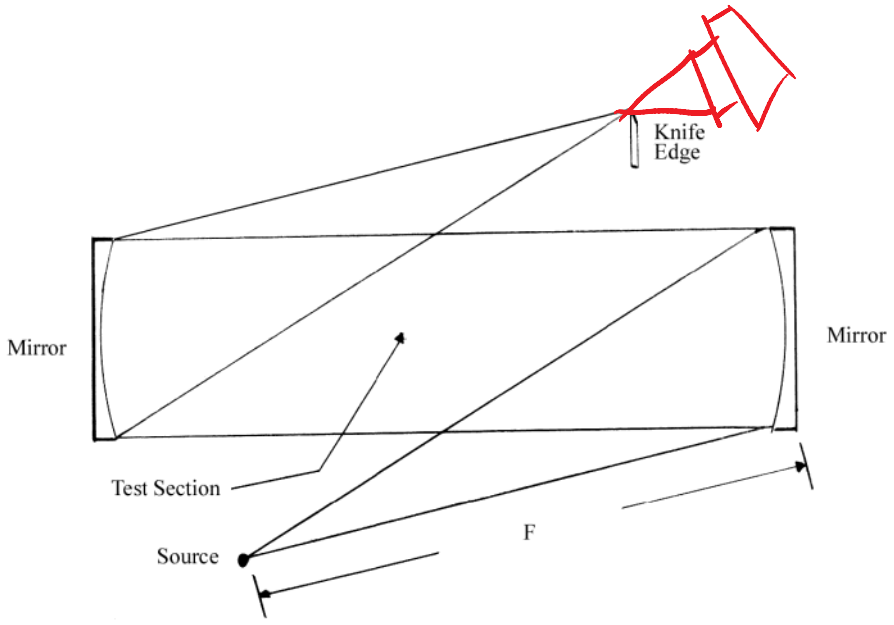
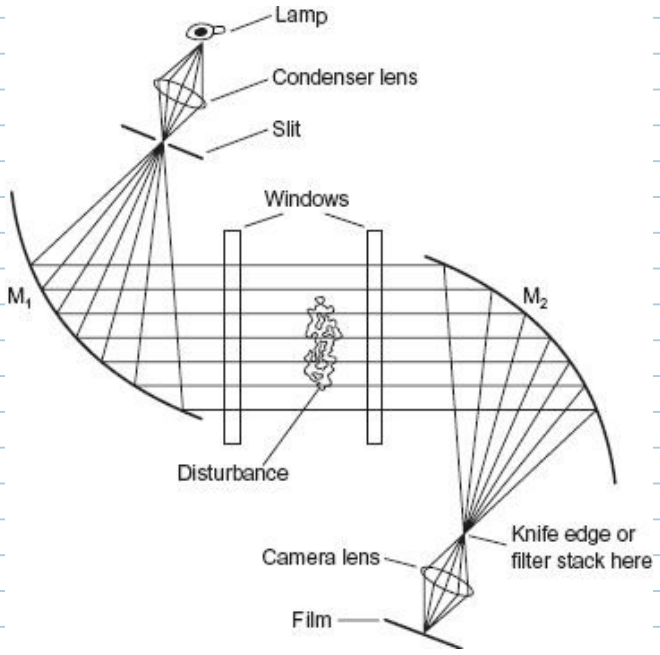


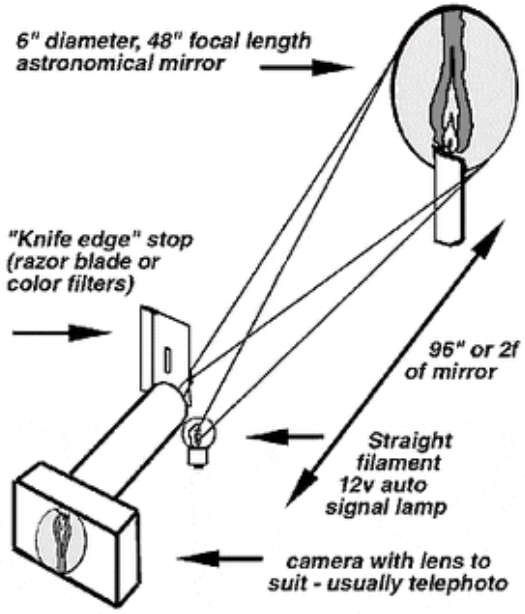
Figure 7. Mirror System

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

Either spherical or parabolic mirrors work.

