PHY385-H1F Introductory Optics

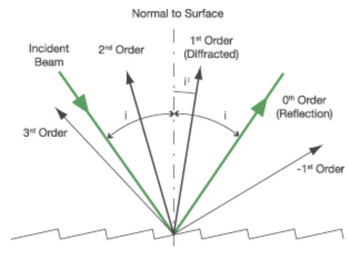
Last Class!! – Outline:

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

Diffraction Gratings

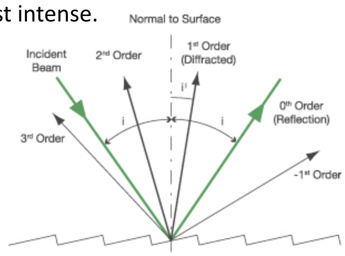
- Reflection gratings obey a similar equation as transmission gratings:

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



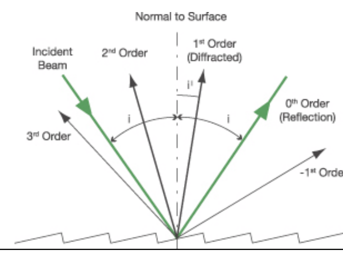
Diffraction Gratings

- 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.



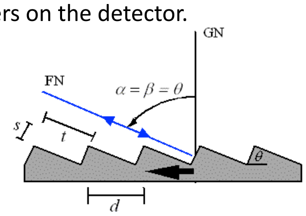
Diffraction Gratings

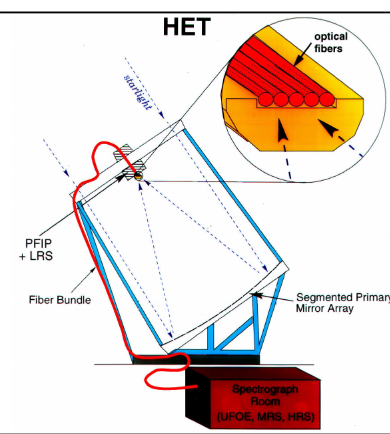
- The grating below is "blazed", meaning its surface is a reflective saw-tooth shape. Blazing can increase the efficiency for a particular order.
- It appears to be blazed for 1st order



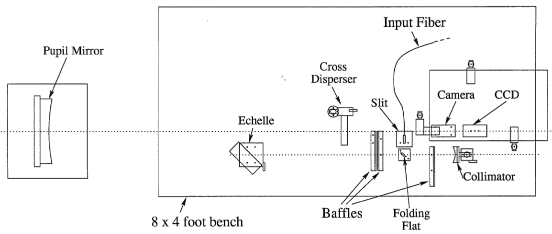
Echelle Gratings

- 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.

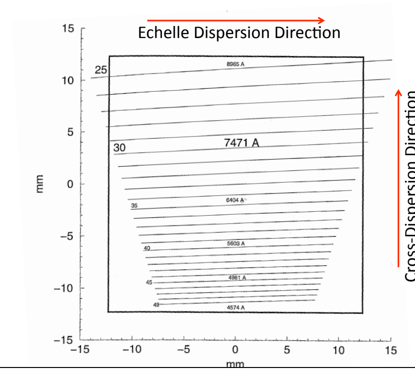




Upgraded Fiber-Optic Echelle (UFOE) Spectrograph – bench layout



Echelle Spectrum on the CCD detector



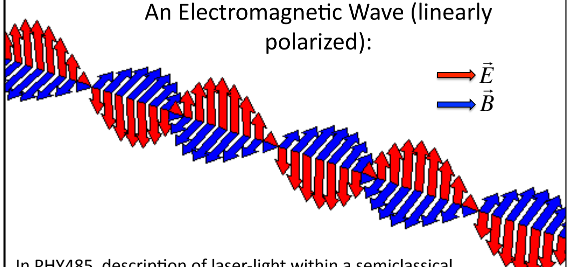
Final Exam

- 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.

