I) CONTINUUM SOURCES (review)

1) <u>Thermal radiation</u> (incandescence)

IR Region

a) Nernst Glower b) Globar

c) Incandescent Wire

Visible Region

a) Tungsten filament b) Tungsten-Halogen

2) <u>Gas Discharge Lamps</u> (High Pressure)

a) Hydrogen Lamp b) Deuterium Lamp

c) Xenon Arc Lamp d) Mercury Lamp

II) LINE SOURCES

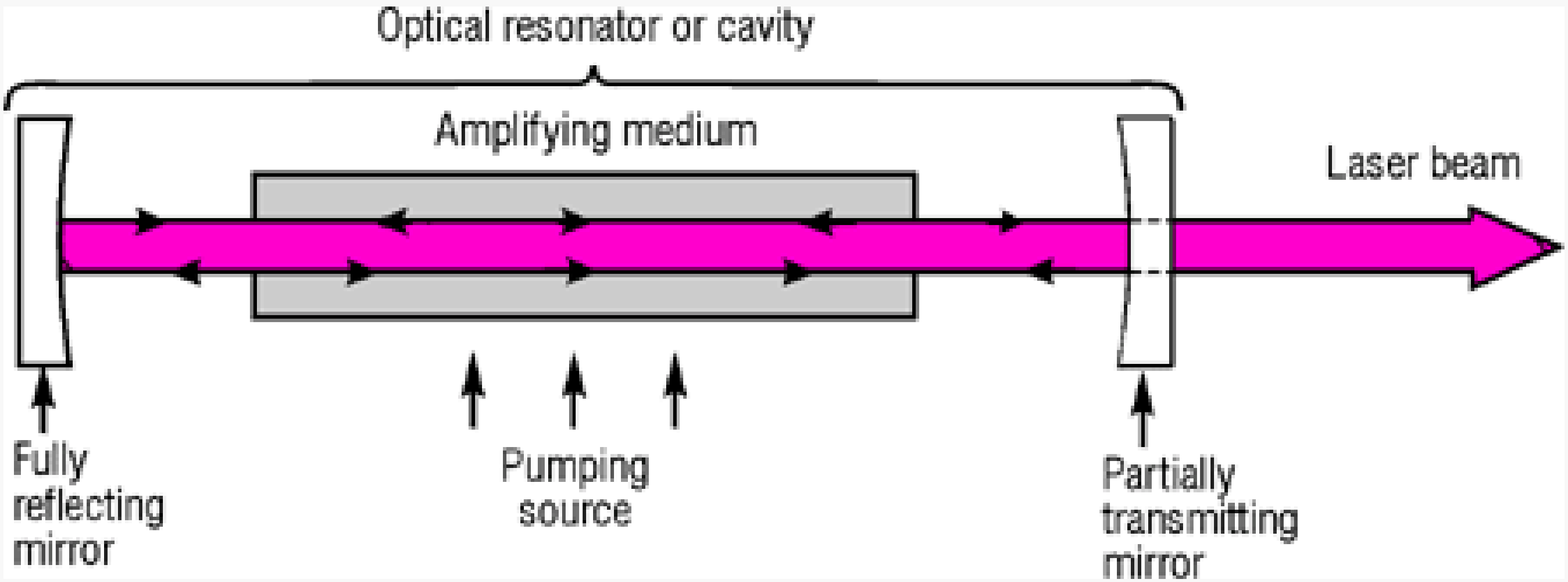
1) **<u>Gas (Vapor) Discharge Lamps</u>** at low pressure (i.e., few torr) – minimize collisional interaction so get line spectrum

   - most common are Hg and Na
   - often used for λ calibration
   - Hg pen lamp
   - fluorescent lights are another example
   - also used UV detectors for HPLC

2) **<u>Hollow Cathode Lamps (HCL)</u>** – for AA

3) **<u>Electrodeless Discharge Lamps (EDL)</u>** - AA

4) **<u>Lasers (Light Amplification by Stimulated Emission of Radiation)</u>** – start with material that will exhibit stimulated emission and populate upper states typically using another light source



Pumping source used to populate upper states can be flashlamp or another laser

Often use prism to select pumping wavelength

Advantages of lasers

1) Intense
2) Monochromatic – very narrow band
3) Coherent – all radiation at same phase angle
4) Directional – full intensity emitted as beam

