Optical instrument

Five components

1. **a stable source of radiant energy**
2. **a transparent container for holding the sample**
3. **a device that isolates a restricted region of the spectrum for measurement**
4. **a radiation detector**
5. **a signal processor and readout**

Sample Holders

Cuvettes

flat surface best - better reproducibility

avoid fingerprints, dust, etc. on surface

must be transparent in region of interest

must be of fixed size for quantitative work (1 cm thickness is a very common size in UV-Vis work)

Sample Holders (Cuvettes)

Cell Materials

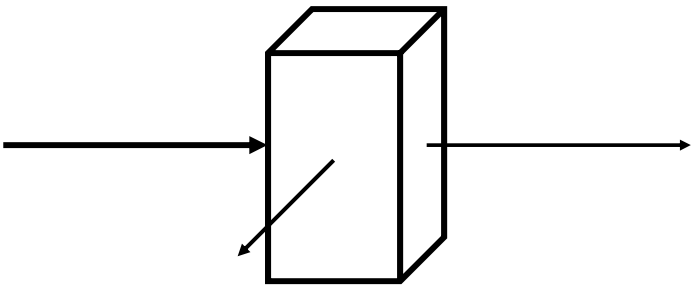
UV – quartz, fused silica

Visible - glass, plastic (UV cells can be used)

IR – NaCl, KBr

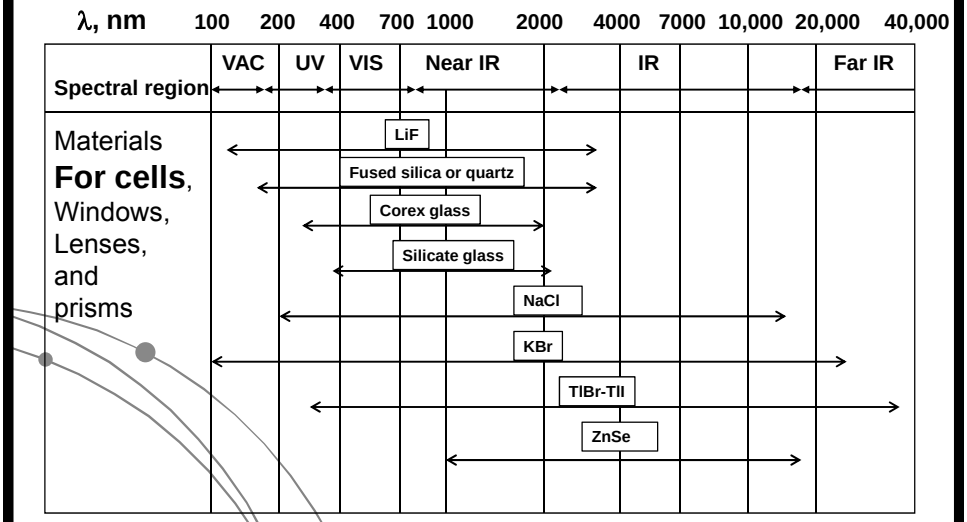
Material	nm range
quartz	150-3000
Glass	375-2000
Plastics	
Polystyrene	360-800
Methacrylate	280-800

Transparent Sample Container



Reflection: $\frac{I_r}{I_0} = \frac{(n_2 - n_1)^2}{(n_2 + n_1)^2}$

Construction Materials



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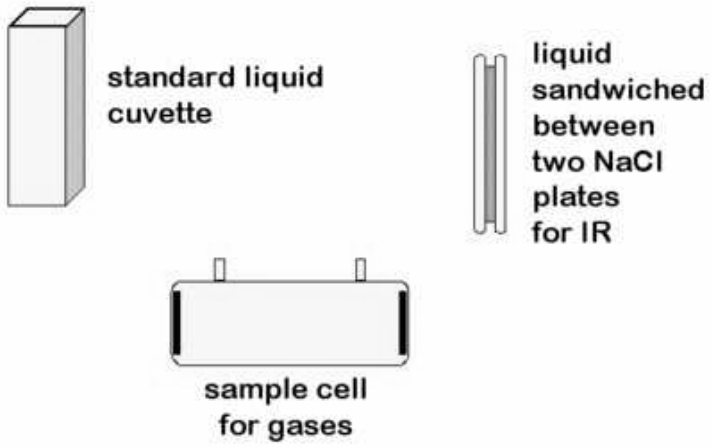
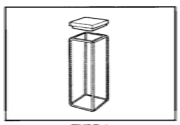
Sample cells



