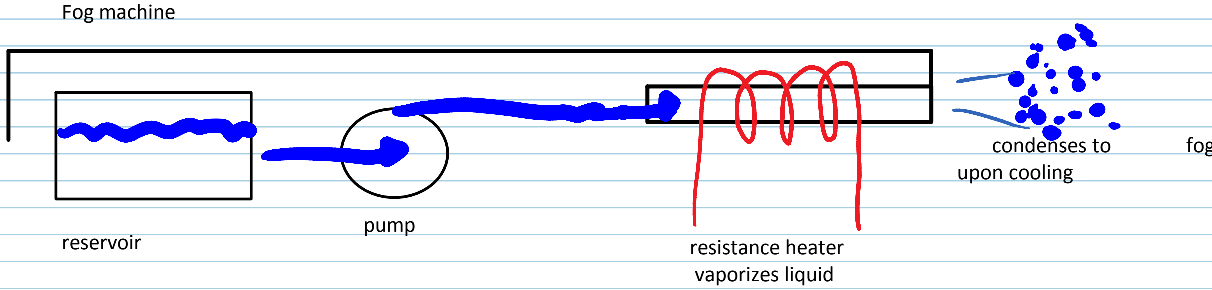
16.Particles2

Wednesday, April 17, 2013
3:26 PM

Last time: Particle generation in air: Smoke
Today:
Fog
Particle gen in water

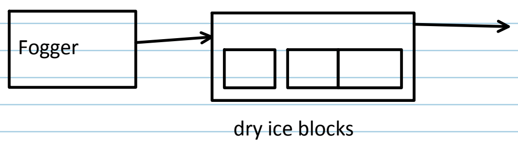
Stage fog = Water + glycerin or propylene glycol. Additive slows evaporation

Fog machine



Small machines: heater too small to run continuously. Buy at Target, 1 month before Halloween for $35.
Large machines: can run continuously. For professional stage and theaters. $1000. Mfg: Roscoe, Le Maitre. 1 gallon lasts 4 hr s.

Health effects are minimal, except to asthmatics and opera singers.

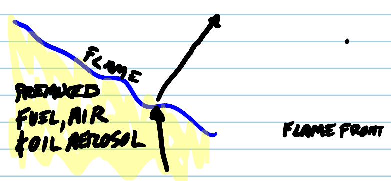


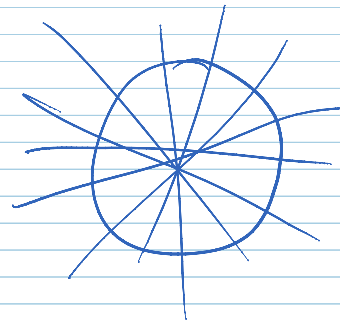
For fog-on-the-ground: chillers

C) Oil aerosols

Won't evaporate unless burned. Oil has low vapor pressure.
Use medical or Bernoulli atomizer/nebulizer

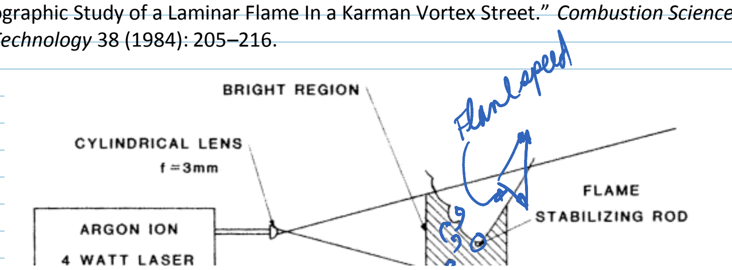
Can be used to mark flame fronts. Illuminate fog with a laser sheet = "laser tomography" in 1980s.





Danger! Oil aerosol will coat lungs ⇒ pneumonia ⇒ death

JEAN R. HERTZBERG, MEHDI NAMAZIAN, and LAWRENCE TALBOT. "A Laser Tomographic Study of a Laminar Flame In a Karman Vortex Street." *Combustion Science and Technology* 38 (1984): 205–216.



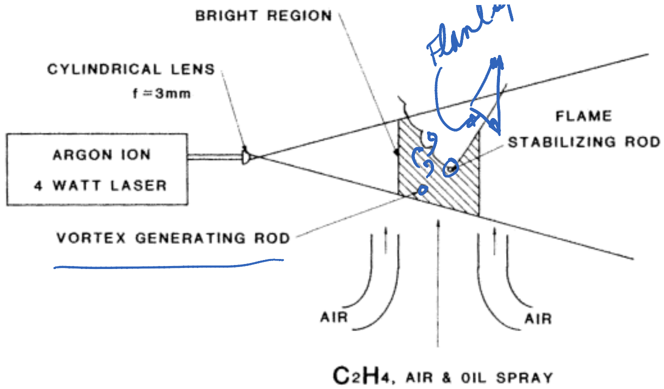


FIGURE 1 Experimental apparatus. The bright region is a cloud of oil droplets illuminated by the laser.