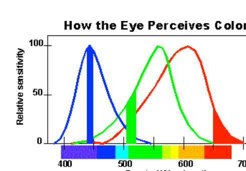
An Electromagnetic Wave (linearly polarized):



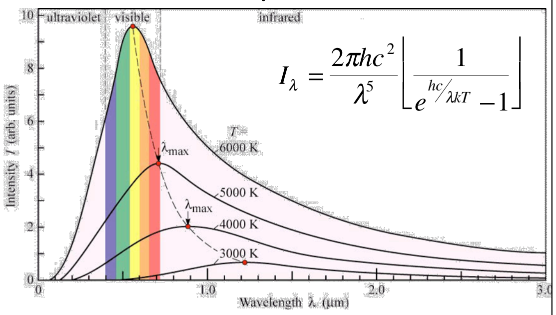
In PHY485 description of laser-light within a semiclassical picture in which the fields are treated classically and matter is treated quantum mechanically.

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.

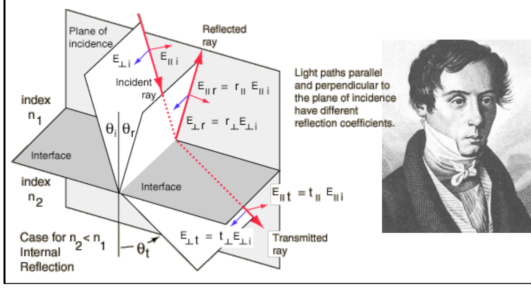


Blackbody Radiation

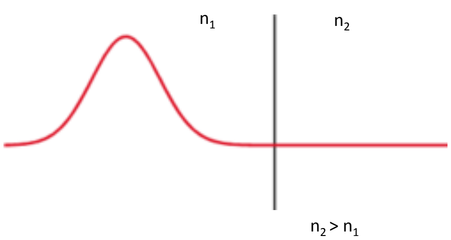


$$I_\lambda = \frac{2\pi hc^2}{\lambda^5}\left[\frac{1}{e^{hc/\lambda kT}-1}\right]$$

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



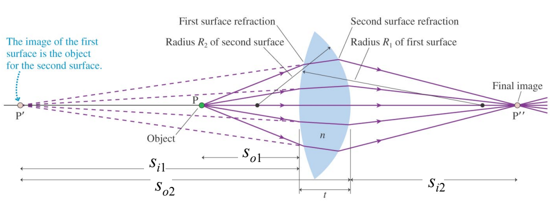
Partial transmission and reflection amplitudes of a wave travelling from a low to high refractive index medium.



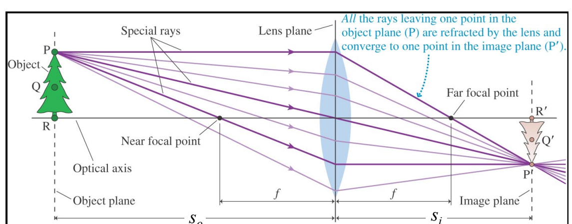
Practicals Activity 10.1

- 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: $\frac{1}{s_o} + \frac{1}{s_i} = \frac{1}{f}$

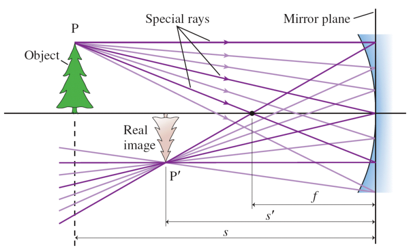
f is positive for a converging lens
f is negative for a diverging lens
s_o is positive means object is real, to the left of lens
s_i is positive means image is real, to the right of lens
s_i is negative means image is virtual, to the left of lens

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

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

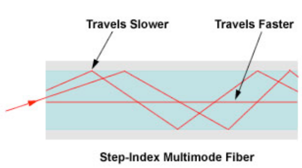
where the focal length f is related to the mirror's radius of curvature by