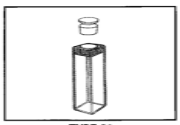
UV-Vis Sample Cells (Cuvettes)

Standard Cell



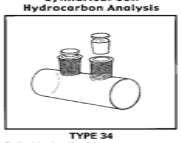
TYPE 1
Cell with fitted cover. Satin finish on two sides. Lightpaths: 1, 2, 5, 10, 20, 40, 50 and 100 mm. Outside dimensions: 45 mm high, 12.5 mm wide.

Standard Cell



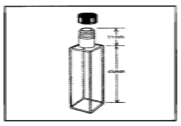
TYPE 21
Same as Type 1, but with tapered teflon stopper.

Cylindrical Cell Hydrocarbon Analysis



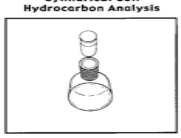
TYPE 34
Cylindrical cell with two stoppers. Lightpaths: 50 and 100 mm. Outside diameter: 22 mm. Use IR Grade for hydrocarbon analysis.

Standard Cell Screw Cap



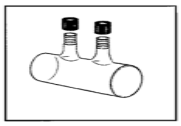
TYPE 1 SC
Same as Type 1 but with screw caps. Lightpath: 10mm only.

Cylindrical Cell Hydrocarbon Analysis



TYPE 32
Cylindrical cell with one stopper. Lightpaths: 2, 5, 10 and 20mm.. Outside diameter: 22 mm. Use IR Grade for hydrocarbon analysis.

Cylindrical Cell Screw Cap



TYPE 34 SC
Cylindrical cell with screw caps. Lightpaths: 50 and 100 mm. Outside diameter: 22 mm. Use IR Grade for hydrocarbon analysis.

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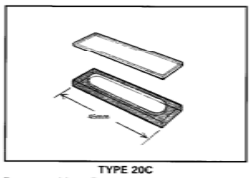
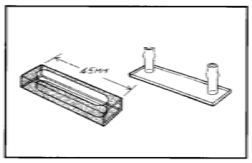
UV-Vis Sample Cells (Cuvettes)

Demountable Cell



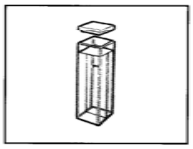
TYPE 20C
Demountable cell. Pathlengths: 0.1, 0.5 and 1mm. Outside Dimensions: 12.5mm wide x 45mm long/high.

Flow Through Demountable Cell



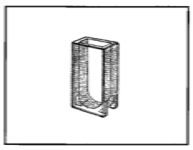
TYPE 49
Flow through demountable cell with hose barbs. Pathlenths: 0.5, 1, 2, 5, 10mm. Outside Dimensions: 12.5mm wide x 45mm long/high.

Divided Cell



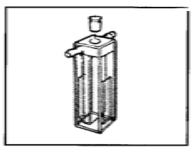
TYPE 26
Divided pathlength cell with fitted cover. Lightpaths: 2 mm x 10 mm. Outside dimensions: 45 mm high x 12.5 mm wide.

Absorptiometer Cell



TYPE 60
Made of optical glass. Cell for Absorptiometer. Lightpaths: 5, 10, 20, 40, 100 mm. Outside Dimensions: 40 mm x 28 mm wide.

