PHY385-H1F Introductory Optics

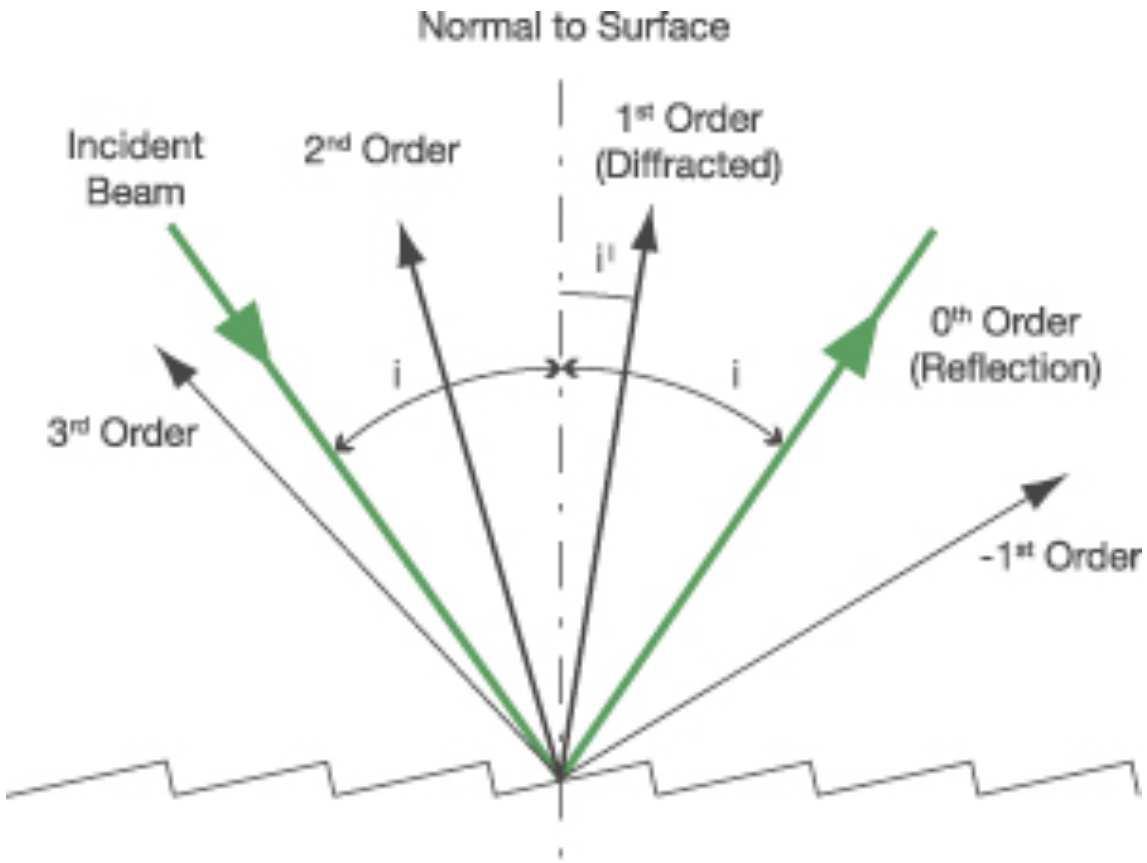
Last Class!! – Outline:

- Diffraction Gratings
- Things to know about the final exam
- A look ahead: PHY485: “Modern Optics”
- Some Course Review

Diffraction Gratings

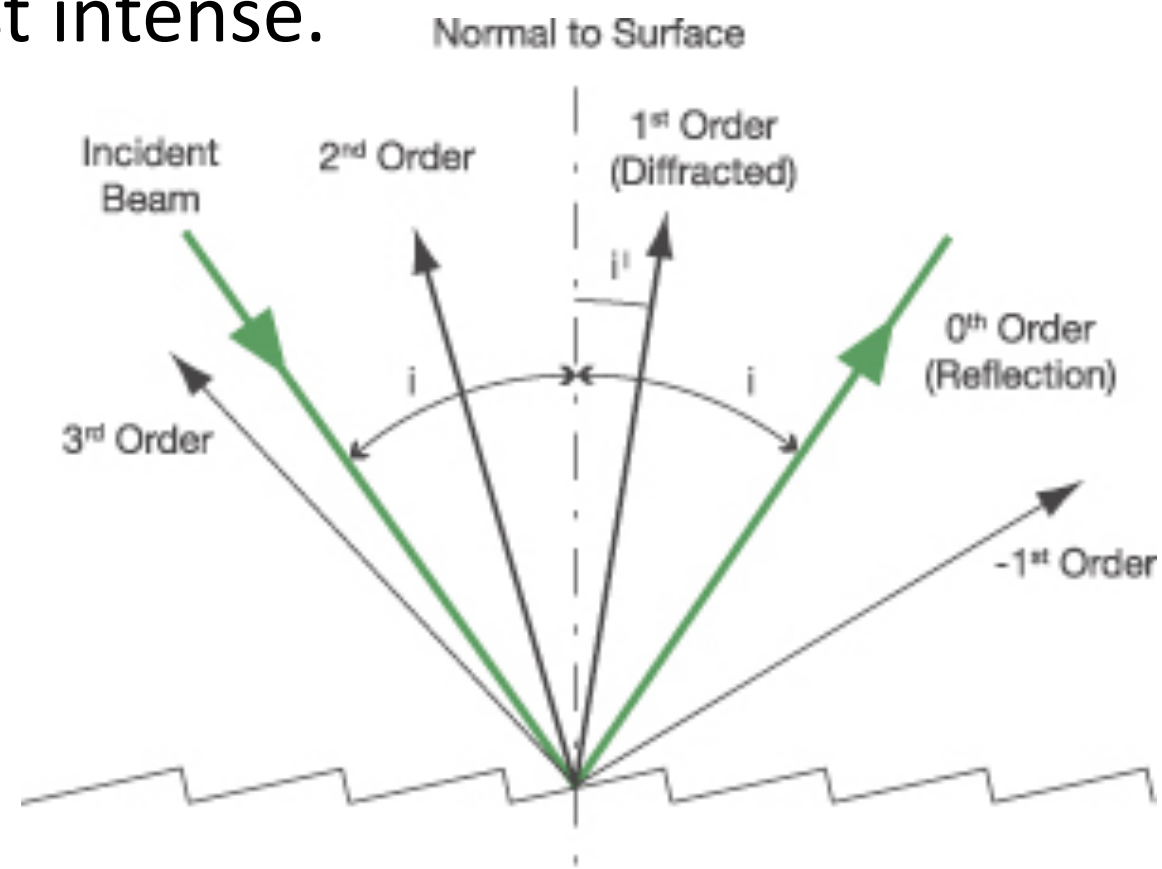
- Reflection gratings obey a similar equation as transmission gratings:

$$m\lambda = a(\sin\theta_m - \sin\theta_i)$$



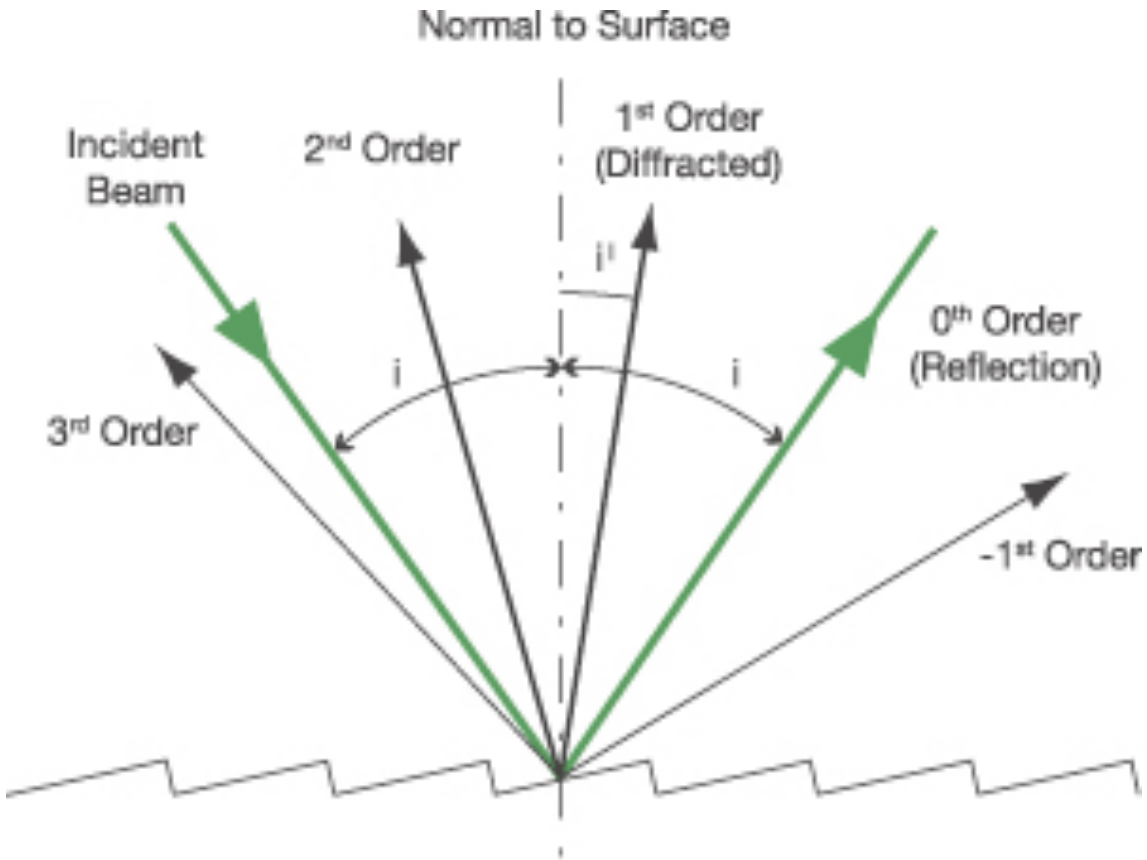
Diffraction Gratings

- The $m = 0$ order corresponds to regular reflection: $\theta_m = \theta_r$: No dispersion.
- Other orders are dispersed: rainbows. Usually the first order lines ($m = 1$ or $m = -1$) are the most intense.



