21.IndexOfRefraction

Wednesday, April 21, 2010 8:50 AM

Still need help with setup and cleanup, at least two more people each.
discussion of art and science/engineering

Discussion questions for Wednesday

1. What is art? How do you know if an image is artistic?
2. What is science? How do you know if an image is scientific?
3. How are art and science similar?
4. How are they different?
5. What is engineering? How does it fit in compared to art and science?
6. What is filmmaking or photography? How does it fit in compared to art, science and engineering)?

Discussion structure: In your groups, discuss.
Choose a scribe.
For each question, list answers (on paper, to hand in)
A) you agree on,
B) you disagree on

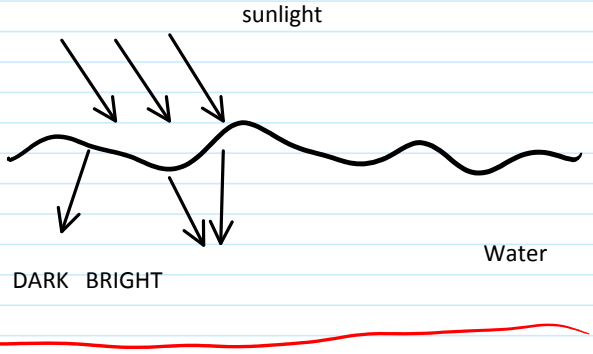
Then we will compare between groups.

Index of refraction techniques

Schlieren and shadowgraphy continued:

Shadowgraphy:

constructive and destructive interference from disturbed parallel light



Caustics; bright light network at bottom
of a swimming pool, hard to simulate

Schlieren:

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

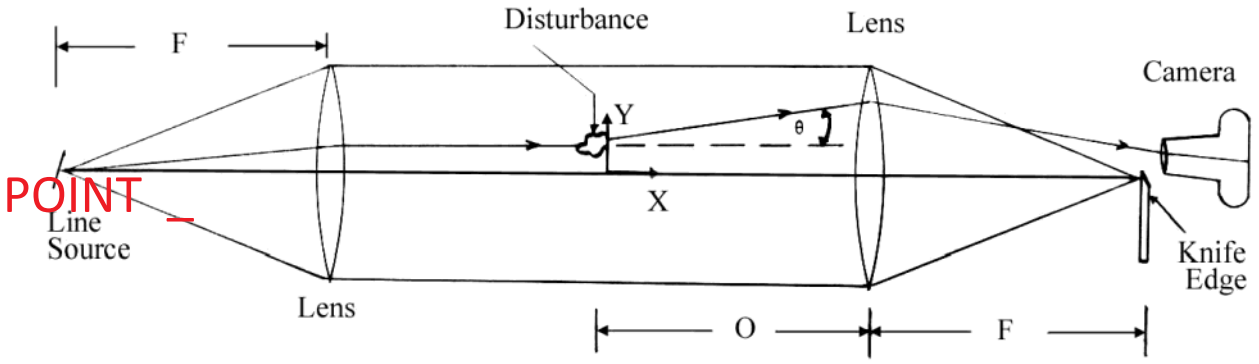
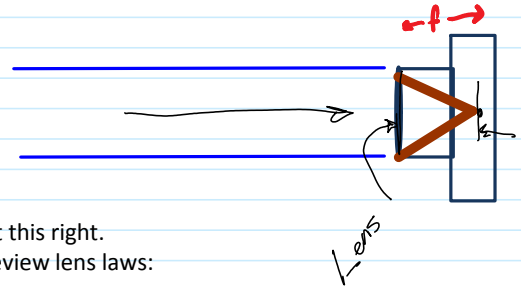


Figure 3. Schlieren System with a Small Disturbance

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?