FIGURE 4 Example of tomography. Free jet, 1.2 m/s, issuing into stagnant room air.

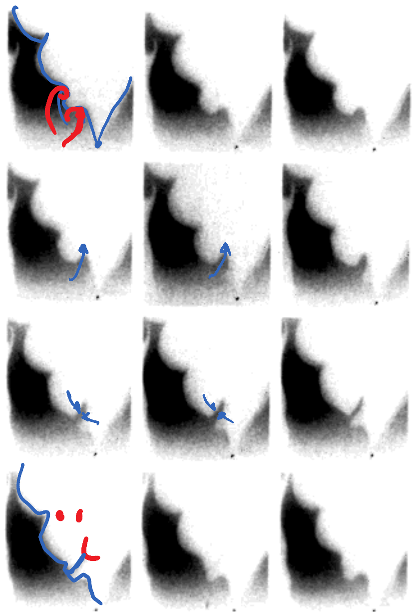
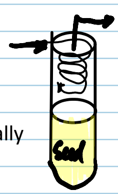


FIGURE 6 Example of tomography with combustion; from high-speed 16 mm film. The flame appears as the boundary of the dark V-shaped region. One complete cycle of interaction with vortex street is shown.

D) Dusts

AlO_2 = alumina, aluminum dioxide. Polishing powder, available in submicron diameters. Inexpensive. Won't burn; is already fully oxidized. Good for imaging individual particles in flames.
Aerosolize in a cyclone seeder:

Inject air tangentially



Large particles centrifuge to walls. Only small particles that track the flow can exit through the center. Like a Dyson vaccuum cleaner.

For heavy seeding, try a fluidized bed.

air injected below

Particles for Water

Hydrogen bubbles (discussed below)
Electrolytic precipitation

Rheoscopic fluids:
- Pearl Ex (art pigment, TiO_2 coated mica)
- Pearl Swirl (Steve Spangler Science)

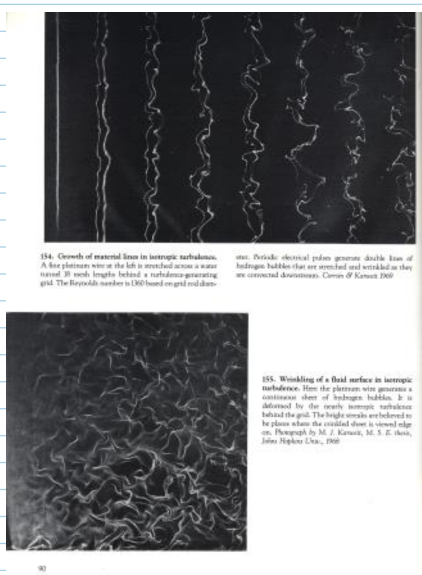
Kalliroscope: expensive Pearl Swirl
fish scales?
BLACKSTOCK

For individual particle images (PIV)

Corn starch (diluted)
Neutral buoyancy
Glass or polystyrene microspheres
Latex bubbles
neck pillow?
Rust (filtered)
Alumina
Wax beads (Pine Sol)

Pine pollen (floats on surface)
Lycopodium powder (also used as flash powder)
http://vimeo.com/89491724 Cymatics

Want neutral buoyancy, but for very small particles viscous forces are high. Can use up to 100 µm particles. Good scatterers.



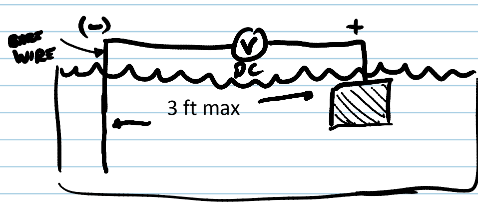
154. Growth of material lines in isotropic turbulence. A fine platinum wire at the left is stretched across a water tunnel 38 mesh lengths behind a turbulence-generating grid. The Reynolds number is 1360 based on grid rod diameter. Periodic electrical pulses generate double lines of hydrogen bubbles that are stretched and wrinkled as they are convected downstream. *Corrsin & Karweit 1969*

155. Wrinkling of a fluid surface in isotropic turbulence. Here the platinum wire generates a continuous sheet of hydrogen bubbles. It is deformed by the nearly isotropic turbulence behind the grid. The bright streaks are believed to be places where the crinkled sheet is viewed edge on. *Photograph by M. J. Karweit, M. S. E. thesis, Johns Hopkins Univ., 1968*

90

Van Dyke's Album of Fluid Motion

Hydrogen Bubbles



H2 bubbles
anode

O2 bubbles
cathode

large plate or pipe

Smallest H2 bubbles if wire is very thin. Bubbles = 1/2 to 1 wire diameter = 25 to 50 µm
Want small enough bubbles to track flow, and have a slow rise time, so < 100 µm needed.
Best if wire is platinum. Other wires oxidize, and don't provide a clean sheet of bubbles.