Water Jacketed Cell



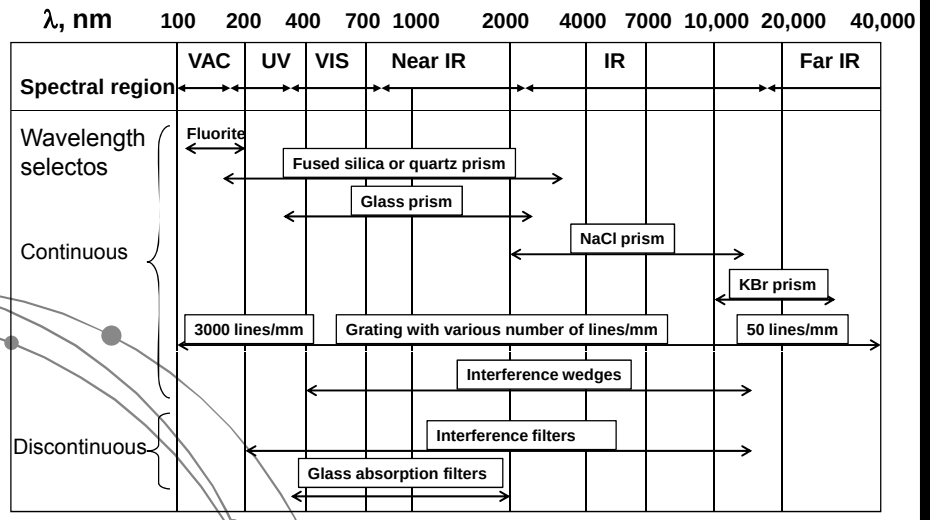
TYPE 24
Jacketed cell for heating or cooling. Sample section 4 mm wide. Lightpath: 10 mm. Outside dimensions: 45 mm, high x 12.5 mm wide.

Optical instrument

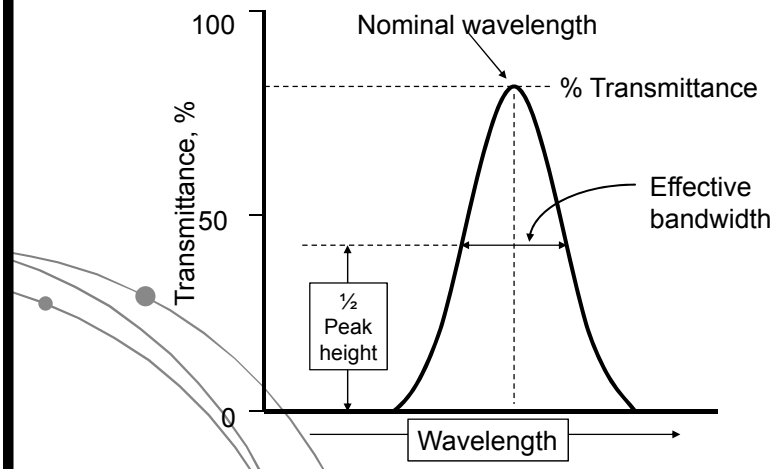
Five components

1. **a stable source of radiant energy**
2. **a transparent container for holding the sample**
3. **a device that isolates a restricted region of the spectrum for measurement**
4. **a radiation detector**
5. **a signal processor and readout**

wavelength selectors for spectroscopic instruments.



Output of a typical wavelength selector



Optical filters

Bandpass filters

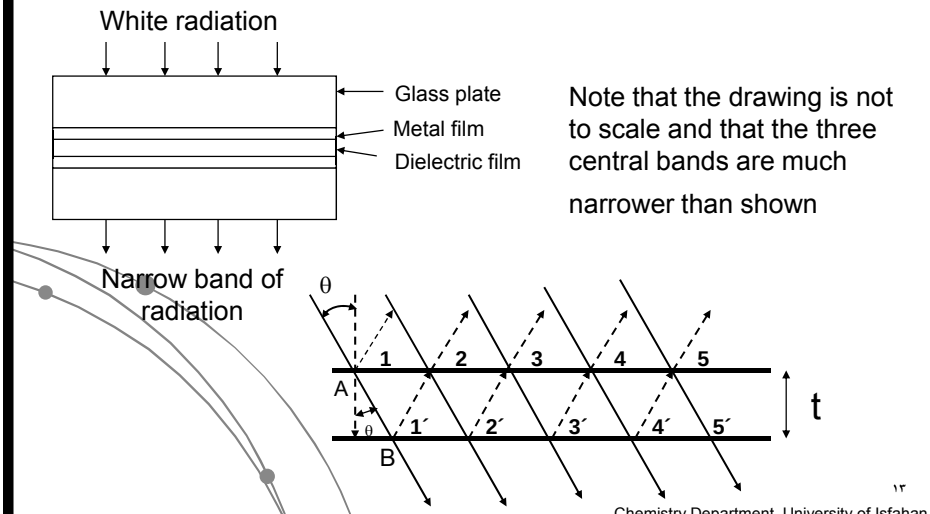
Long pass filters

Short pass filters

Interference filters

Interference filter

Transmits light at a specific wavelength, usually 10-20 nm and 10-20% peak transmission efficiency



Interference filter

- Rely on optical interference to provide relative narrow bands of radiation.