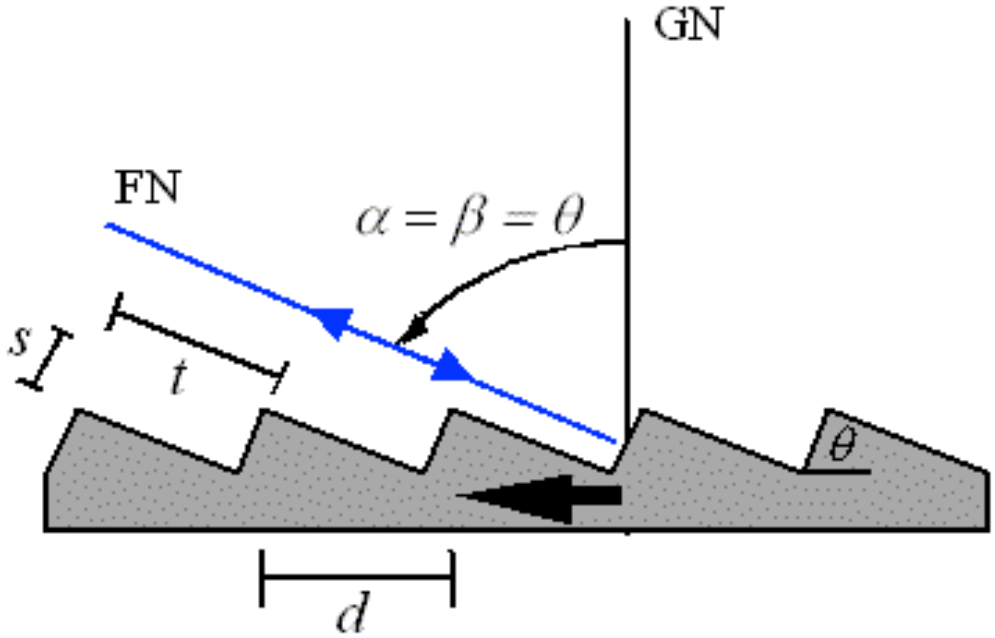
Diffraction Gratings

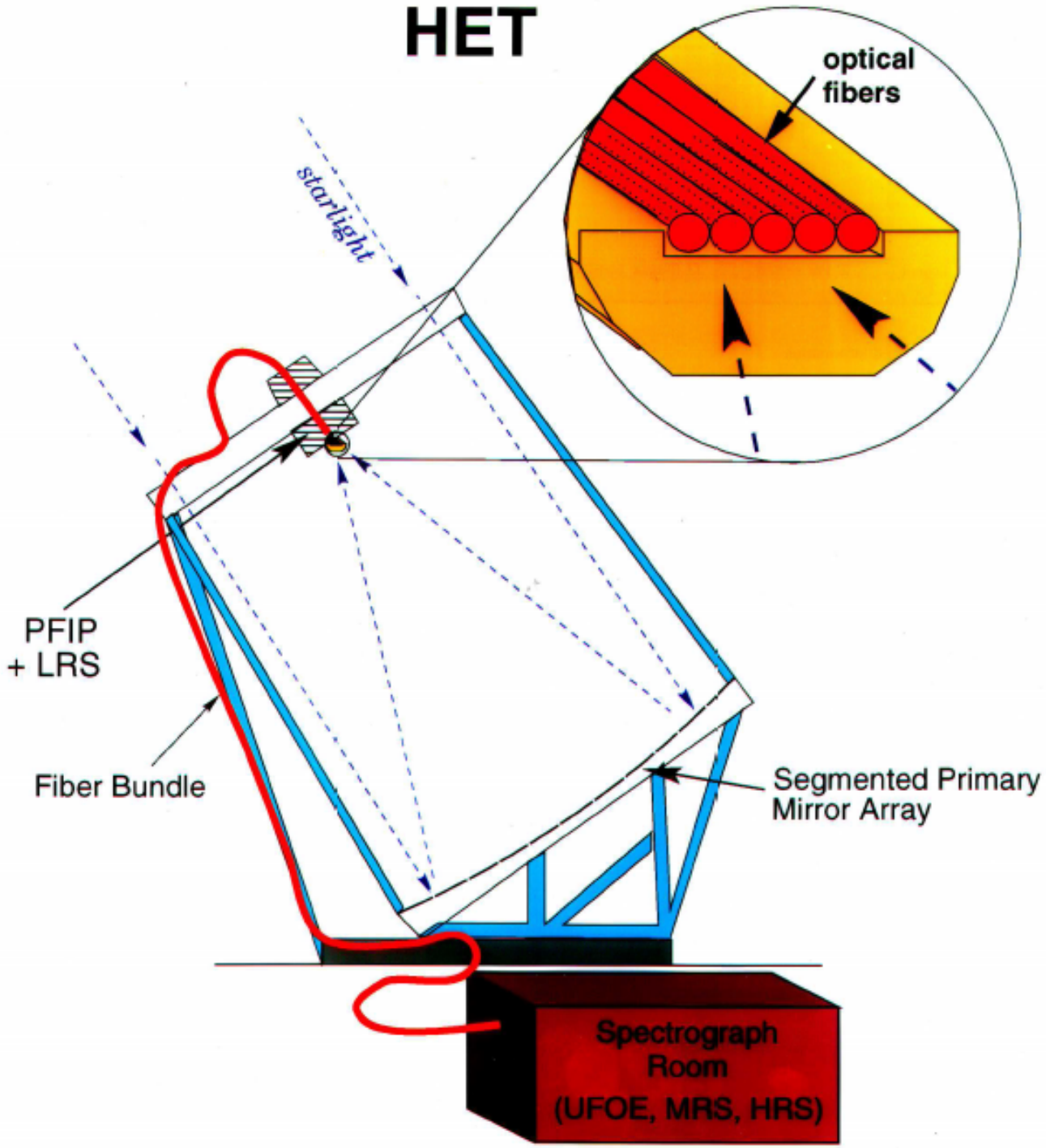
- The grating below is “blazed”, meaning its surface is a reflective saw-tooth shape. Blazing can increase the efficiency for a particular order.
- It appears to be blazed for 1st order



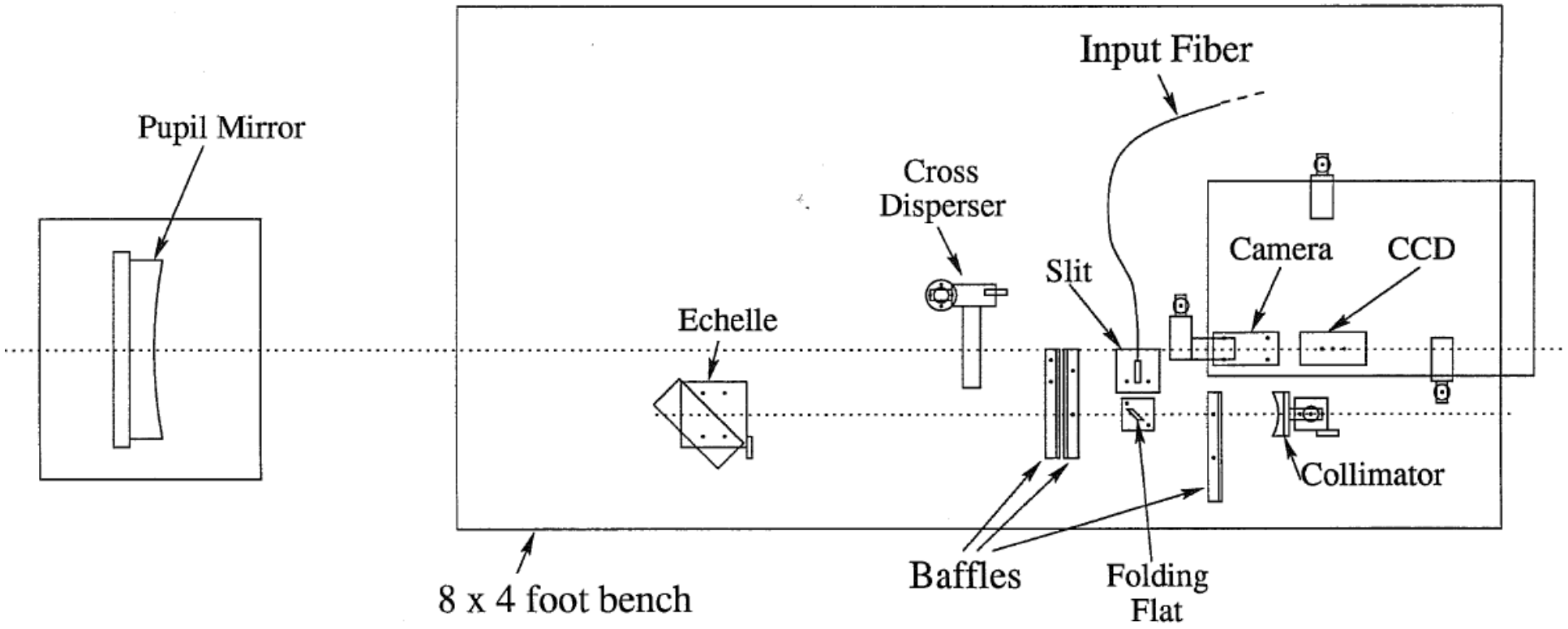
Echelle Gratings

- An echelle grating is blazed for extremely high order. The purpose is to increase dispersion, which is proportional to m.
- In practice, adjacent orders always overlap, so a second "cross-grating" must be used to separate the orders on the detector.

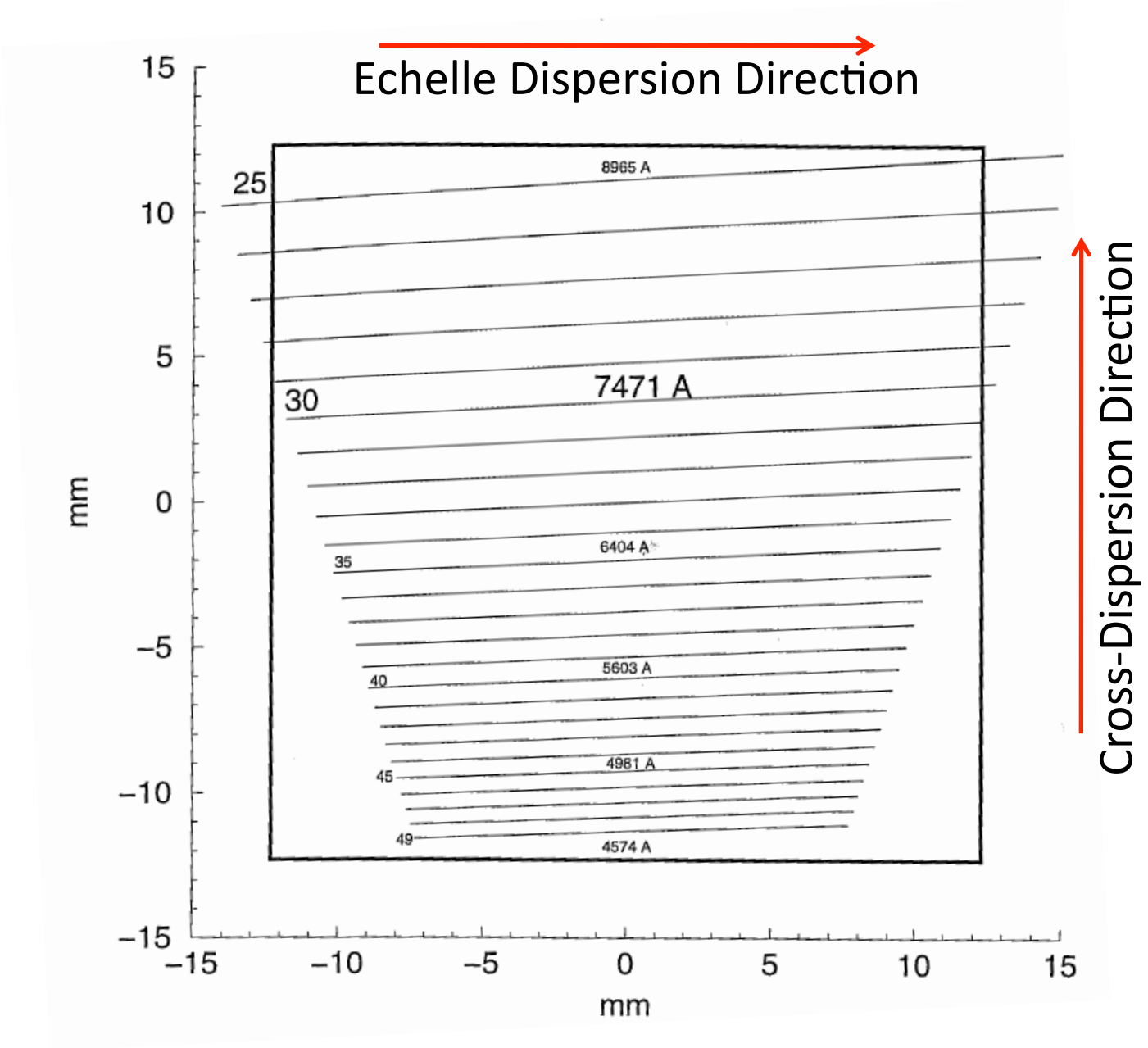



HET
optical fibers
starlight
PFIP + LRS
Fiber Bundle
Segmented Primary Mirror Array
Spectrograph Room (UFOE, MRS, HRS)