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

FOCAL plane

Let's review lens laws:

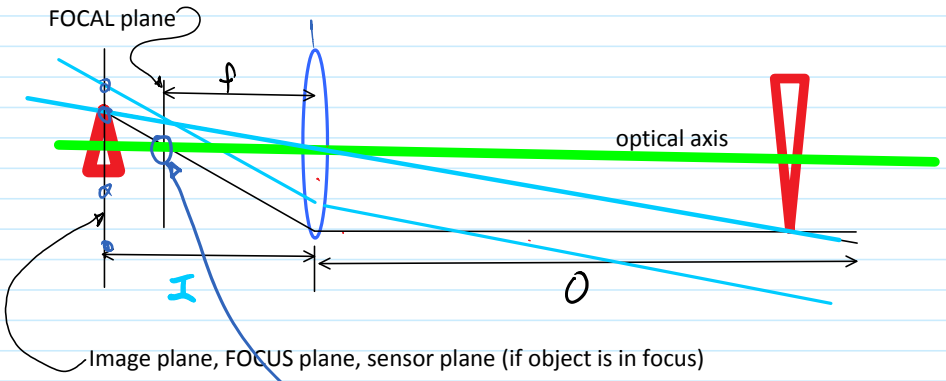


Image plane, FOCUS plane, sensor plane (if object is in focus)

Lens Laws

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

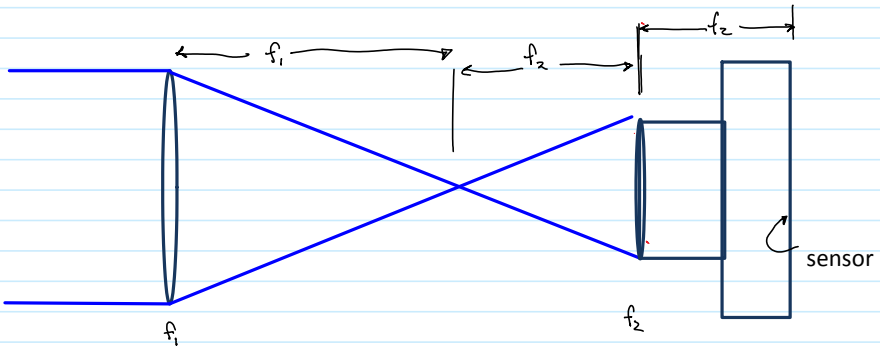
Focus equation

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

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

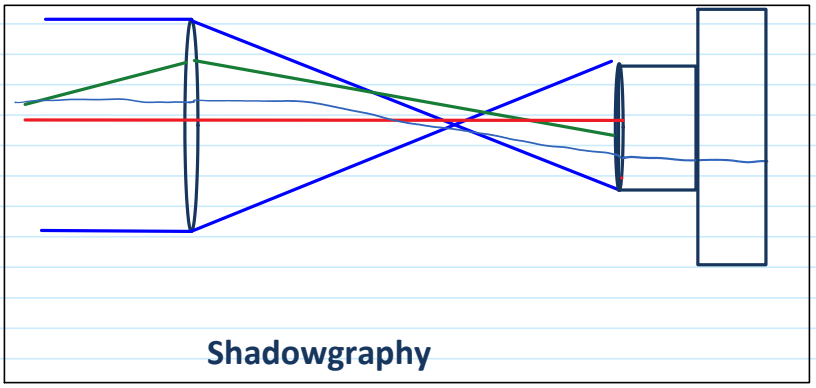
Minute paper, groups: 1) Where is lens relative to sensor when focus is at infinity?