  $\mathbf{n}\lambda' = 2AB$, $AB = t / \cos(\theta)$, $\mathbf{n}\lambda' = 2t/\cos(\theta)$

  (θ approaches zero) $\mathbf{n}\lambda' = 2t$

  λ' = The wavelength in the medium, $\lambda = \eta\lambda'$

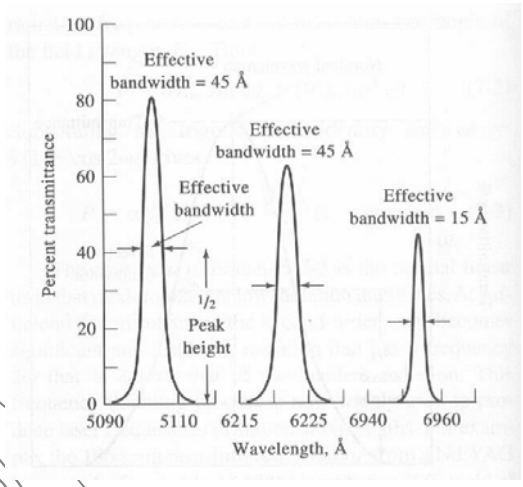
  η = refractive index of the medium

- The wavelength of radiation transmitted by the filter are:

  $\lambda' = 2t/\mathbf{n}$, $\lambda = 2t\eta/\mathbf{n}$ ($\mathbf{n}$ is the order of interference)

  - Interference filters: ultraviolet to about 14 μm in the infrared
  - typically, effective bandwidths are about 1.5% of the wavelength at peak transmittances.

Interference filter

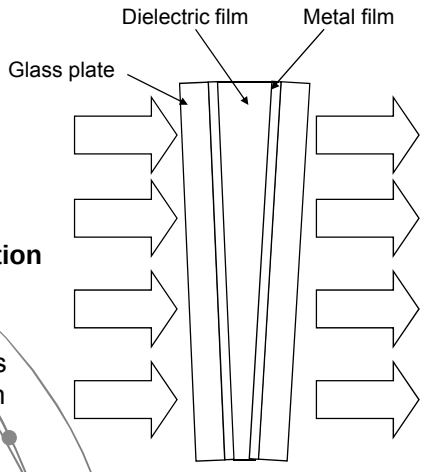


Transmission characteristics of typical interference filters

Interference filter (Wedges)

Transmits light of different wavelengths, depending on the thickness of the filter subjected to the incident radistion.

The length of the filter ranges from 50 to 200 mm.



Note that the drawing is not to scale and that the three central bands are much narrower than shown

White radiation

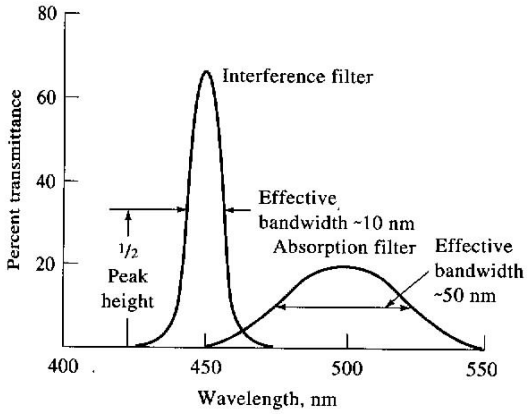
Narrow band of radiation

The radiation transmitted varies continuously from one ened to the other

Absorption filters

function by absorbing certain portions of the spectrum, with bandwidths that range from perhaps 30 to 250 nm;

This figure compares the effective bandwidths of interference and absorption filters.