Upgraded Fiber-Optic Echelle (UFOE) Spectrograph – bench layout



Echelle Spectrum on the CCD detector



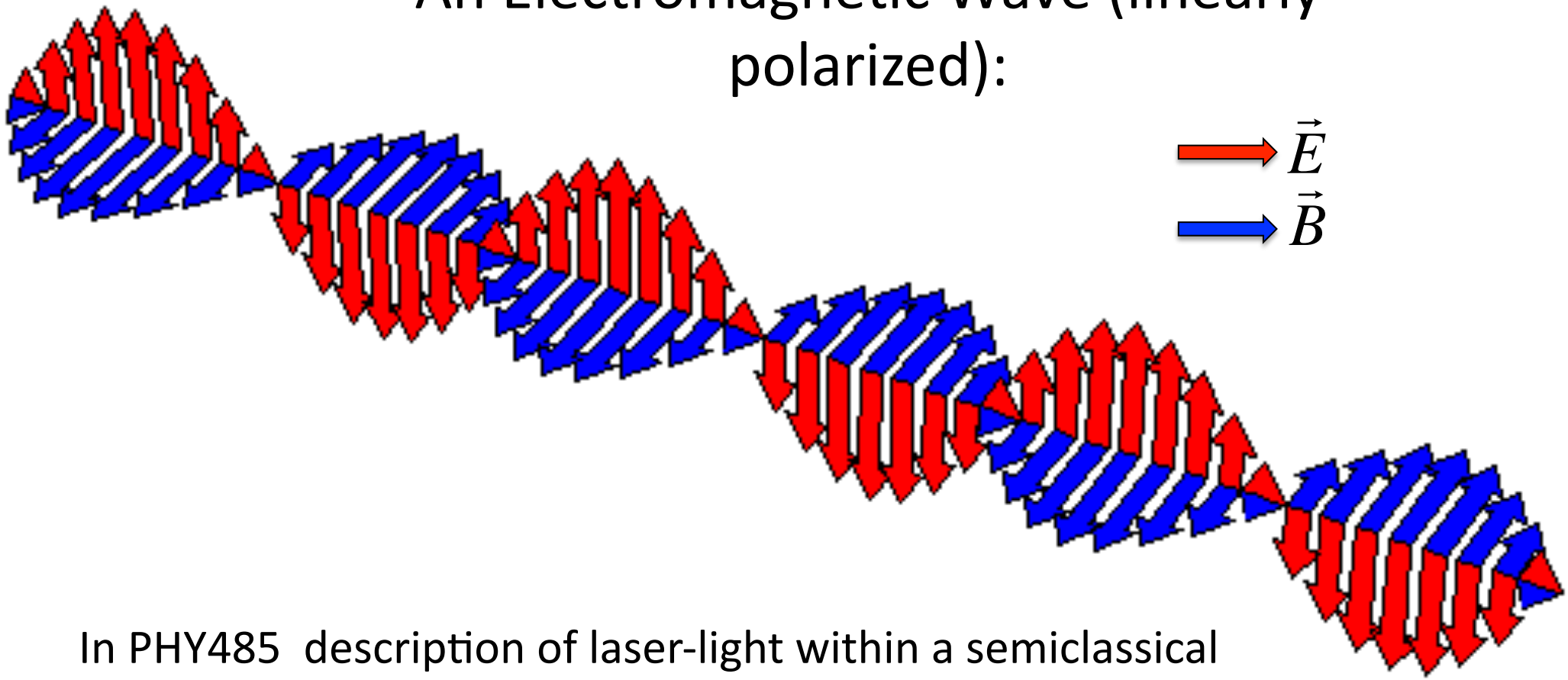
Final Exam

- Tuesday Dec. 13 (one week from today) from 9:00 to 11:00am, in Sid Smith: SS1074
- First Page with “helpful information” is posted on the course web-site, under “Materials”.
- Allowed aids include your textbook, a calculator, and up to 2-pages of hand-written notes.
- There are 8 problems, similar to the style you have seen on the mid-terms.
- The material includes the entire course, spread evenly.

PHY1485H-F / 485

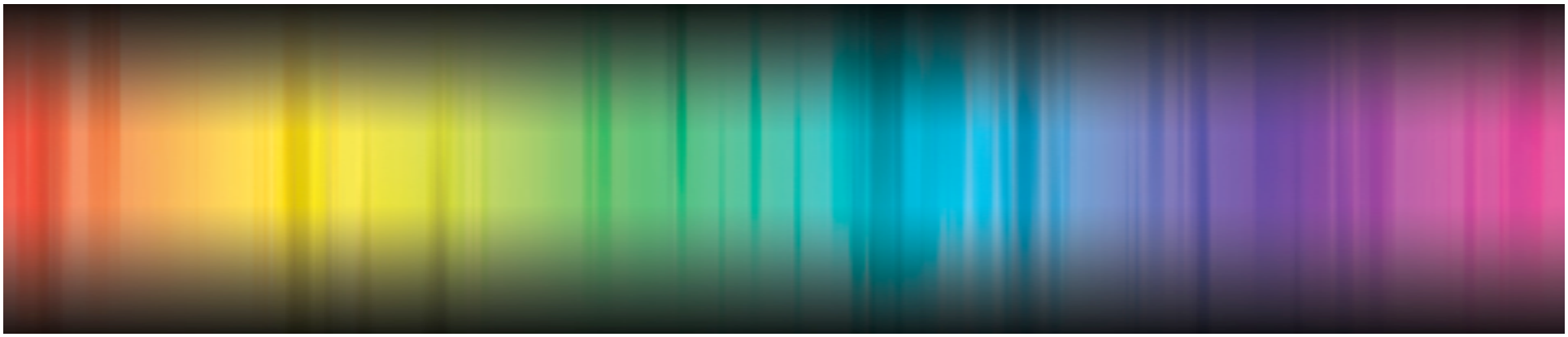
- “Lasers and Modern Optics” is a cross-listed course (grad students and undergrads), currently taught by Professor van Driel. He recommends Hecht 4e.
- Current Pre-requisites are “Electromagnetic Theory” (PHY350) and “Quantum I” (PHY356)
- Topics include:
  - Gaussian beam modes and their relation to optical resonators
  - Fibre and Slab waveguides
  - Laser Cooling
  - Photonic bandgap structures
  - Extreme optics
  - Quantum information
- There are End-of-year student seminars.

An Electromagnetic Wave (linearly polarized):

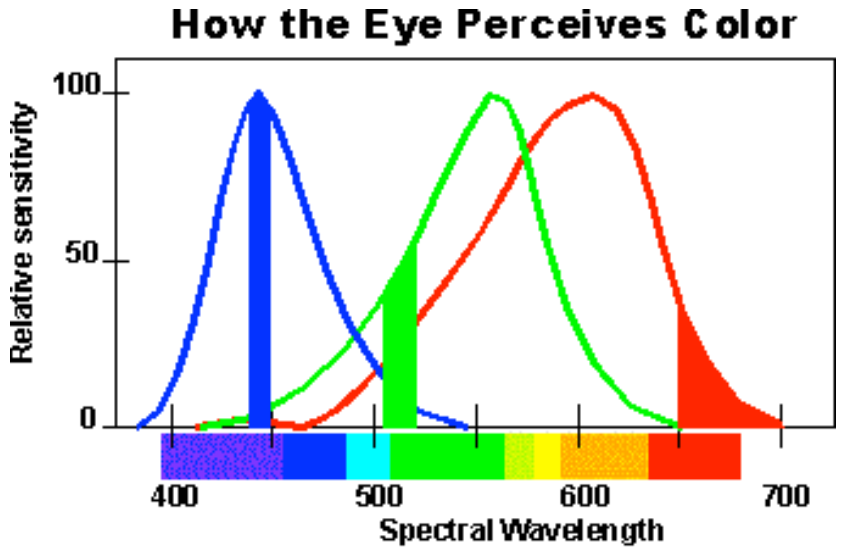


In PHY485 description of laser-light within a semiclassical picture in which the fields are treated classically and matter is treated quantum mechanically.

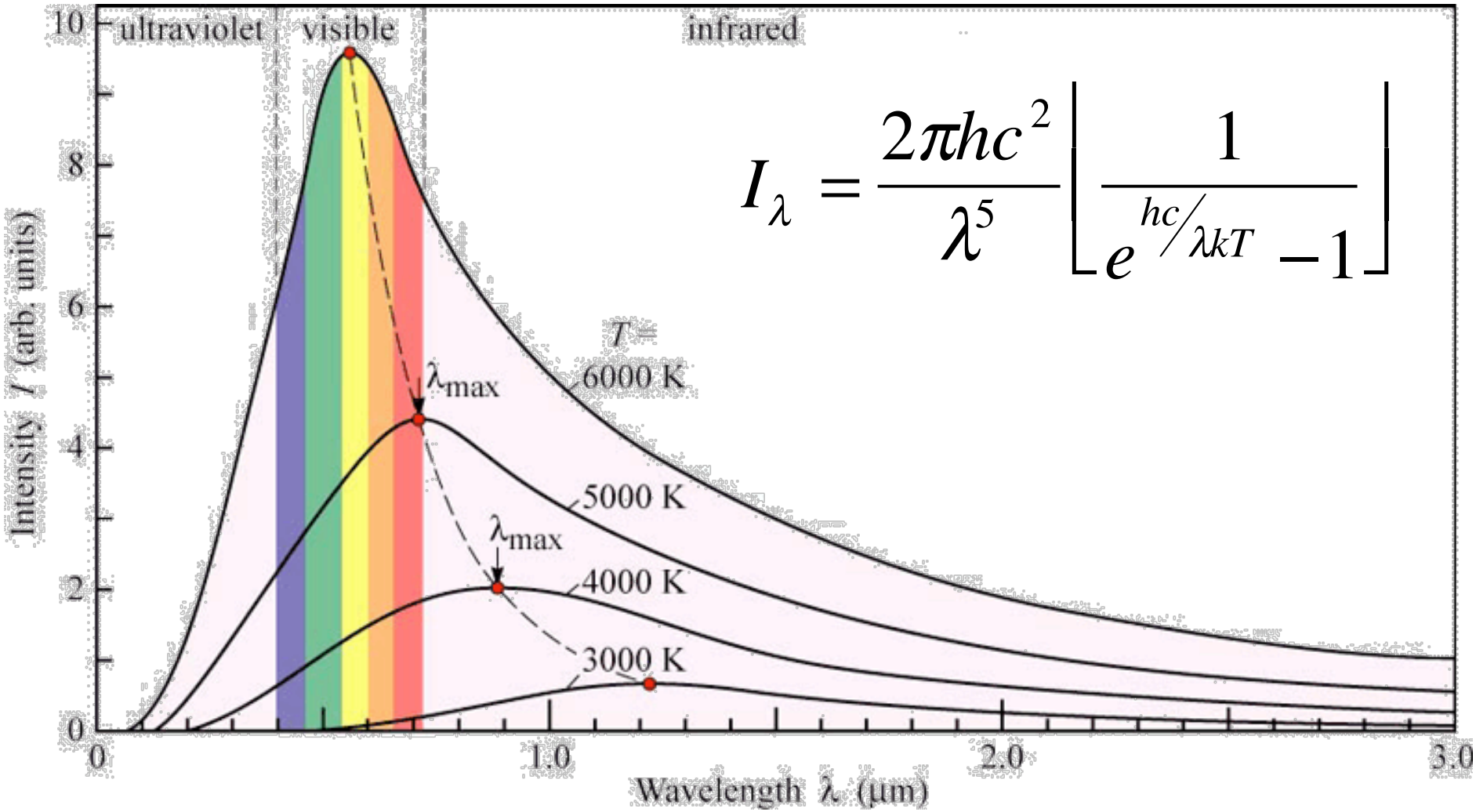
Some Review… Visible Light



- Hecht says: 455 to 780 nm. Personally, I can't see light beyond about 700 nm. And I am able to see violet down to about 420 nm.