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

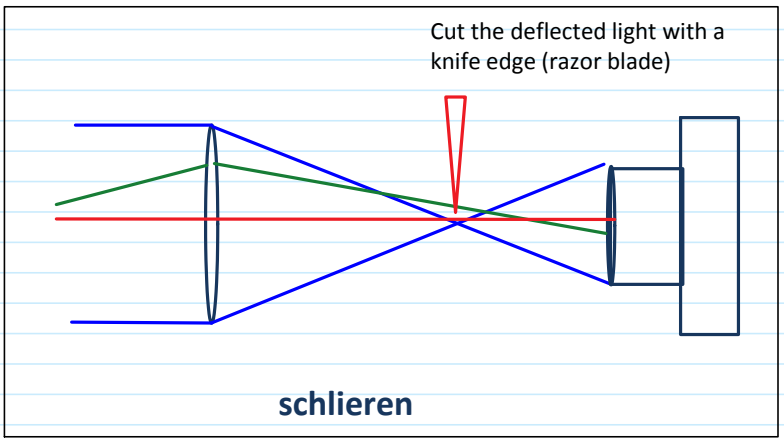


Camera lens+body

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



Shadowgraphy



schlieren

By Foucault, 1859

schlieren: German noun, Not a name

Shadowgraph Equation

Shadowgraph, sensitive to 2nd derivative of n

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

Relative light intensity at exit. Light propagates in Z direction

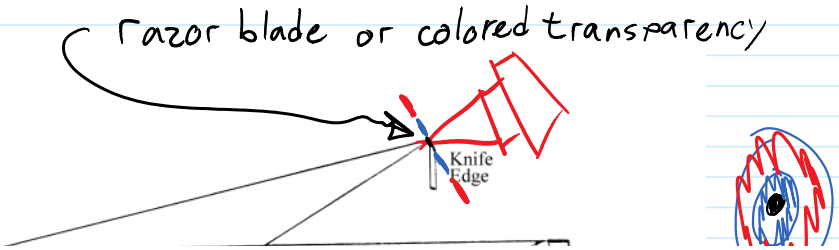
Integrated along line of sight. Drawback for looking at 3-d phenomena

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:



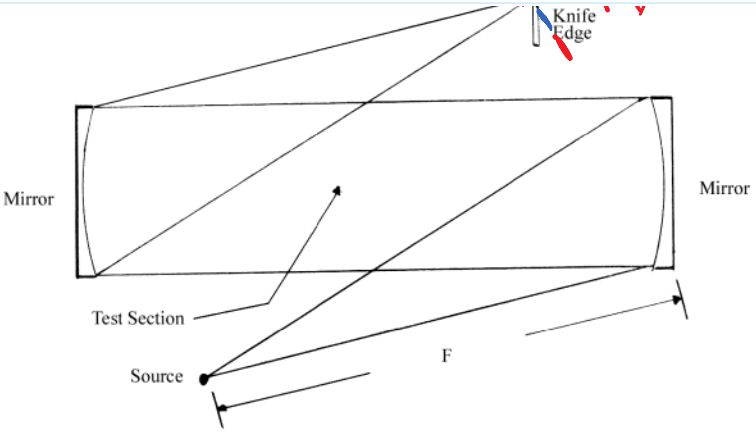
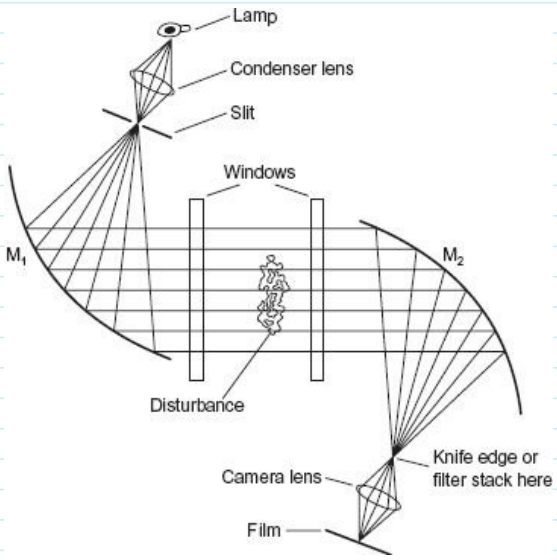


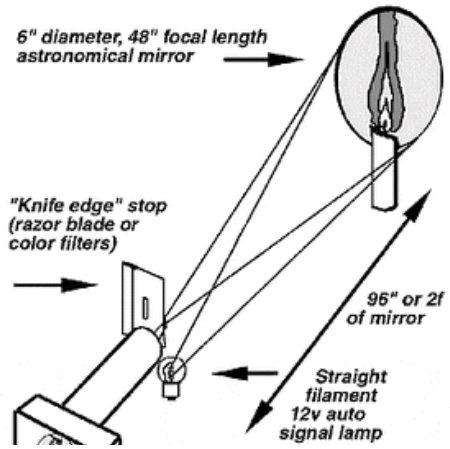
Figure 7. Mirror System

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

Either spherical or parabolic mirrors work.