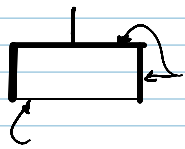
Minute paper: Why not use O2?

For same current, get half as much O_2
diffusivity
relative solubility
surface tension

Need 50 - 70 VDC, 1 amp minimum.
For long wires (200 mm) need 250 V, 2 amps
Expensive power supply.

The water must conduct well.
Add salt. Some refs say sodium sulfate is better than sodium chloride, table salt.
Weak acid or base would also conduct, but may eat wire.

Too much salt = bigger bubbles



Probe.
Insulate

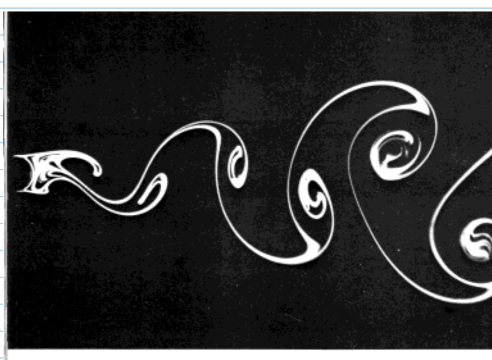
Pt wire, tight and smooth. Big bubbles form at kinks.

Any ions in the water are attracted to the electrodes, so material plates onto the electrodes, fouls the wire.
"Cleaning" = Reverse polarity briefly now and then for a few seconds

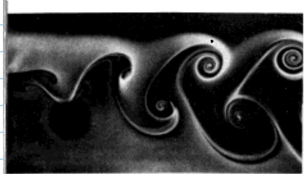
---

Electrolytic Precipitation Technique

- Same circuitry as H2 bubbles, but 10VDC, 10 mA. Much more reasonable requirements but....
  Tracer is electrolytically precipitated oxide at anode, of anode material.
  Metal often used = solder = tin+lead. Two heavy metals you don't want to put down the drain; needs 5 um filter.



94. Kármán vortex street behind a circular cylinder at R=140. Water is flowing at 1.4 cm/s past a cylinder of diameter 1 cm. Integrated streaklines are shown by electrolytic precipitation of a white colloidal smoke, illuminated by a sheet of light. The vortex sheet is seen to grow in width downstream for some diameters. *Photograph by Sadatoshi Taneda*



95. Kármán vortex street behind a circular cylinder at R=200. This photograph, made using a different fluid (and in another country) happens to have been timed so as to resemble remarkably the flow pattern in the upper picture. A thin sheet of tobacco smoke is introduced upstream in a low-turbulence wind tunnel. *Photograph by Gary Koopmann*

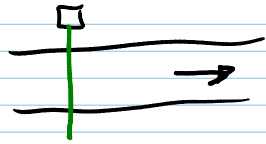
56

Latex Microbubbles.
If too dense, can be 'cooked' to expand to neutral buoyancy

Very expensive! $100 for a few grams worth.

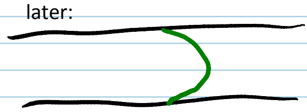
Molecular Tagging Velocimetry

Laser beam "uncages" dye along a beam line, which
then deforms with the fluid:



flow in a tube

later:



Many beams

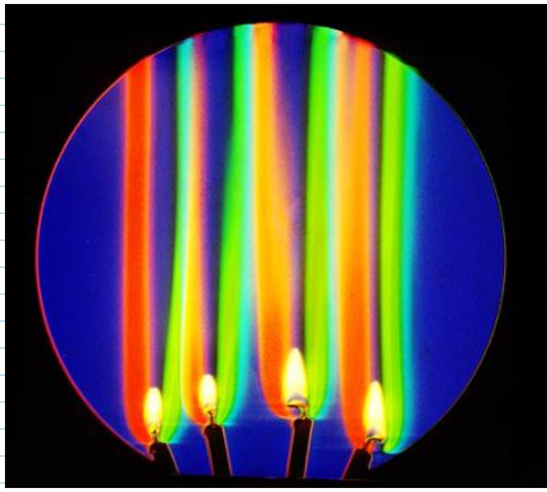
Can be quantified to measure
velocity field.