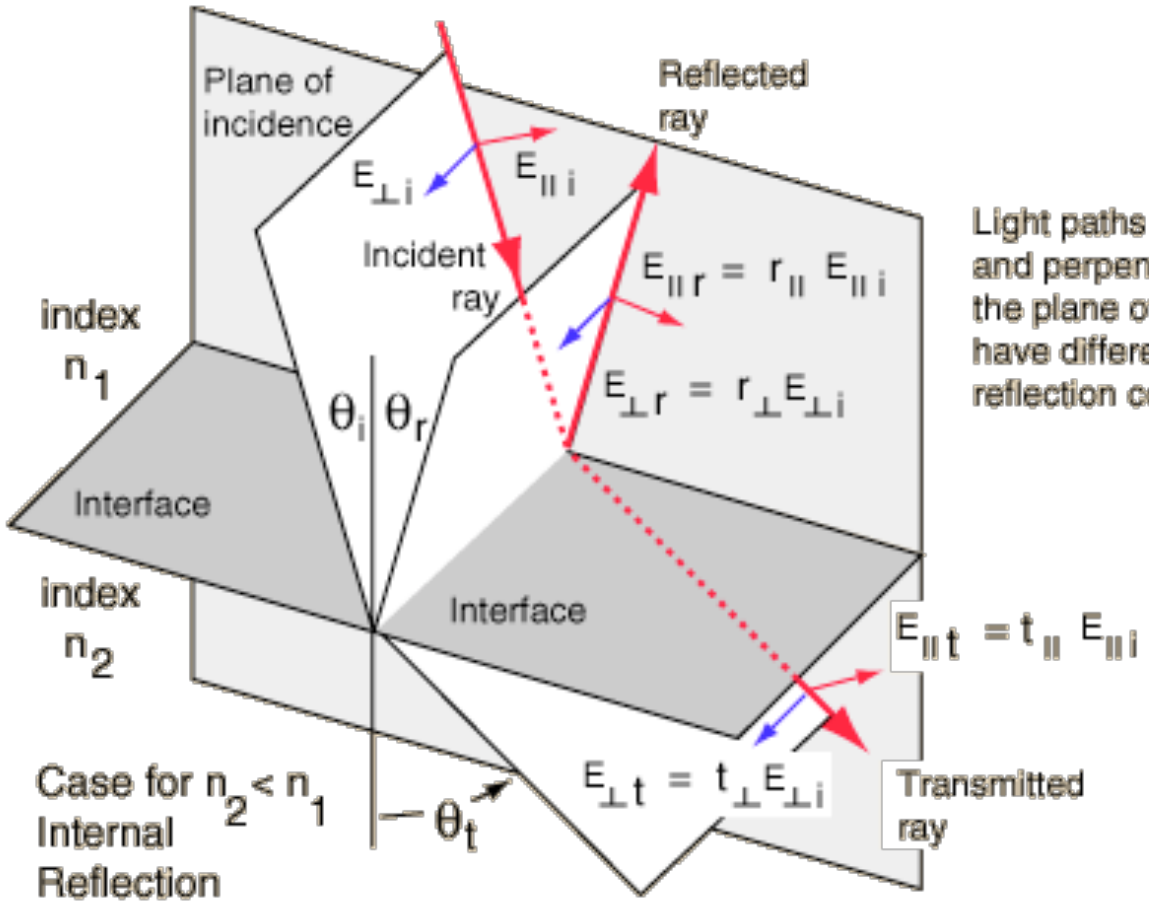


Blackbody Radiation

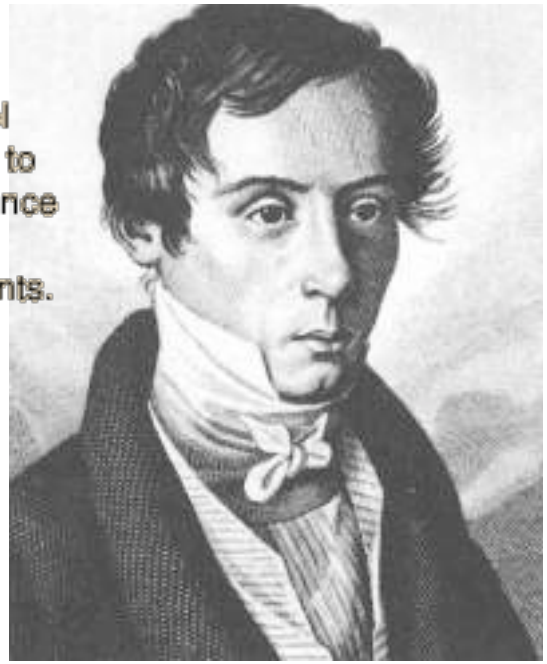


$$I_\lambda = \frac{2\pi hc^2}{\lambda^5}\left[\frac{1}{e^{hc/\lambda kT} - 1}\right]$$

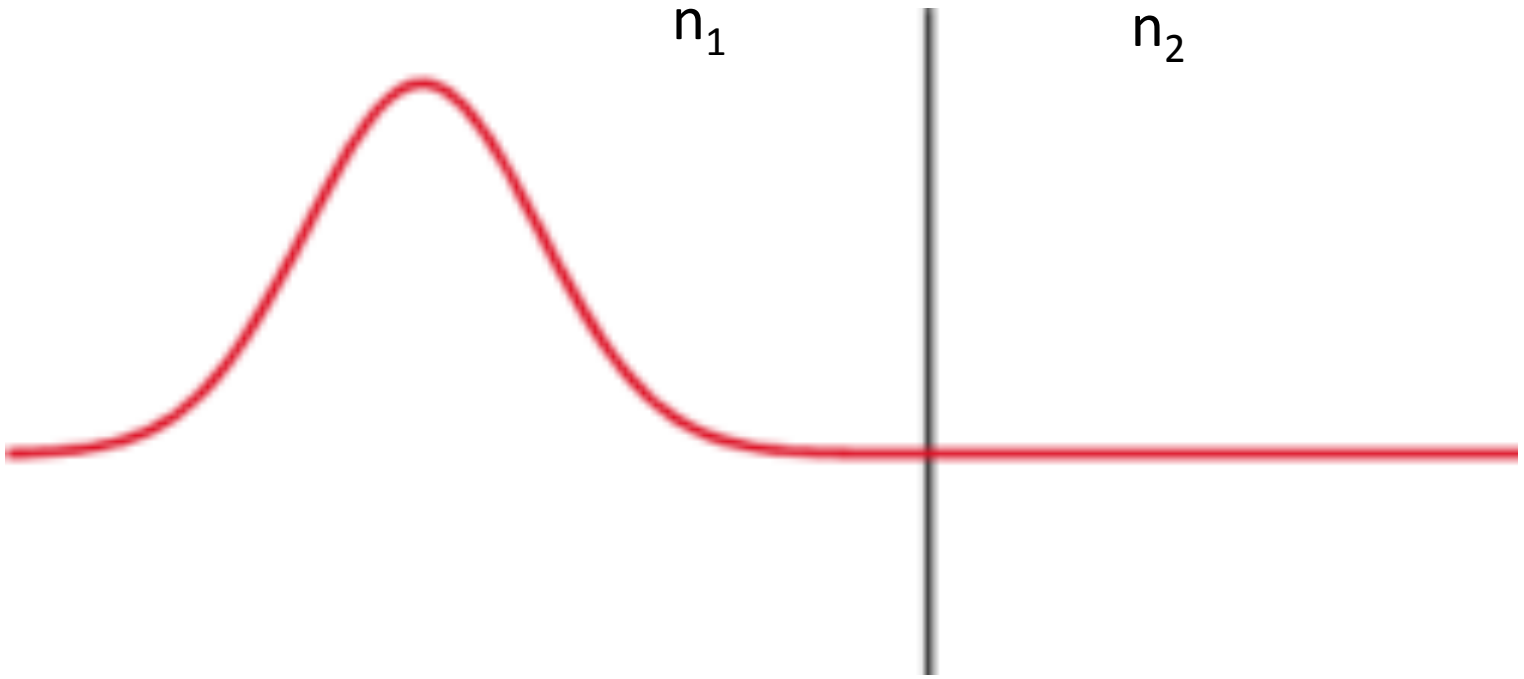
- 1814 – **Jean Fresnel** used the idea of polarization to predict amplitudes of reflected and transmitted light from glass interfaces.



Light paths parallel and perpendicular to the plane of incidence have different reflection coefficients.



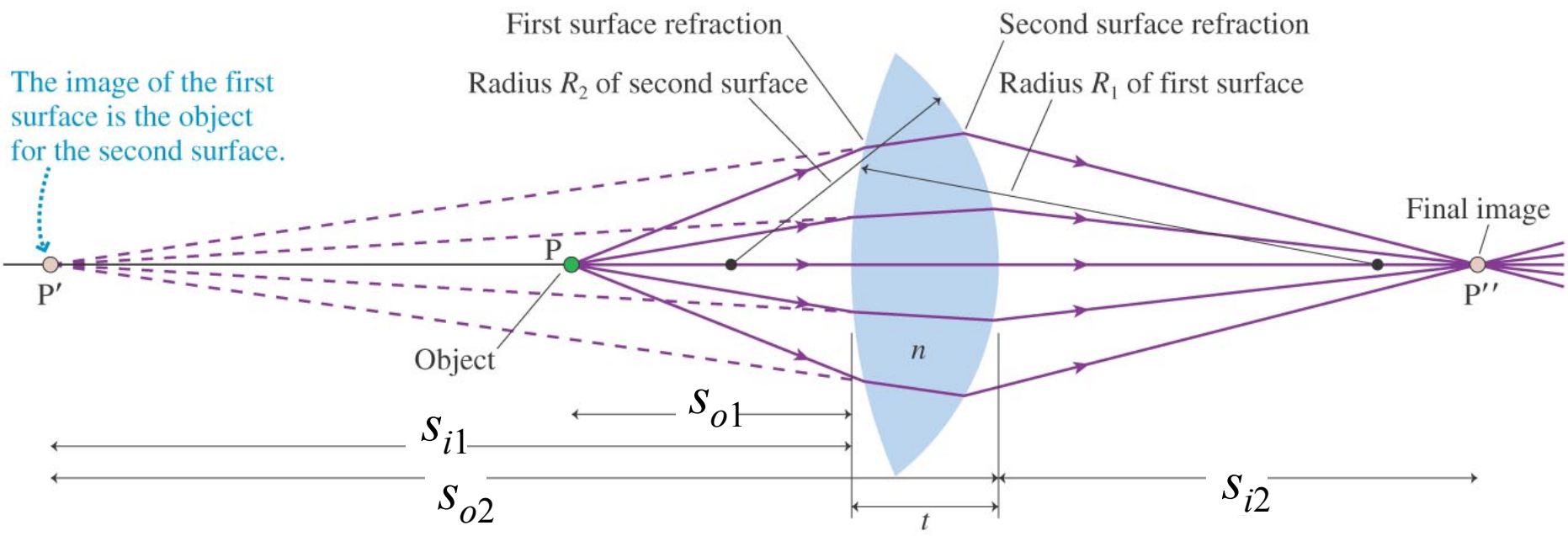
Partial transmission and reflection amplitudes of a wave travelling from a low to high refractive index medium.