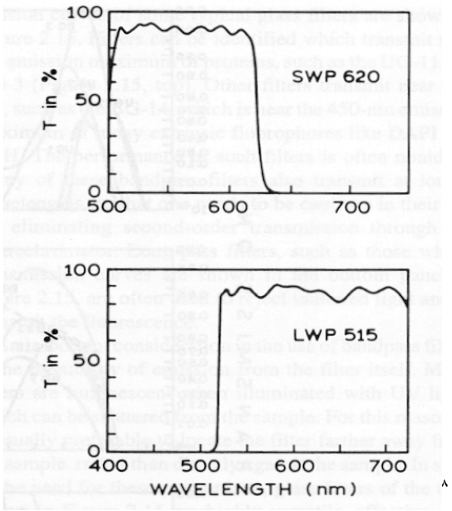


Long pass filter and short pass filters

Transmit a relative large range of radiation

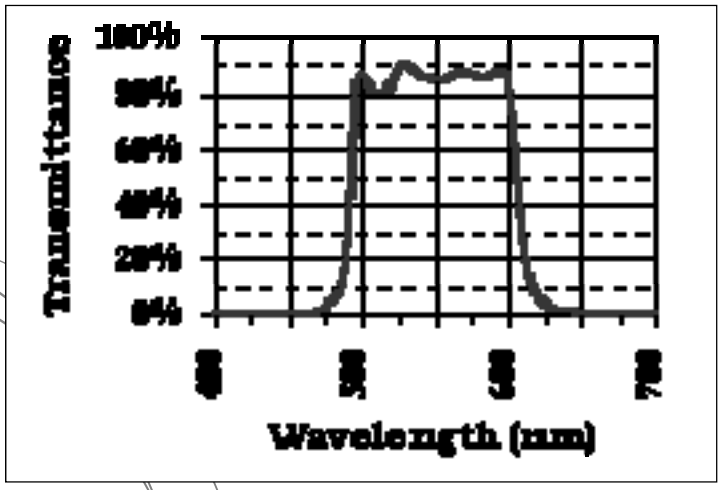
Transmission (T) curves of

- a 620-nm short-wavelength-pass filter (Cut-off)
- a 515-nm long-wavelength-pass filter (Cut-on)



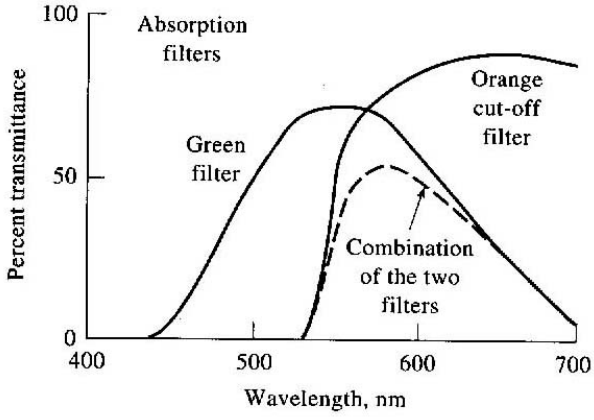
Band-Pass Filters

Transmit a relative large range of radiation



Absorption filters

Comparison of various types of absorption filters for visible radiation.



MONOCHROMATORS

used to disperse polychromatic or white light into the various colors or wavelengths.

dispersion can be accomplished using two types of dispersing elements: prisms or reflection gratings (At present. mostly diffraction gratings)

The performance specifications of a monochromator include the dispersion, the efficiency, and the stray light levels.

MONOCHROMATORS

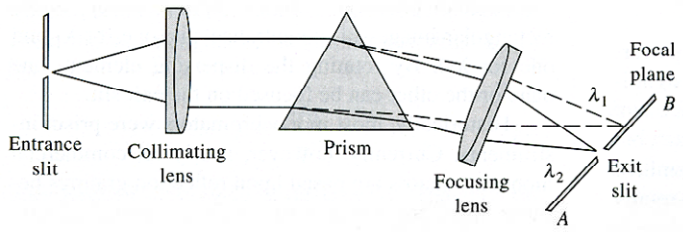
Major components:

- Entrance slit
- Collimating lens
- Prism or grating that disperses the radiation into its component λ
- Focusing elements to refocus the image on a focal plane
- Exit slit that isolates the desired spectral band

- Grating monochromators: angular dispersion of the λ results from diffraction, which occurs at the reflective surface;
- Prism monochromators: refraction at the two faces results in angular dispersal of the radiation.