Dye is molecular, no seed problems.

http://www.egr.msu.edu/tmual/MTV.html

Index of Refraction Techniques
Requires no seed. Can visualize differences and gradients in temperature and chemical concentration,
as both change the index of refraction of the media.
Techniques discussed in detail: schlieren and shadowgraphy

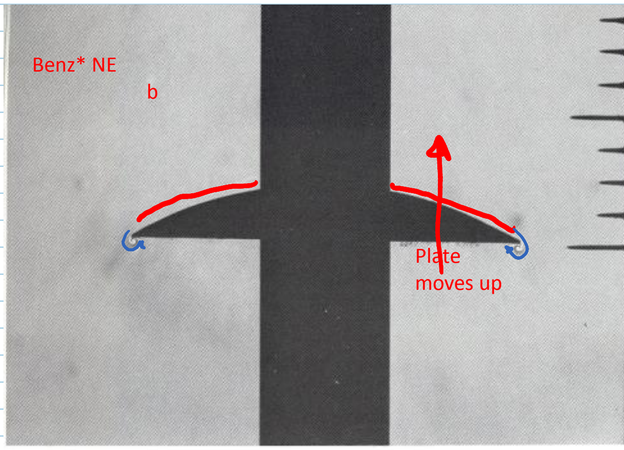
Color schlieren



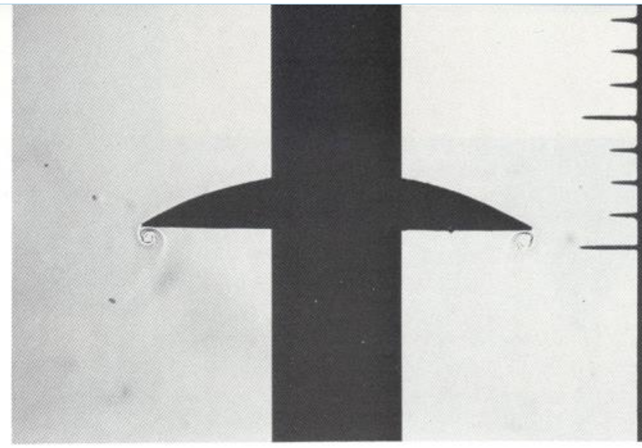
Pasted from <http://www.compadre.org/informal/images/features/schlierenlarge-11-29-06.jpg>