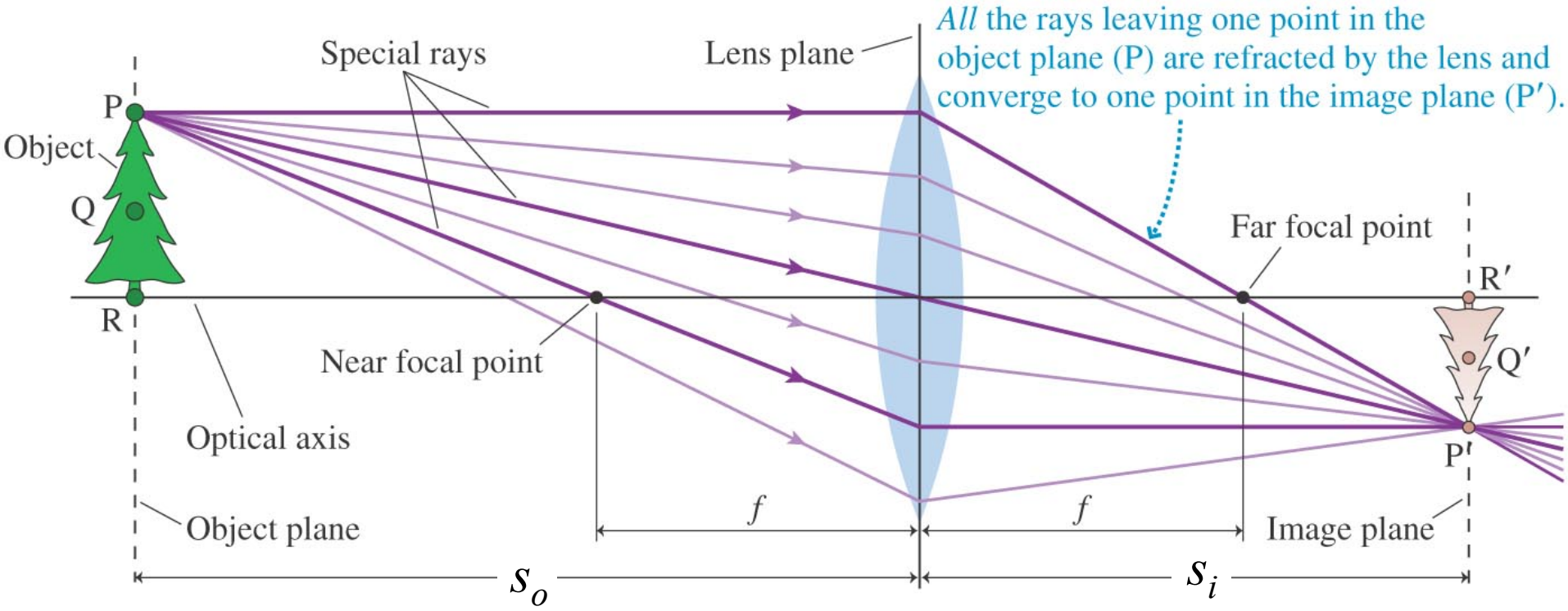
Practicals Activity 10.1

- Calculate the percent reflectance for the TM mode of light in air incident at 50° on a glass surface of index of refraction 1.60.

Lensmaker's Formula



$$\frac{1}{f} = \frac{n_l - n_m}{n_m}\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$



The Thin Lens Equation: $$\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$$

f is positive for a converging lens

f is negative for a diverging lens

s_o is positive means object is real, to the left of lens

s_i is positive means image is real, to the right of lens

s_i is negative means image is virtual, to the left of lens

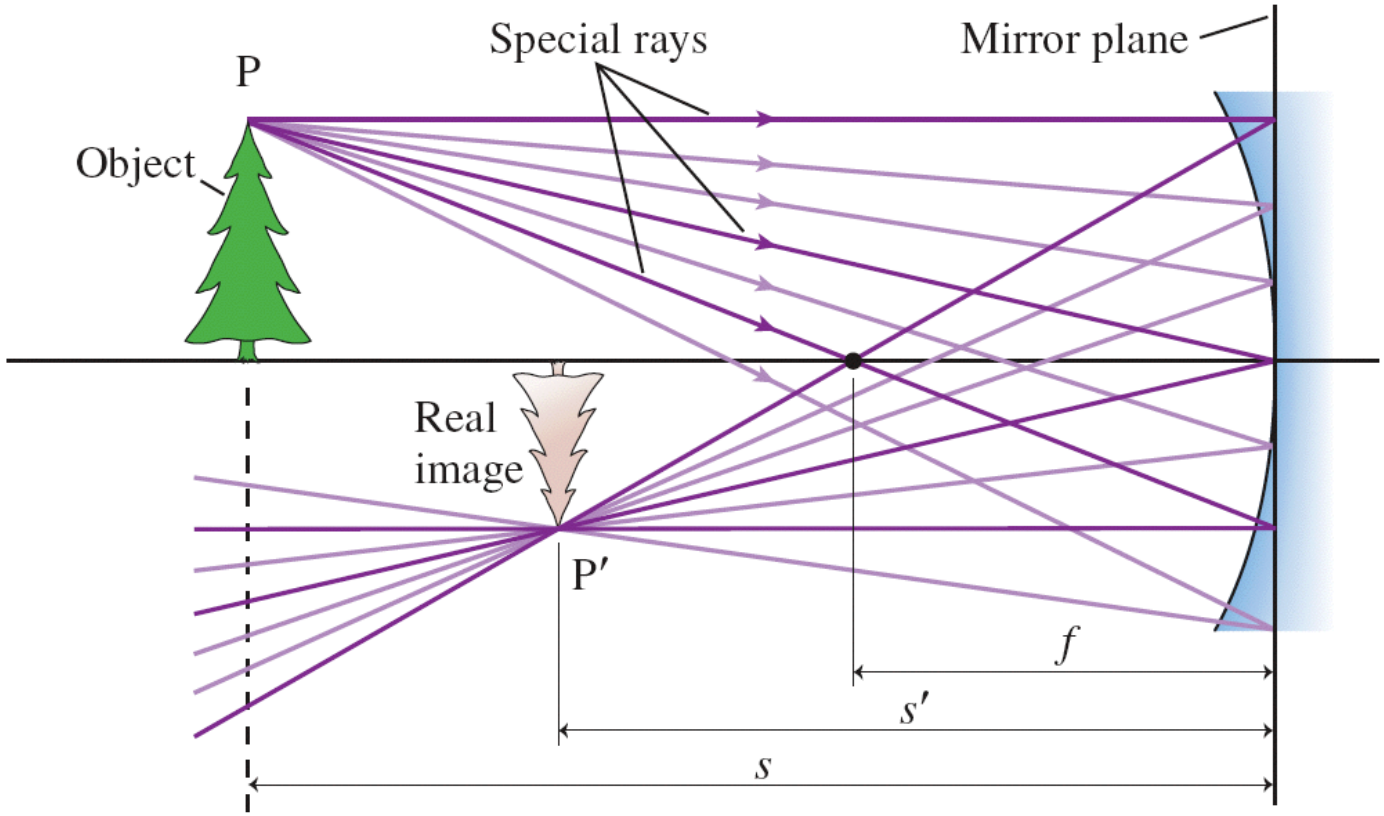
Practicals Activity 10.2

- A bi-convex thin lens with index of refraction 1.50 has a focal length of +30.0 cm in air. When immersed in a certain transparent liquid, it becomes a negative lens with a focal length of −188 cm. Determine the index of refraction of the liquid.

- The total amount of light collected by the lens is proportional to D^2.
- The image area of an extended object is proportional to f^2.

- So the flux density at the image plane varies as $(D/f)^2$.
- D/f is called "relative aperture"
- f/D is called the "f-number" (ie F1.4, F2, F16, etc)
- $(f/D)^2$ is called the "speed". The higher the speed, the shorter an exposure time you need for the same image brightness.
- That's why f-numbers tend to increase by factors of $\sqrt{2}$ on cameras – for each step you have to double the exposure time.

FIGURE 23.52 A real image formed by a concave mirror.



The Mirror Equation

For a spherical mirror with negligible thickness, the object and image distances are related by

$$\frac{1}{s_o}+\frac{1}{s_i}=\frac{1}{f} \qquad \text{(thin-mirror equation)}$$

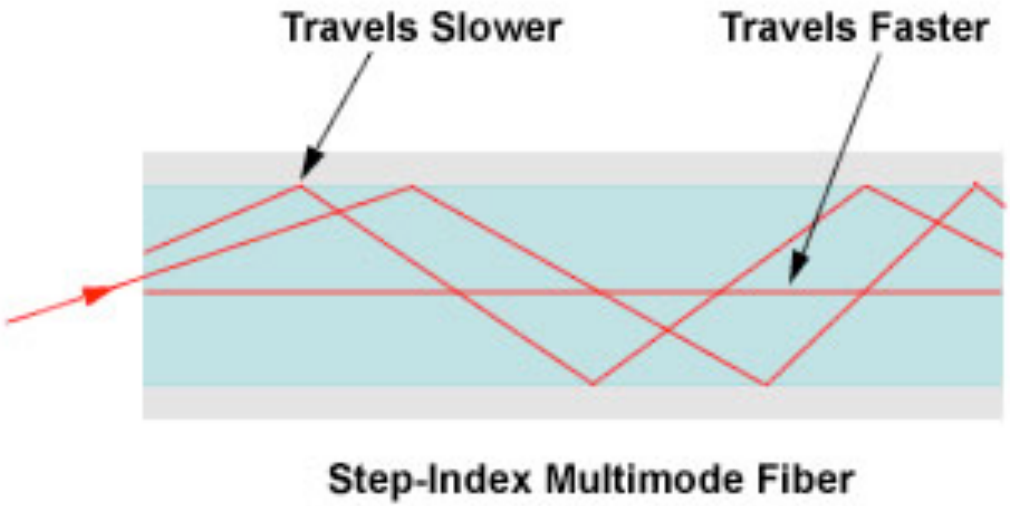
where the focal length f is related to the mirror's radius of curvature by