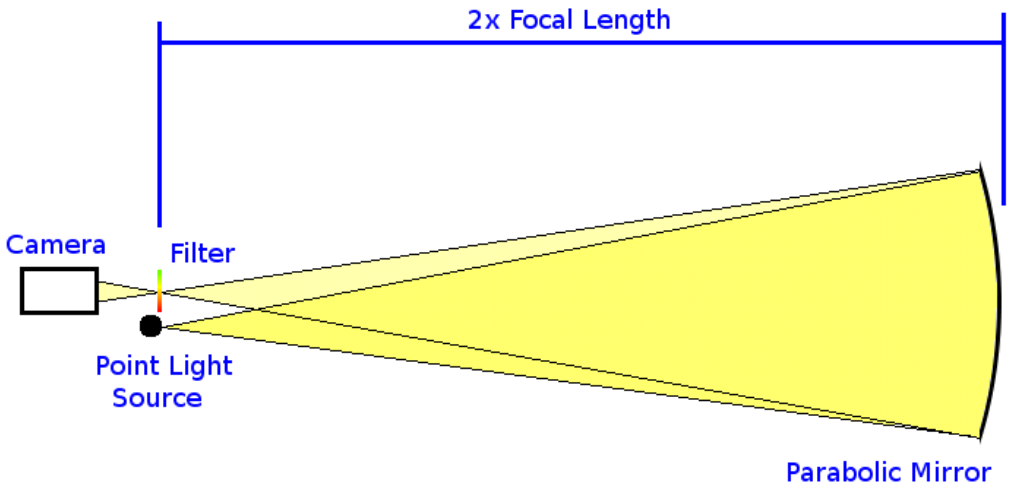


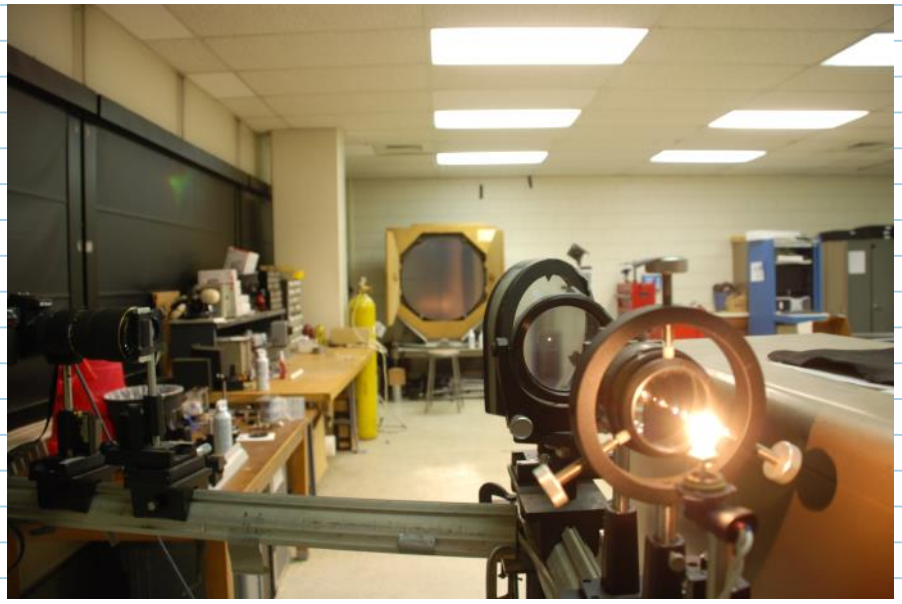
Pasted from <http://2.bp.blogspot.com/_JUESvkRXuK0/SQZ0JdkMBAI/AAAAAAAABPk/OGvKULVzNJ4/s320/schlieren.gif>



Single mirror system

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





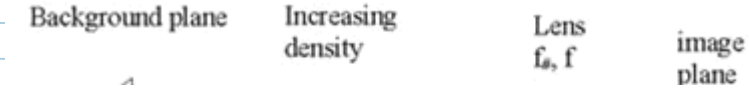
Gas Dynamics lab at Penn State University
Prof. Gary Settles, author of