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

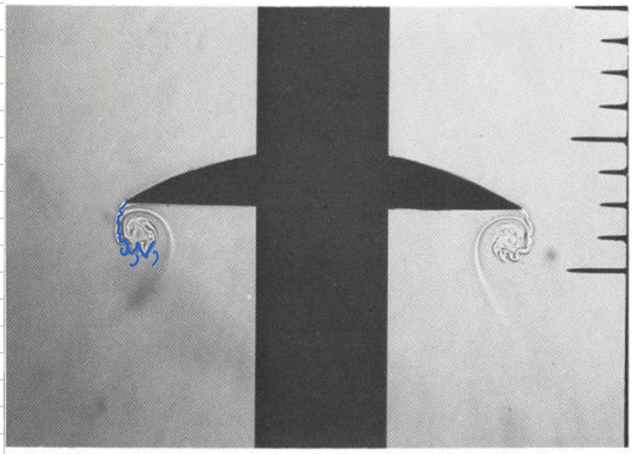
SHADOWGRAPH



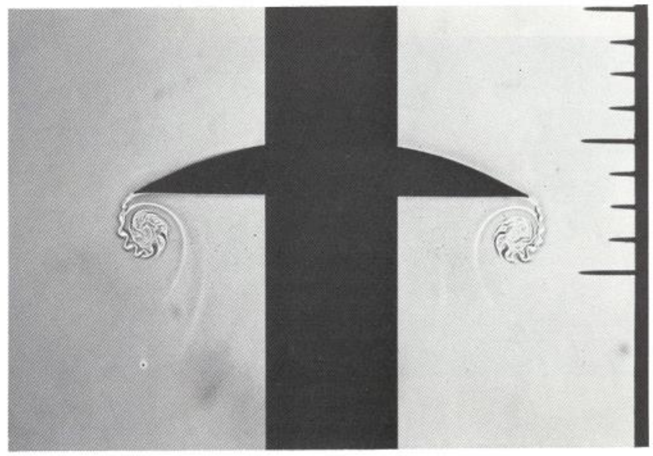
$t = 1.05$ ms, $v = 5.5$ ft/s



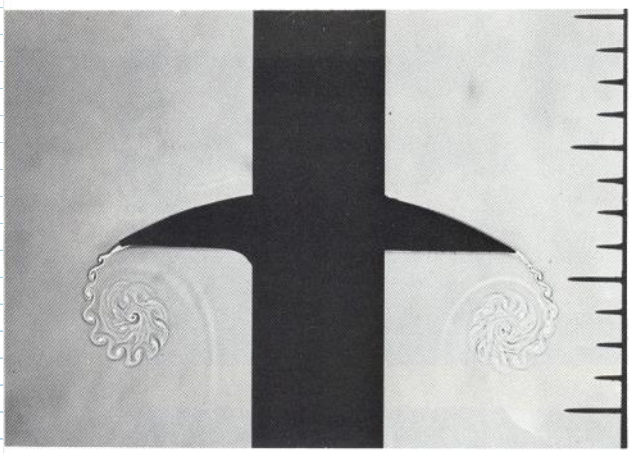
$t = 2.14$ ms, $v = 11.1$ ft/s



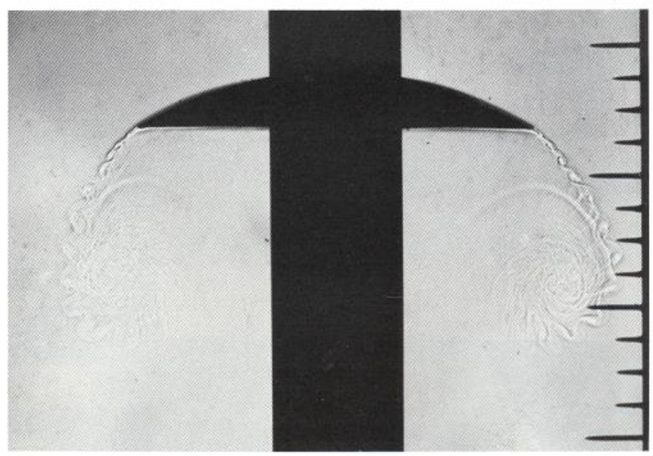
$t = 3.22$ ms, $v = 16.9$ ft/s



$t = 4.30$ ms, $v = 21.0$ ft/s

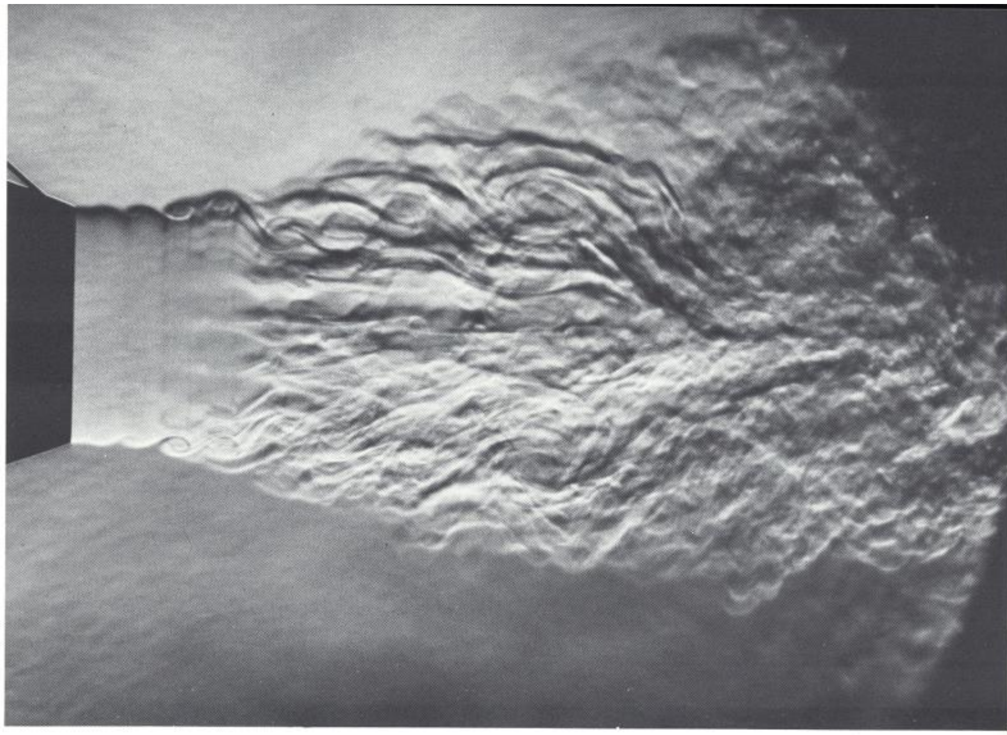


$t = 6.53$ ms, $v = 24.0$ ft/s

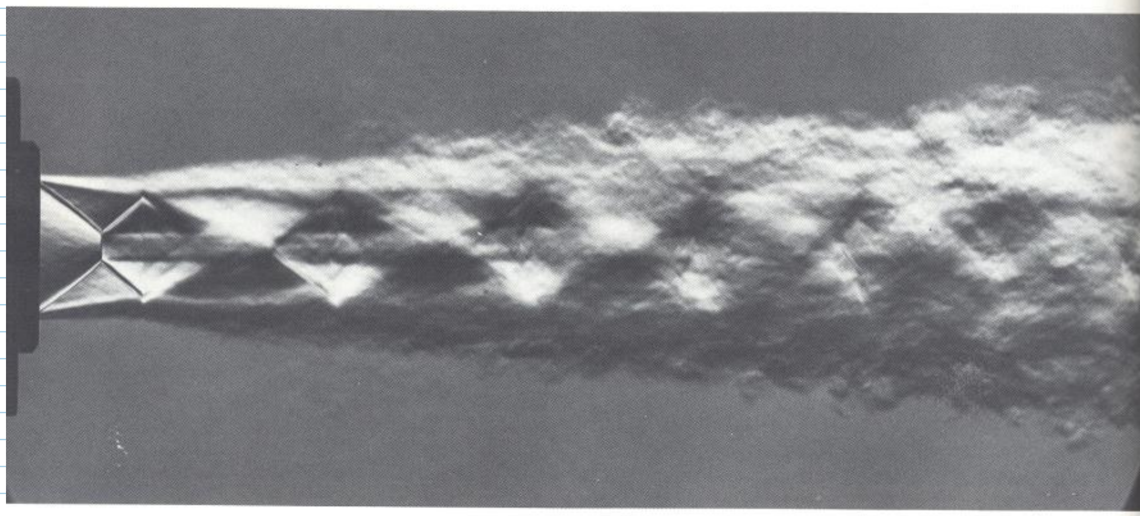


$t = 10.66$ ms, $v = 24.0$ ft/s

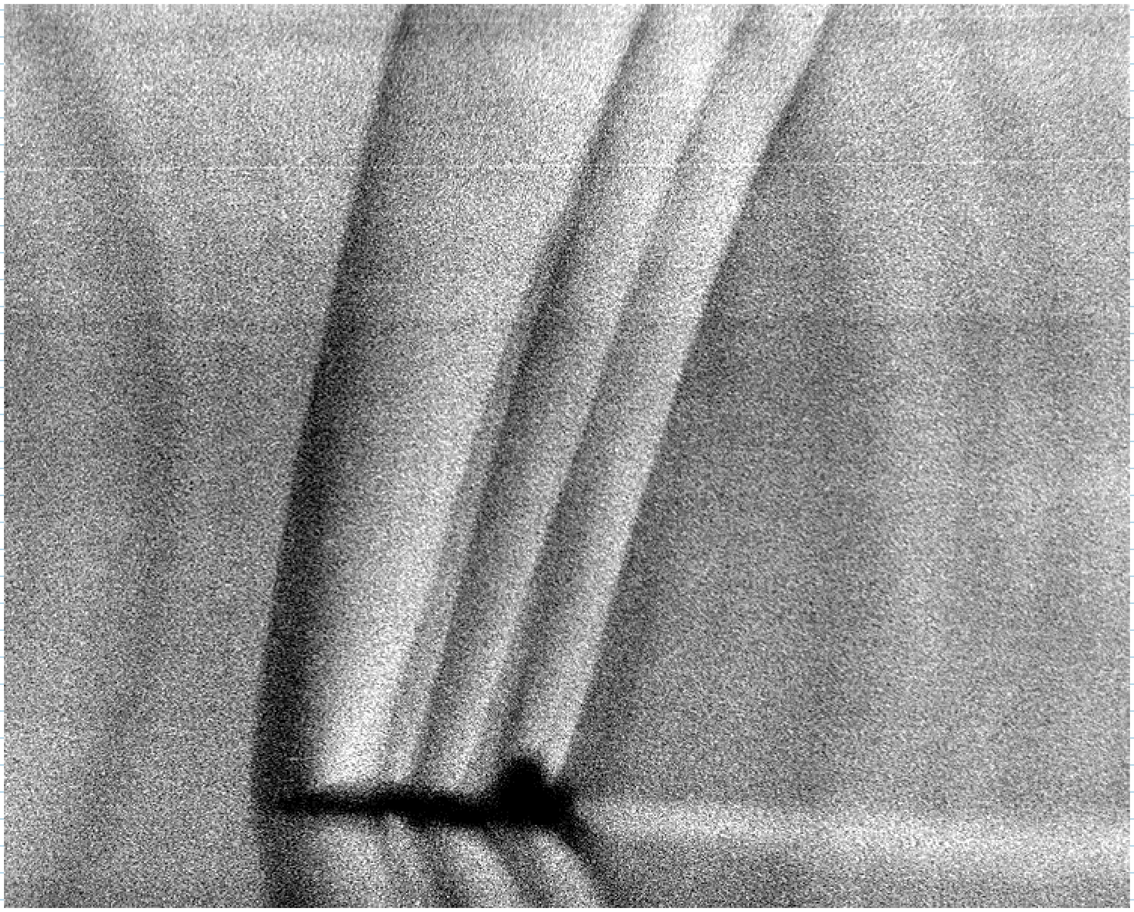
81. Growth of vortices on an accelerated plate. Spark shadowgraphs show the history of a 3-inch-square plate in air, accelerated from rest to 24 ft/s. The sharp edge of the plate is initially opposite the first of a series of pins spaced ¼ inch apart. The motion is actually vertical, and the flow is 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 paths of their boundaries visible. Care was taken to ensure that the undulations observed in the vortex sheet were not caused by vibrations of the model. *Pierce 1961*