$$f=\frac{R}{2}$$

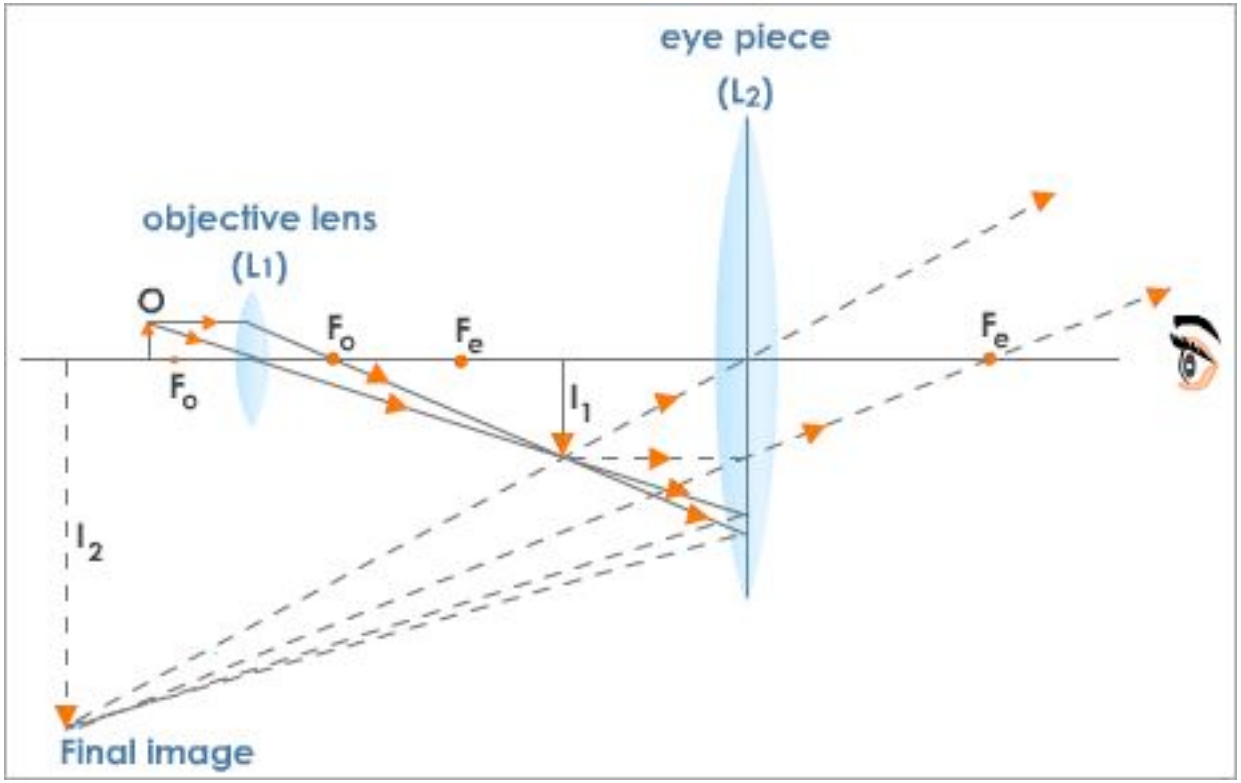
Sign convention for spherical mirrors

	Positive	**Negative**
R and f	Concave toward the object	Convex toward the object
s_i	Real image, same side as object	Virtual image, opposite side from object

Modal Dispersion In Optical Fibres



Compound Microscope



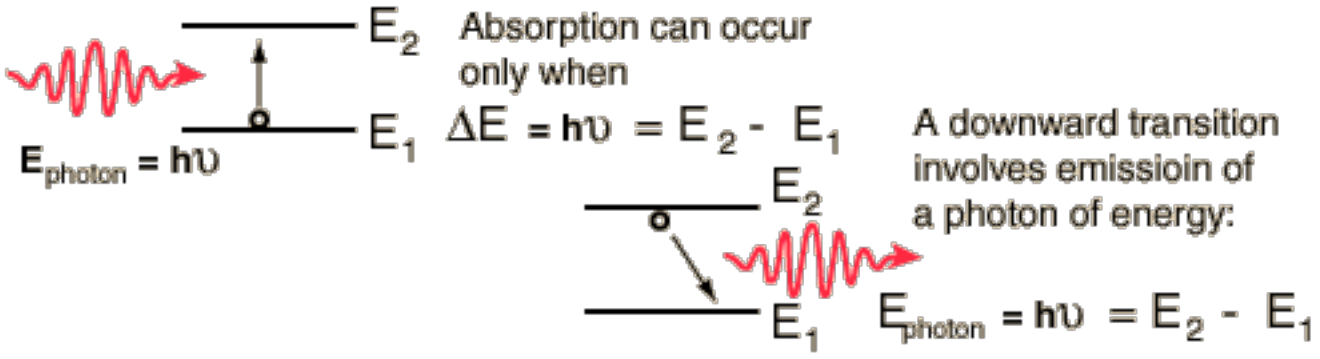
$$MP = \left(-\frac{16\,\text{cm}}{f_o} \right) \left(\frac{25\,\text{cm}}{f_e} \right)$$

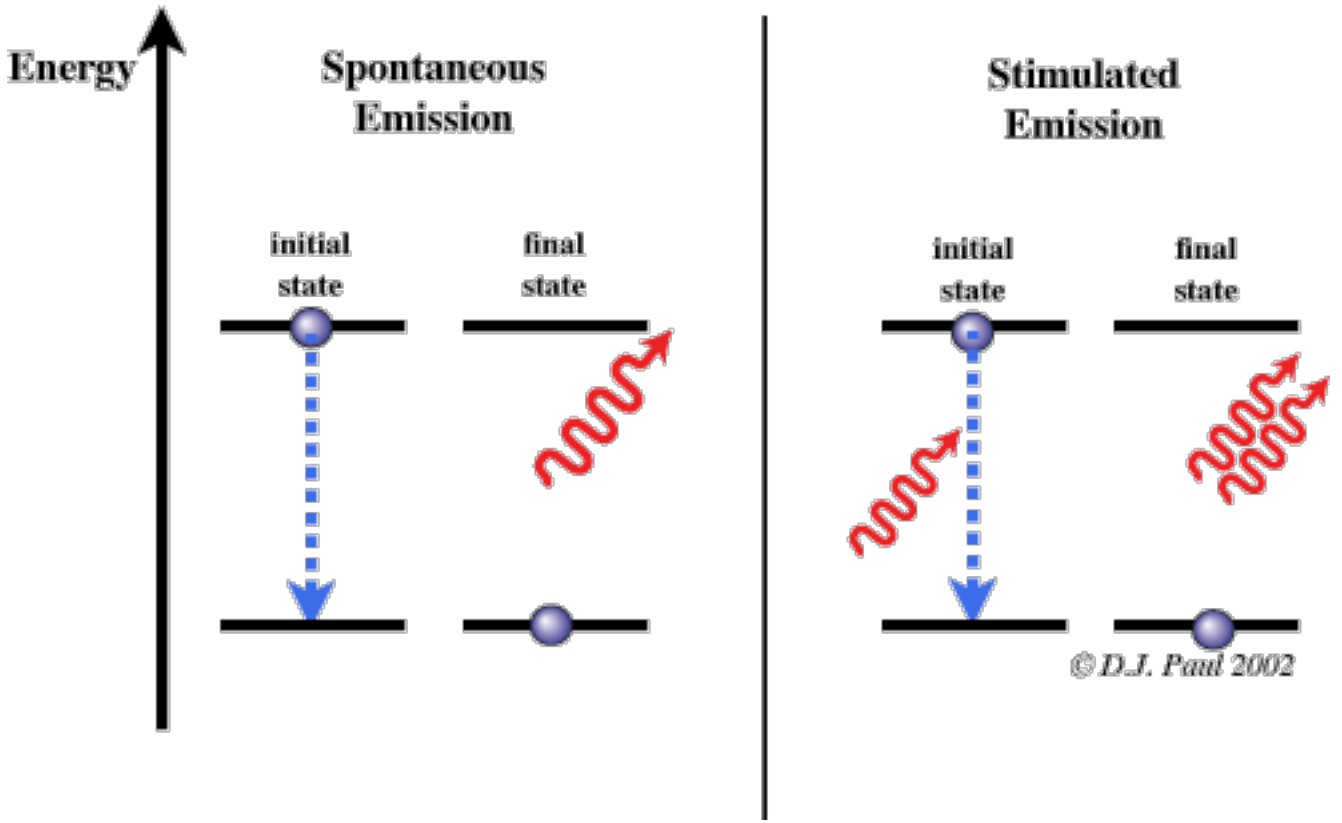
Telescope

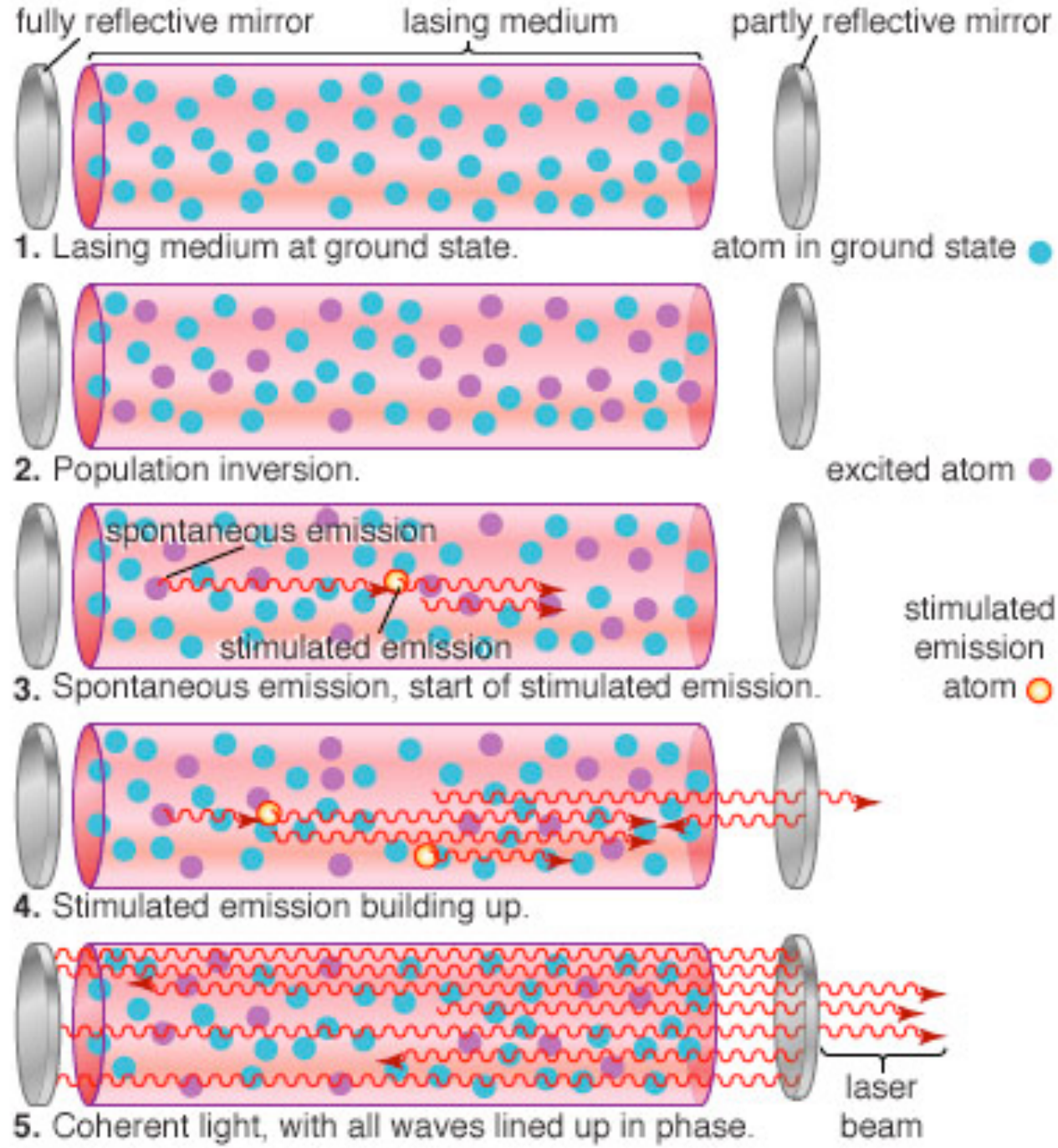
- Invented by somebody in Holland (1608), or Galileo of Italy (1610).
- Objective forms a real, inverted image in the tube.
- Eyepiece is used as a magnifier to view this image.