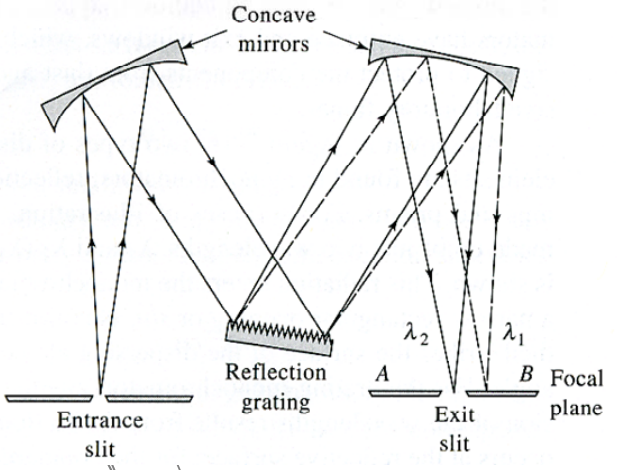
Prism Monochromator

Bunsen Prism Monochromator



Grating Monochromator

Czerney-Turner
Grating Monochromator



Advantages of Grating Monochromators

- Wavelength independence of dispersion.
- Fixed dispersion makes it easy to scan an entire spectrum at constant bandwidth after initial adjustment of slitwidth.
- Better dispersion for same size of dispersing element.
- Can disperse radiation in far UV and infrared regions where absorption prevents use of prisms.

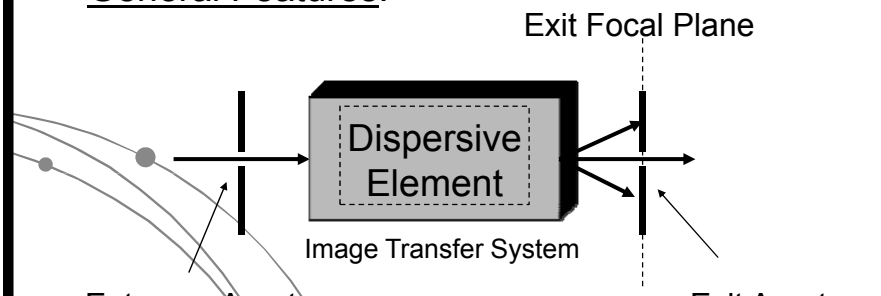
Disadvantages of Grating Monochromators

- Produce great amounts of stray radiation.
- Produce more high-order spectra.
- Both of these disadvantages can be minimized with filters.

Wavelength Selectors

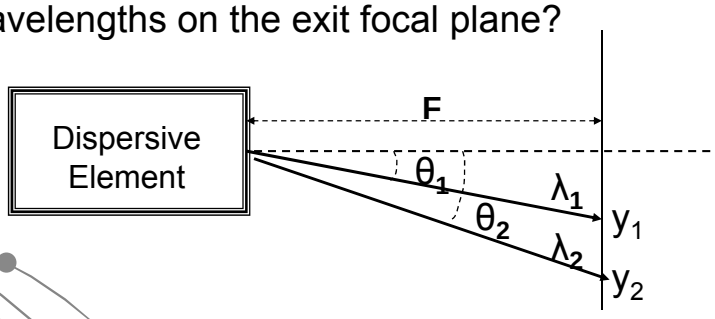
- Dispersive Devices
  - separates EMR into individual λ-components

General Features:



Dispersion (Terminology)

- How do we quantify the spatial separation of wavelengths on the exit focal plane?