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

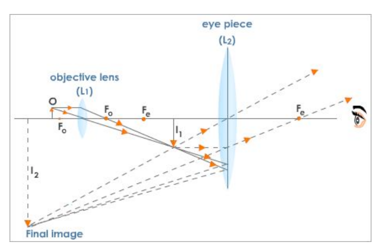
Sign convention for spherical mirrors

	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



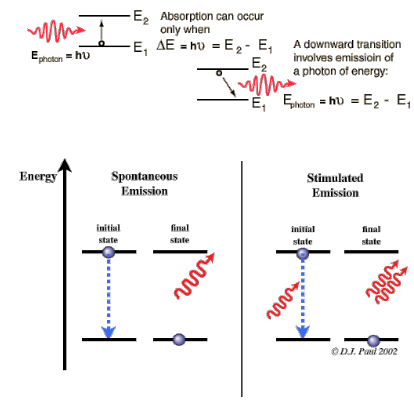
$$MP = \left(-\frac{16\,\text{cm}}{f_o}\right)\left(\frac{25\,\text{cm}}{f_e}\right)$$

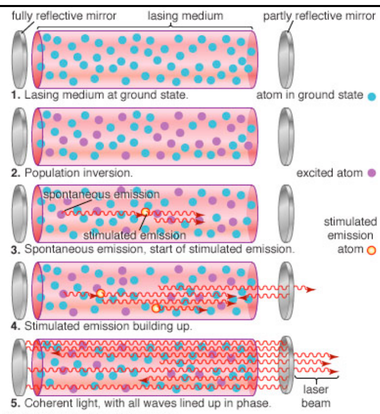
Telescope

- 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.

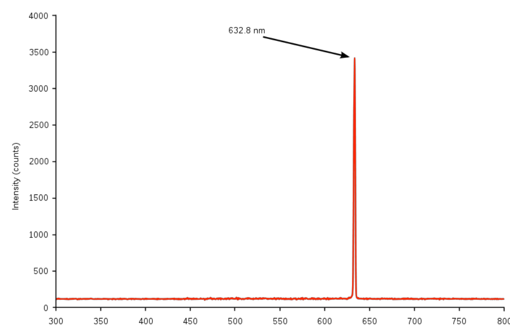
Galileo Galilei

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

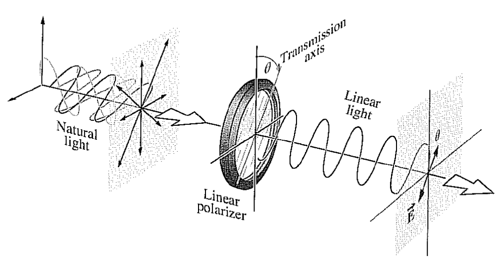




Spectrum of a He-Ne Laser

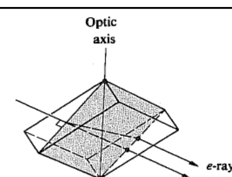


Dichroism



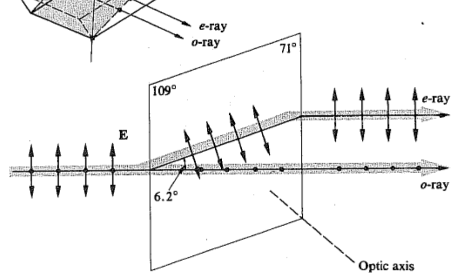
"Unpolarized" light incident on a linear polarizer tilted at an angle θ with respect to the vertical

---



Birefringence

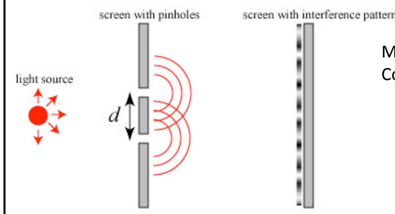
$$n_x \neq n_y$$



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

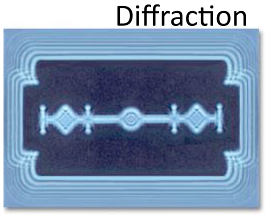


Measures Spatial Coherence

- 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 ~ 10^{-2} mm^2
- Coherence area for filtered starlight: A ~ 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 $d = \frac{1}{2} a t^2$.)