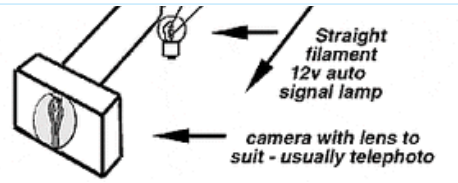


Pasted from <http://2.bp.blogspot.com/_JUESvkRXuK0/SQZ0JdkMBAI/AAAAAAAABPk/OGvKULVzNJ4/s320/schlieren.gif>

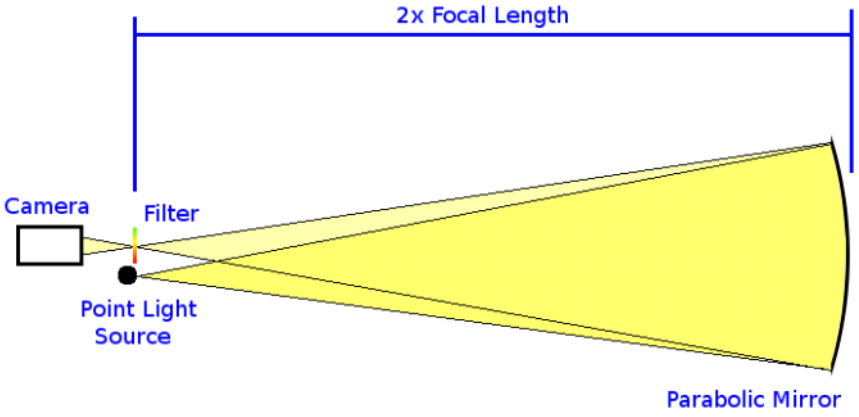


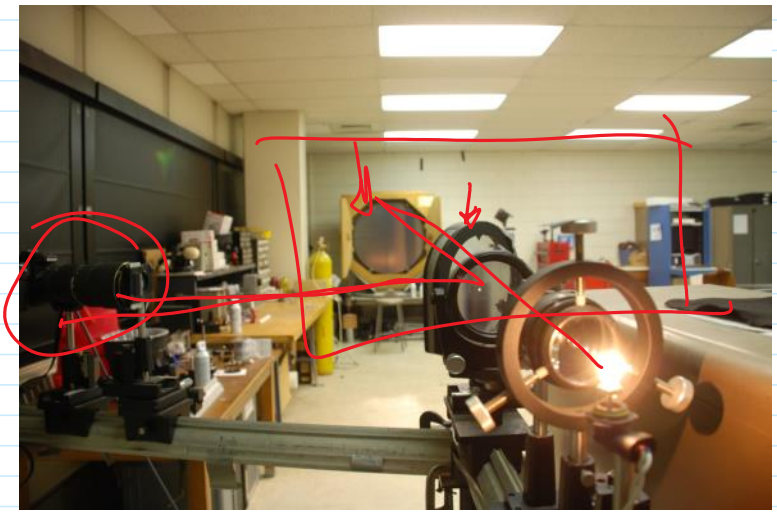
Single mirror system

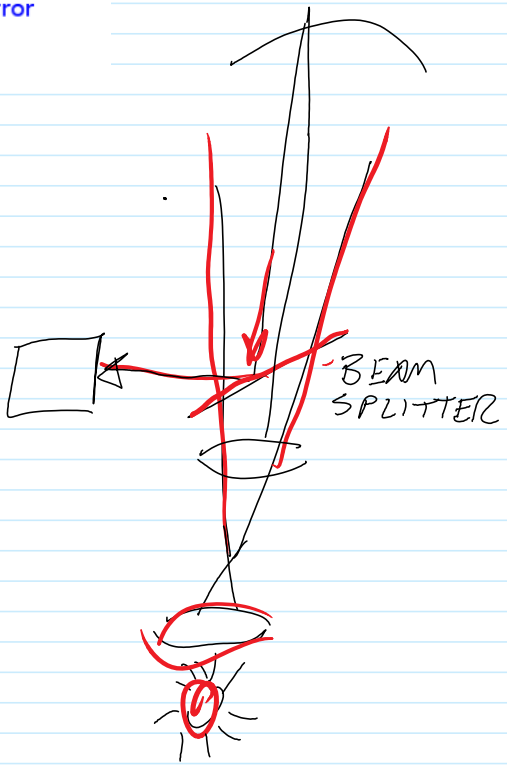
Pasted from <http://www.jap.org/Schlieren/S



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







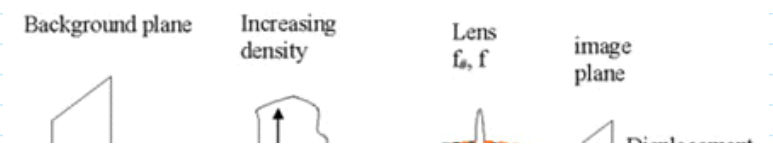
Gas Dynamics lab at Penn State University
Prof. Gary Settles, author of