Angular Dispersion: $D_a = d\theta/d\lambda$ (property of dispersive element)

Linear Dispersion: $D = dy/d\lambda$ (property of dispersive device)

More Dispersive Terminology

- If dθ is small, it can be shown that:

$$D = F \times D_a$$

Sin dθ = dθ = dy/F

- More commonly, we will use:
- **Reciprocal Linear Dispersion** (D^{-1}) = 1/D
  - -typically around 0.1 - 20 Å/mm in UV/Vis
- **Effective Bandwidth:**

$$\Delta\lambda_{eff} = D^{-1} \times w$$

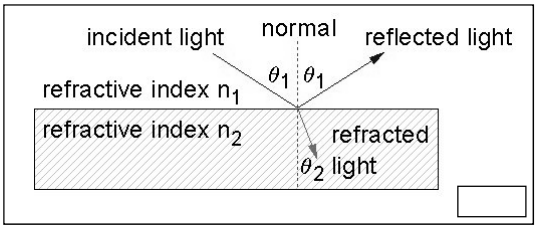
Slit-width

D^{-1} = 16 Å/mm
w = 100 µm
$\Delta\lambda_{eff}$ **= 1.6 Å**

Prism

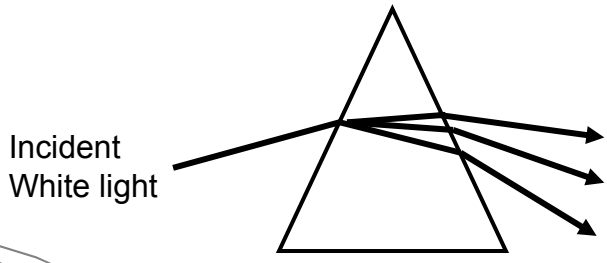
- As we saw in the previous chapter, refraction of light is given by Snell's law:

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

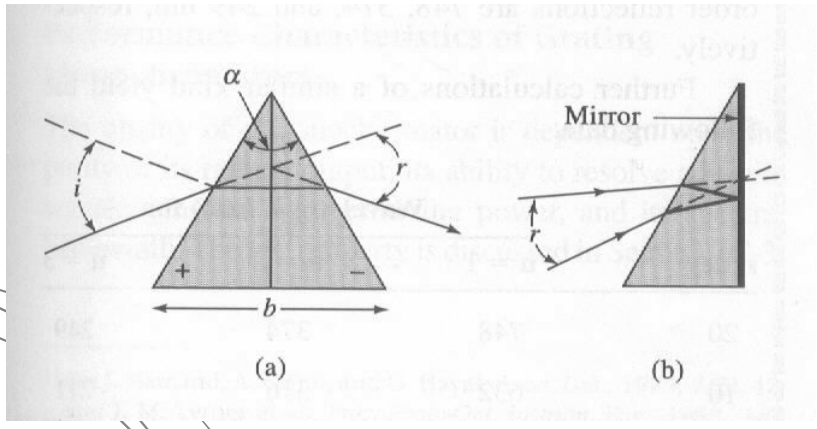


A prism is a transparent optic that is shaped to bend light. Since the refractive index of a material varies with wavelength, prisms are useful for dispersing different wavelengths of light.

Dispersion of white light by a prism



Dispersion by a prism



(a) quartz Cornu types and (b) Littrow type

Wavelength selectors

Advantages of prisms

Allow selection of a range of λ.

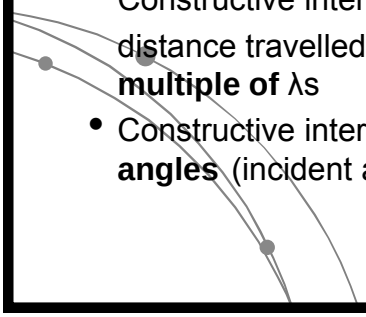
Relative inexpensive.

Disadvantages

Small dispersion at long λ.

Light must pass through the prism which limits the λ that can be used (not absorbed).

Rainbow

Diffraction Gratings

- Typically, a series of closely spaced facets ruled onto a reflecting surface
  - Spacing of facets must be comparable to λ of EMR
  - Parallel EMR rays striking adjacent facets will travel different distances
  - Constructive interference occurs if the **difference** in the distance travelled by the two rays is an **integer multiple of** λs
  - Constructive interference will be a function of the **angles** (incident and reflection) and the **wavelength**