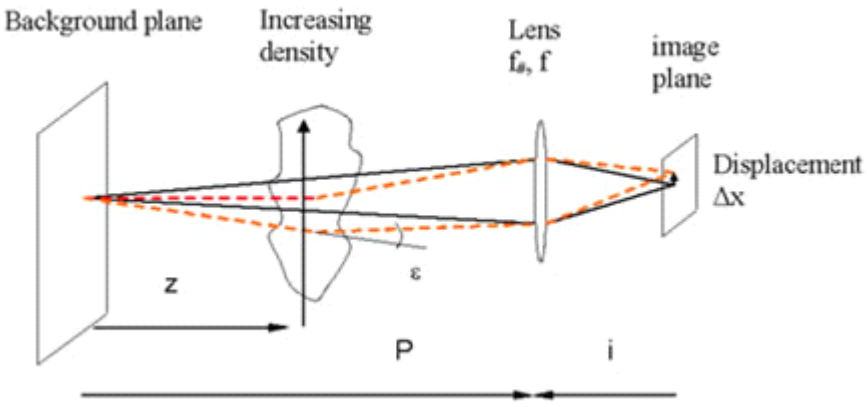
Schlieren & Shadowgraph Techniques, Corrected. (Springer, 2001).

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

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.



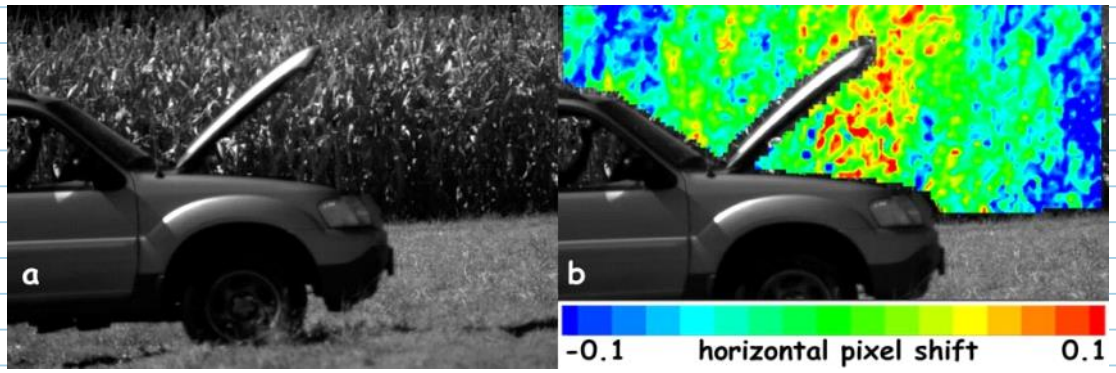


http://www.dlr.de/as/en/desktopdefault.aspx/tabid-183/251_read-2726/

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>

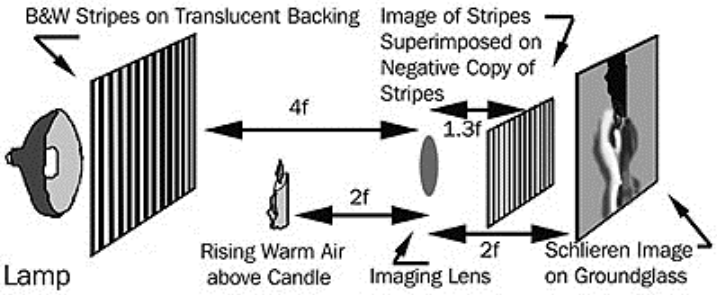


Hargather, Michael, and Gary S. Settles. "BACKGROUND-ORIENTED SCHLIEREN VISUALIZATI ON OF HEATING AND VENTILATION FLOWS: HVAC-BOS. Paper 266." In *ISFV14 - 14th International Symposium on Flow Visualization*, 1–8. EXCO Daegu, Korea, 2010.

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 Background Oriented Schlieren Photography (LFBOS)

http://www.cs.ubc.ca/nest/imager/tr/2011/LFBOS/

Air-Water interface;
very large change in refractive index
Dip drip?