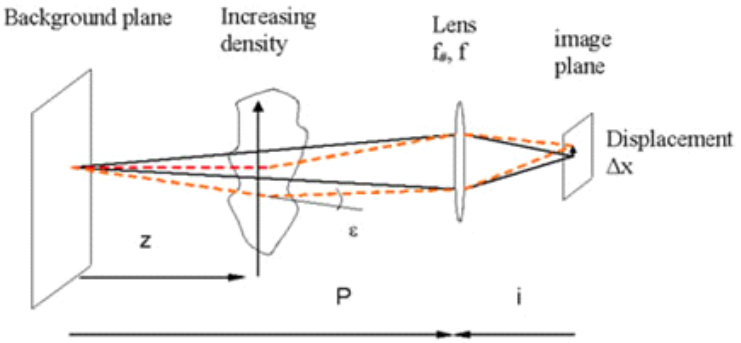
Schlieren & Shadowgraph Techniques, Corrected. (Springer, 2001).

<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.

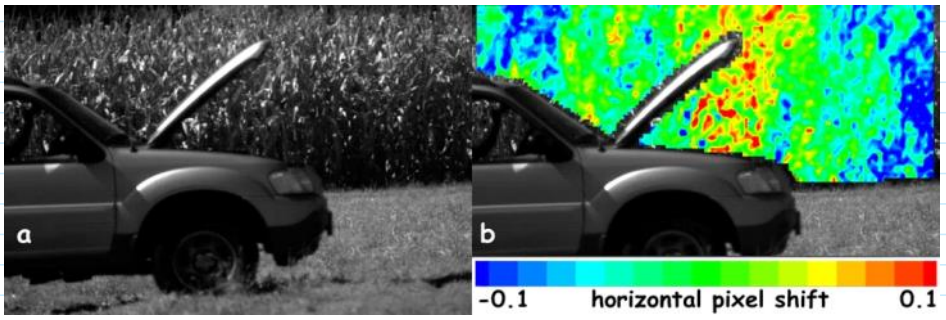




http://www.dlr.de/as/en/desktopdefault.aspx/tabid-183/251_read-2726/

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.

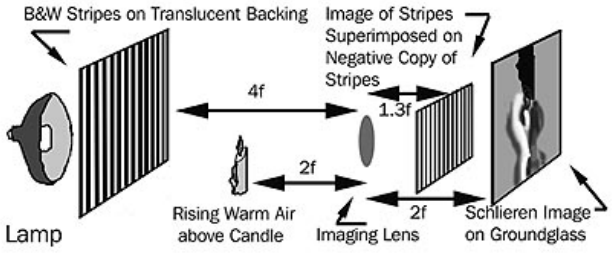
Pasted from <http://www.mne.psu.edu/psgdl/Res-Optical.html>



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 Back-

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