Galileo Galilei

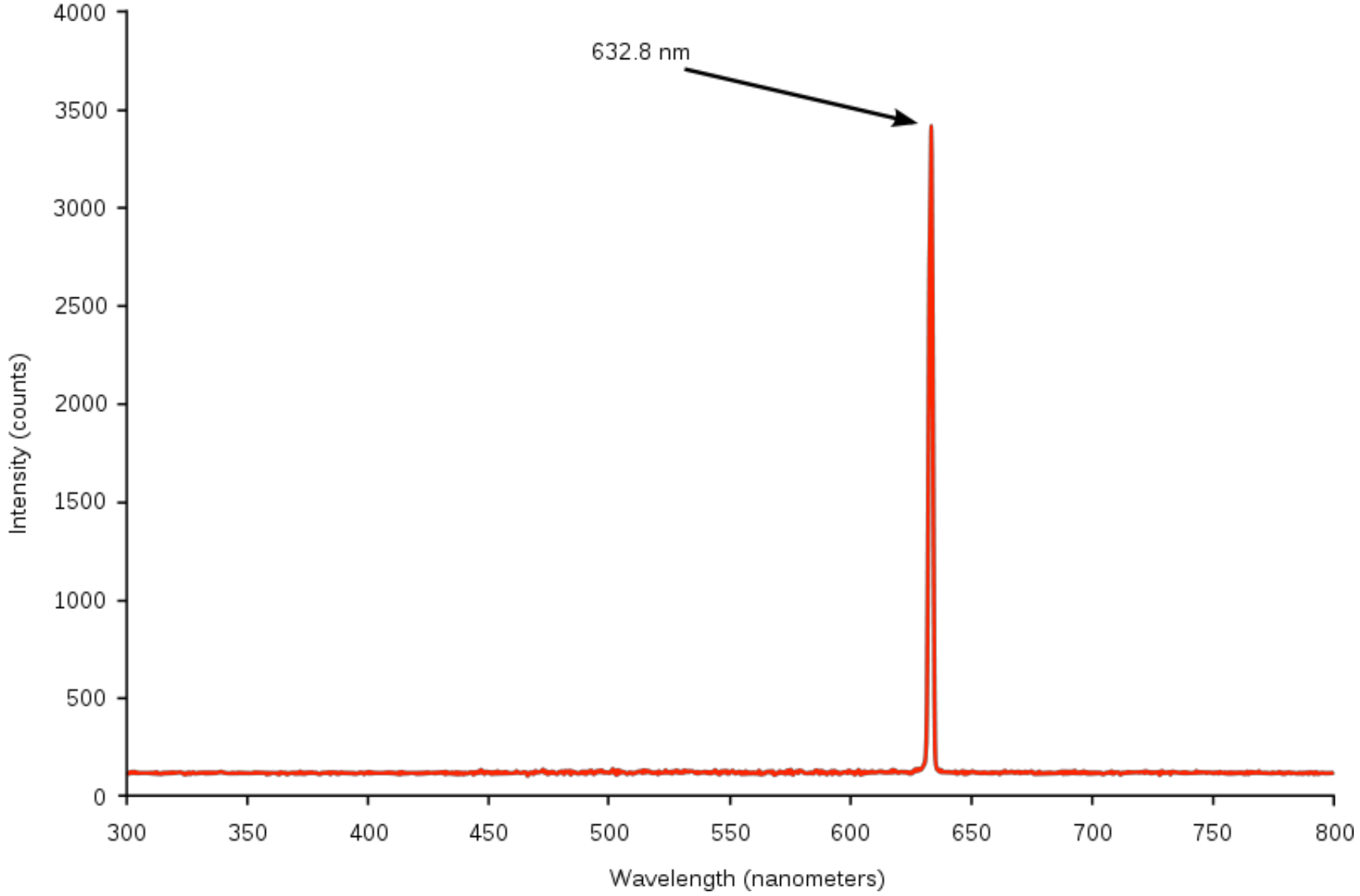
$$MP = \frac{\alpha_a}{\alpha_u}$$


E_2
E_1
$E_{photon} = h\upsilon$
Absorption can occur only when
$\Delta E = h\upsilon = E_2 - E_1$
A downward transition involves emissioin of a photon of energy:
E_2
E_1
$E_{photon} = h\upsilon = E_2 - E_1$

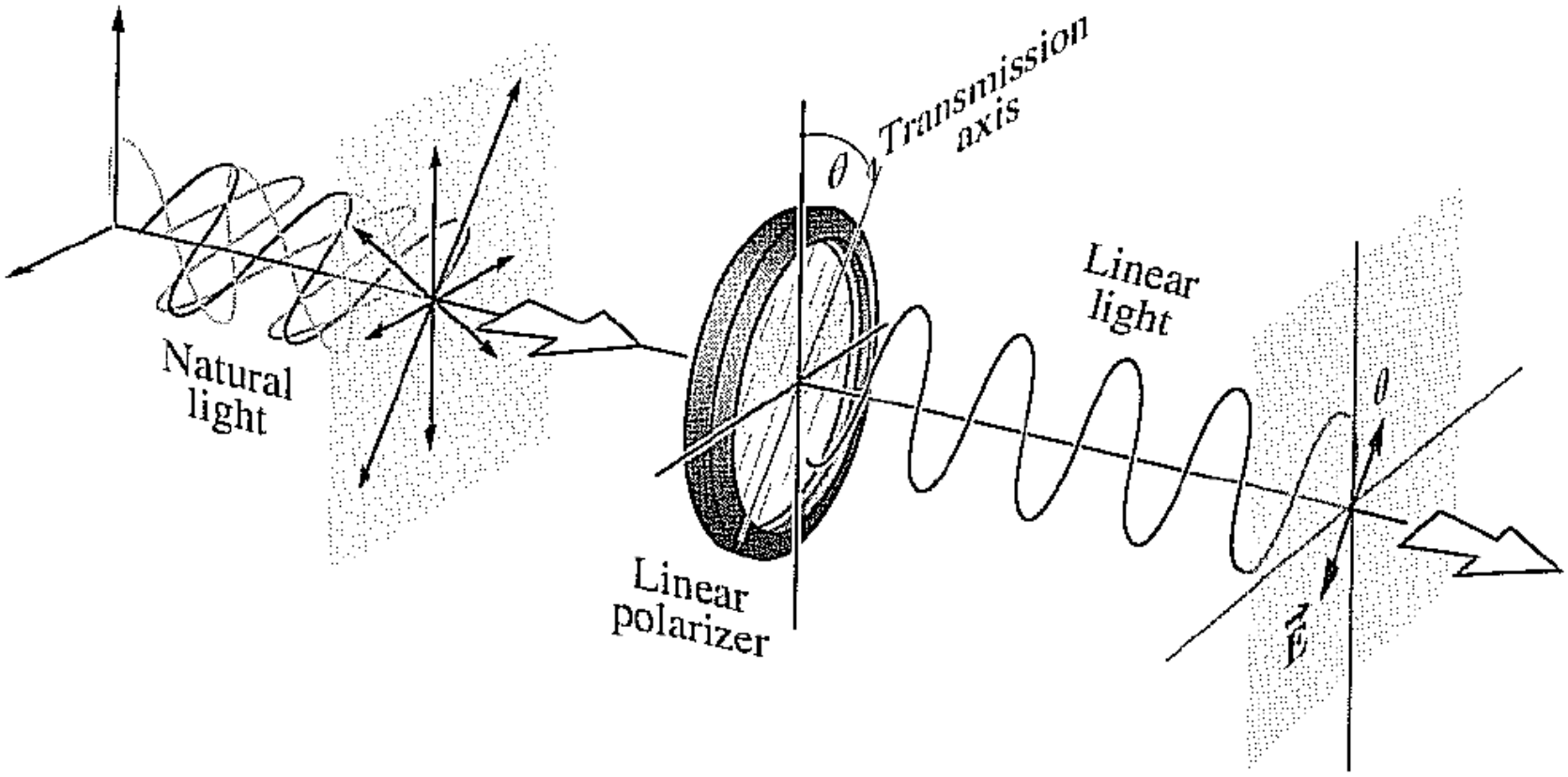

Energy
Spontaneous Emission
initial state
final state
Stimulated Emission
initial state
final state
© D.J. Paul 2002



Spectrum of a He-Ne Laser



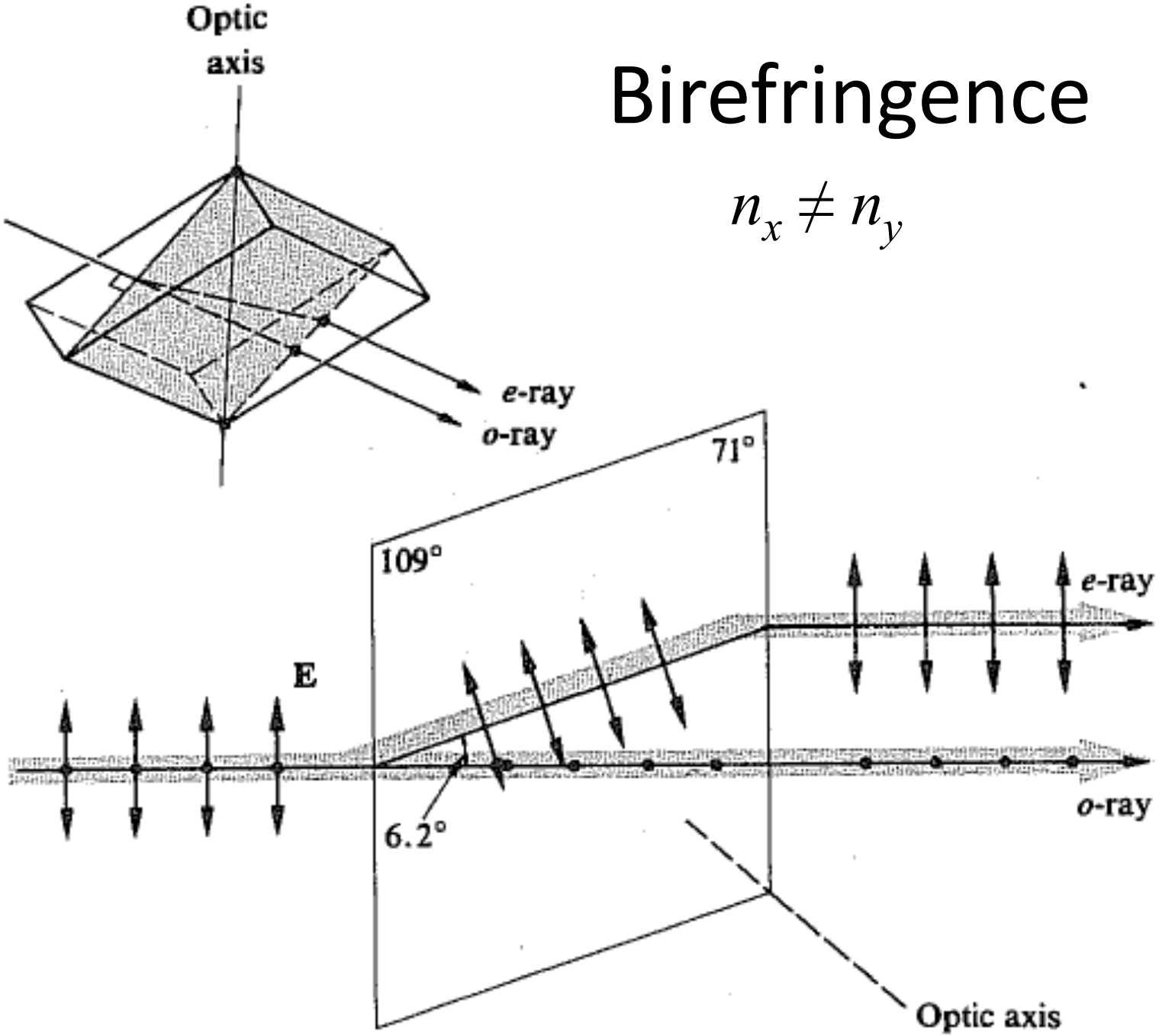
Dichroism



"Unpolarized" light incident on a linear polarizer tilted at an angle θ with respect to the vertical