167. Subsonic jet becoming turbulent. A jet of air from a nozzle of 5-cm diameter flows into ambient air at a speed of 12 m/s. The laminar interface becomes unstable as in figure 102, and the entire jet eventually becomes turbulent. *Bradshaw, Ferriss & Johnson 1964*



168. Supersonic jet becoming turbulent. At a Mach number of 1.8 a slightly over-expanded round jet of air adjusts to the ambient air through a succession of oblique and normal shock waves. The diamond-shaped pattern persists after the jet is turbulent. *Oertel 1975*



Pasted from <http://commons.wikimedia.org/wiki/File:Schlieren_photograph_of_T-38_shock_waves.jpg>

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

http://fuckyeahfluiddynamics.tumblr.com/post/47622561173/this-high-speed-video-shows-schlieren-photography

CO_2 bottle rocket video. Shows Mach diamonds and expansion fans.

How it works:

http://www.npr.org/2014/04/09/300563606/what-does-sound-look-like
Michael Hargather, New Mexico Tech

$$\eta = \frac{C_{VACUUM}}{C_{MEDIUM}}$$

n = index of refraction

Light is deflected towards more dense medium

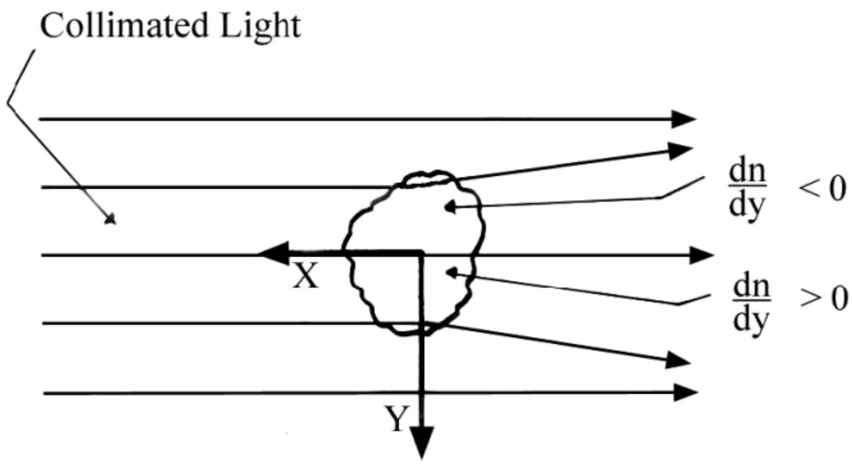
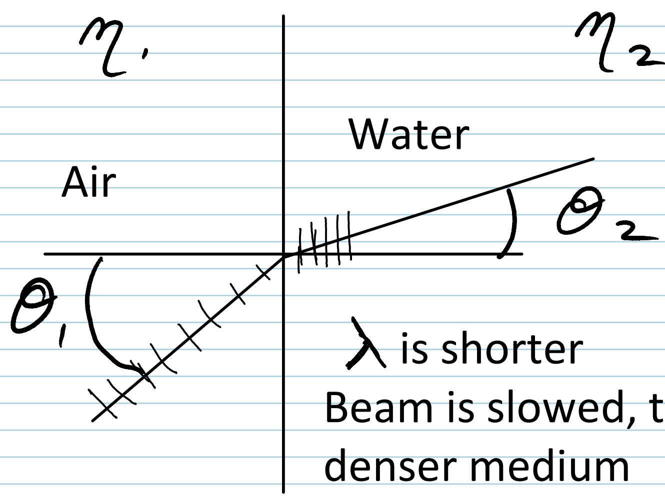