Birefringence

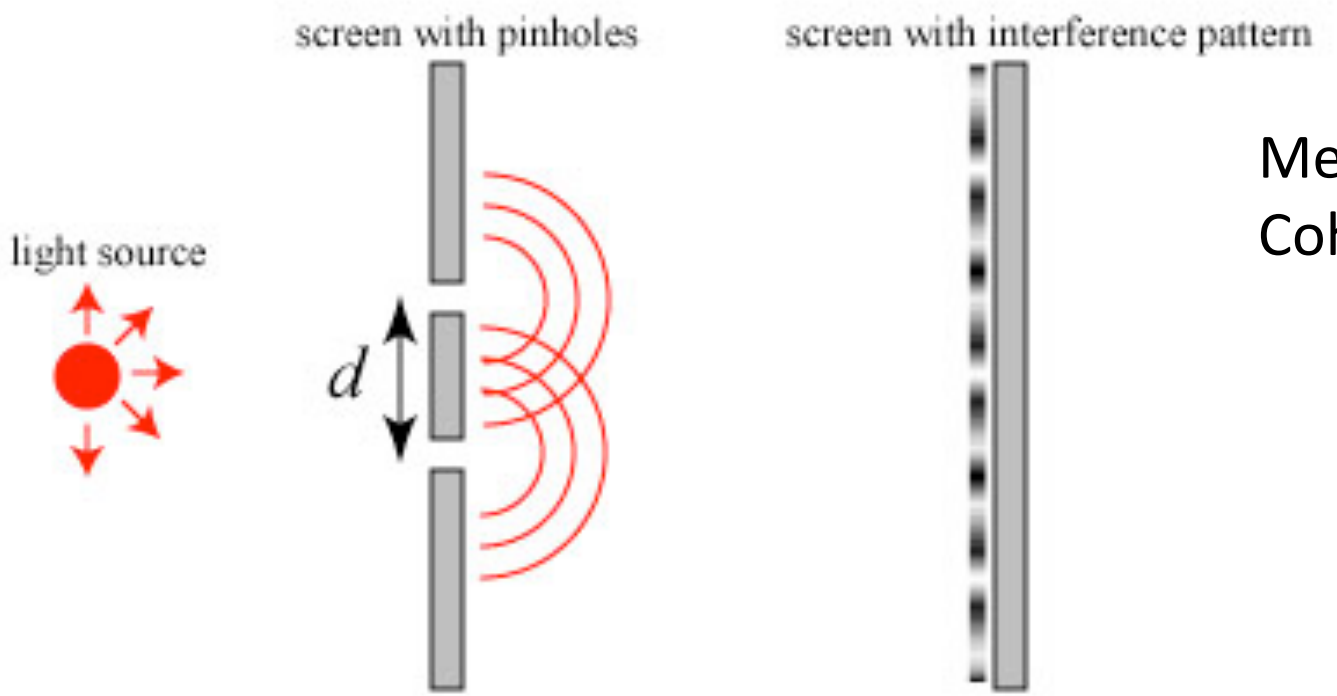
$$n_x \neq n_y$$



Practicals Activity 10.3

- A thin plate of calcite is cut with its Optical Axis (OA) parallel to the plane of the plate. What minimum thickness is required to produce a quarter-wave path difference for sodium light whose wavelength in a vacuum is 589 nm? [Note the ordinary and extraordinary indices of refraction for calcite: n_o = 1.6584 , n_e = 1.4864.]

A Young Double Slit Experiment

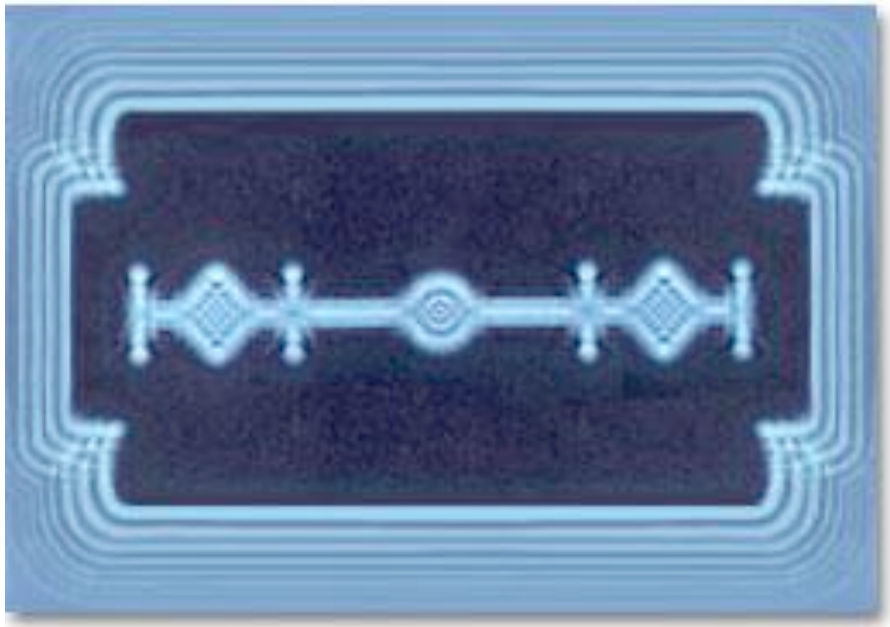


Measures Spatial Coherence

- When d exceeds a critical value, D, the fringes disappear
- D = "Transverse Coherence Length" for this particular light source
- πD^2 is the "Coherence Area"
- Coherence area for filtered sunlight: $A \sim 10^{-2}$ mm^2
- Coherence area for filtered starlight: $A \sim 6$ m^2

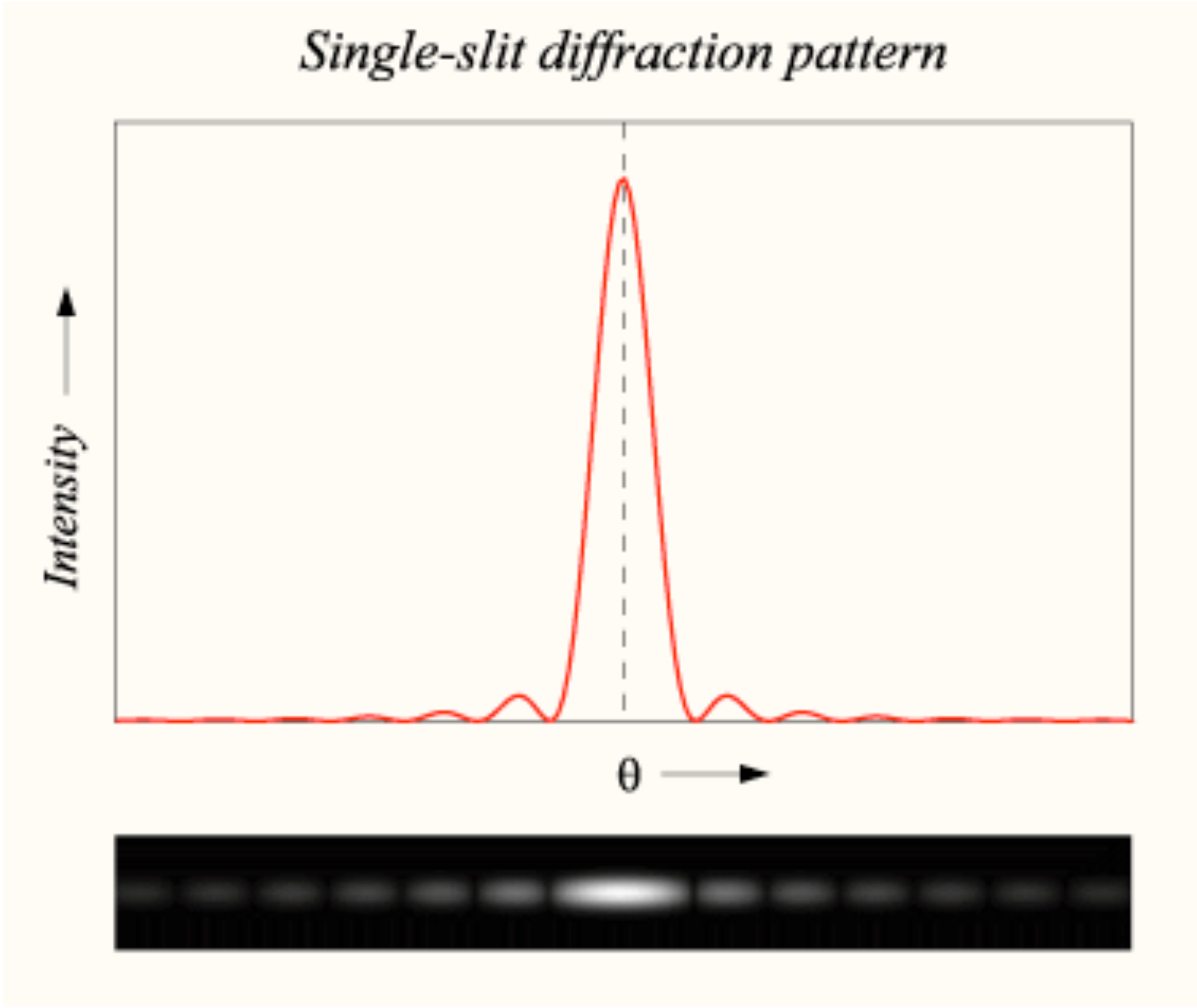
Source: http://skullsinthestars.com/2008/09/03/optics-basics-coherence/

Diffraction



Francesco Grimaldi

- Sometimes light does not travel in straight lines, or rays. The rays bend around edges, because light is actually a wave.
- This was first noted and discussed by Grimaldi in 1640.
- (Grimaldi also discovered the freefall equation $d = \frac{1}{2} a t^2$.)


Single-slit diffraction pattern
Intensity
θ