Figure 1. Disturbance in Collimated Beam

$$\frac{1}{\eta}\frac{\partial \eta}{\partial y} = \frac{\partial^2 y}{\partial x^2}$$

curve of disturbed line

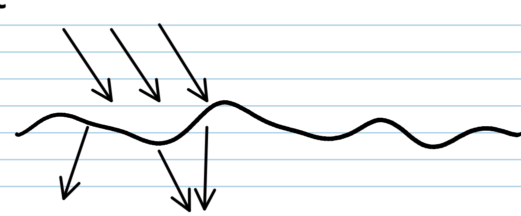
SNELL'S LAW



λ is shorter

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

like a caustic sunlight



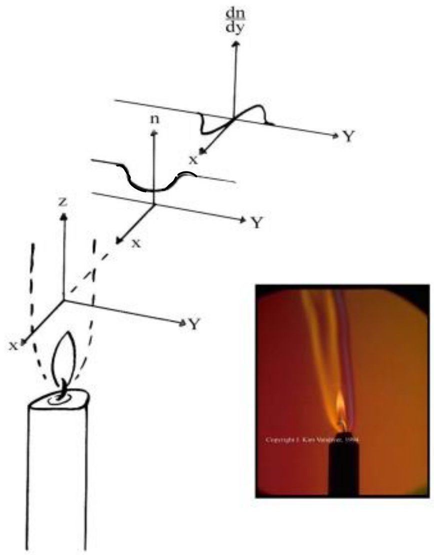


Figure 2. The Refractive Index Gradient Above a Candle

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

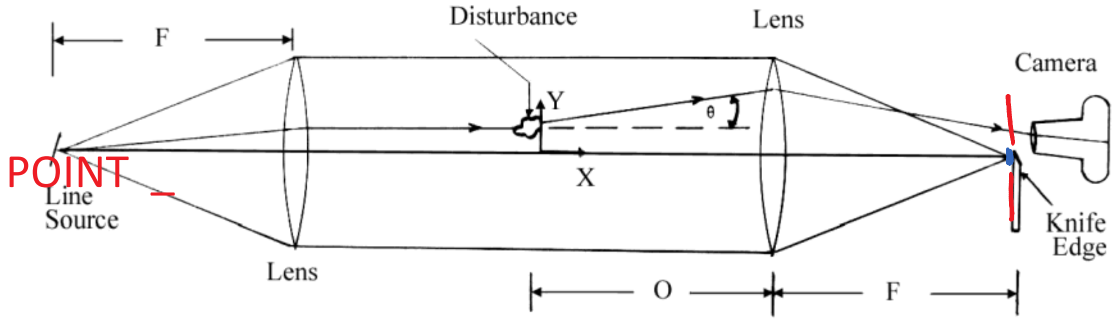
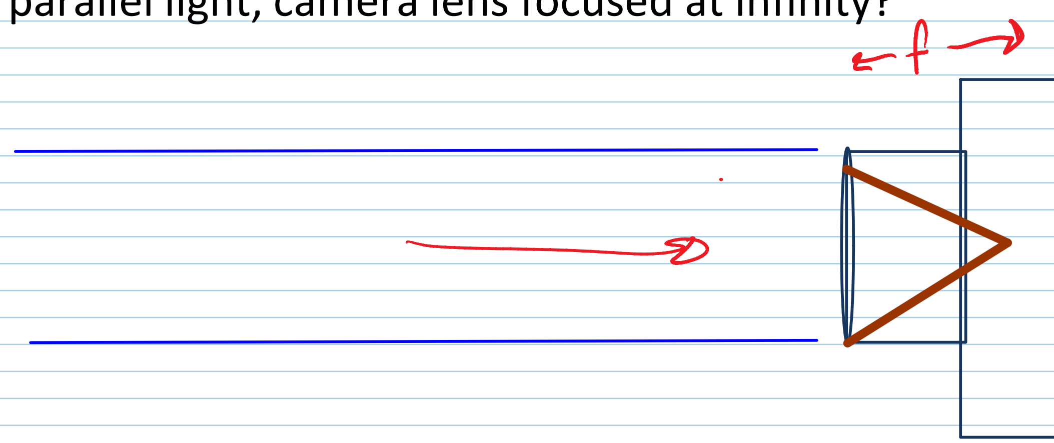


Figure 3. Schlieren System with a Small Disturbance

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



Works the other direction too; a light source at the focal point becomes parallel light exiting the lens.