Limitations of lasers

1) High cost in many cases
2) Wavelength range is somewhat limited
3) Many operate in pulsed mode – some are continuous wave (CW)

Pulsed mode lasers are not always problematic as light sources, can use pulse frequency with gated detection

Wavelength Selection

Three main approaches:

1) Block off unwanted radiation – optical filters

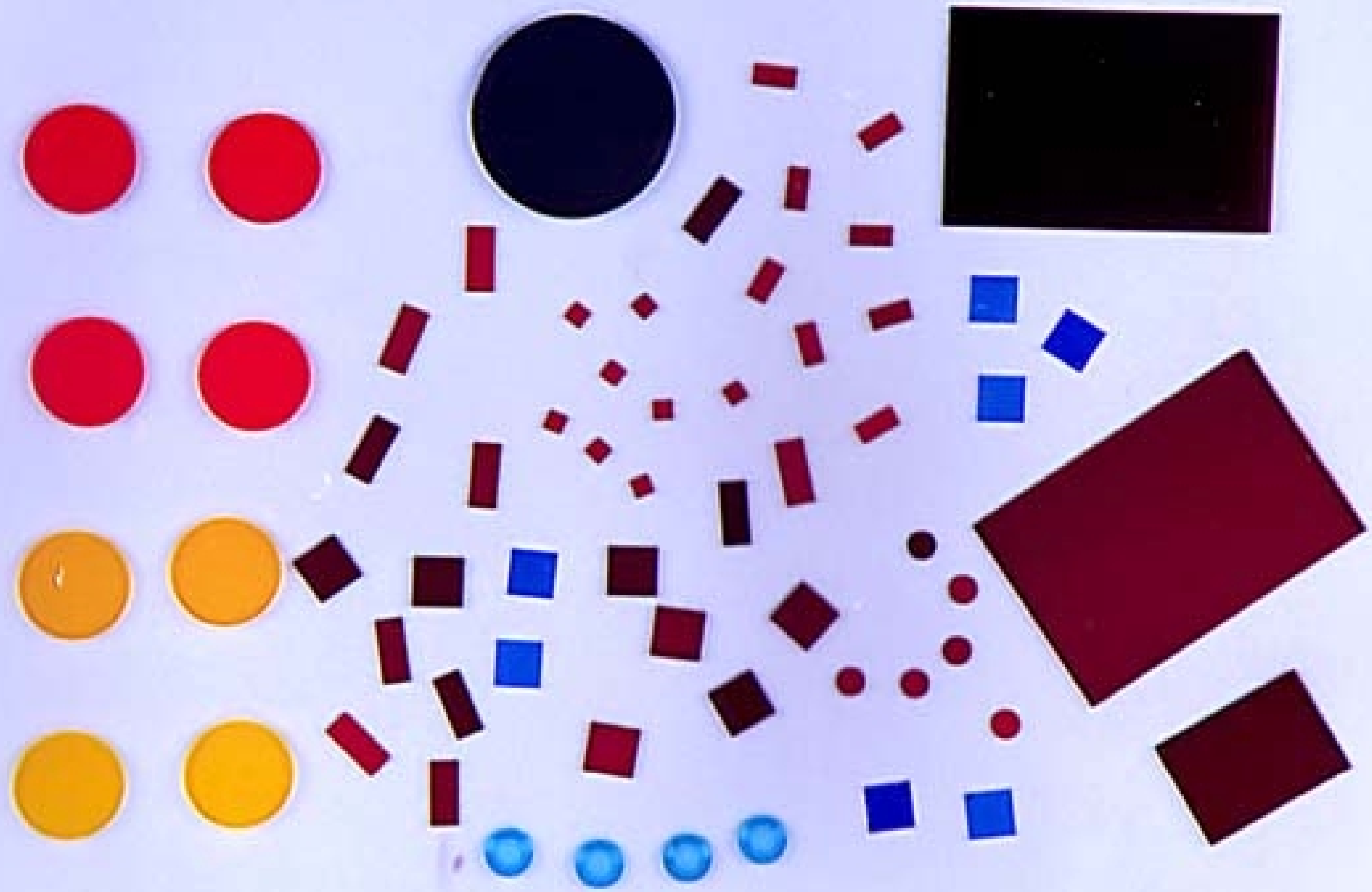
2) Disperse radiation & select desired band – monochromator

3) Modulate wavelengths at different frequencies - interferometer

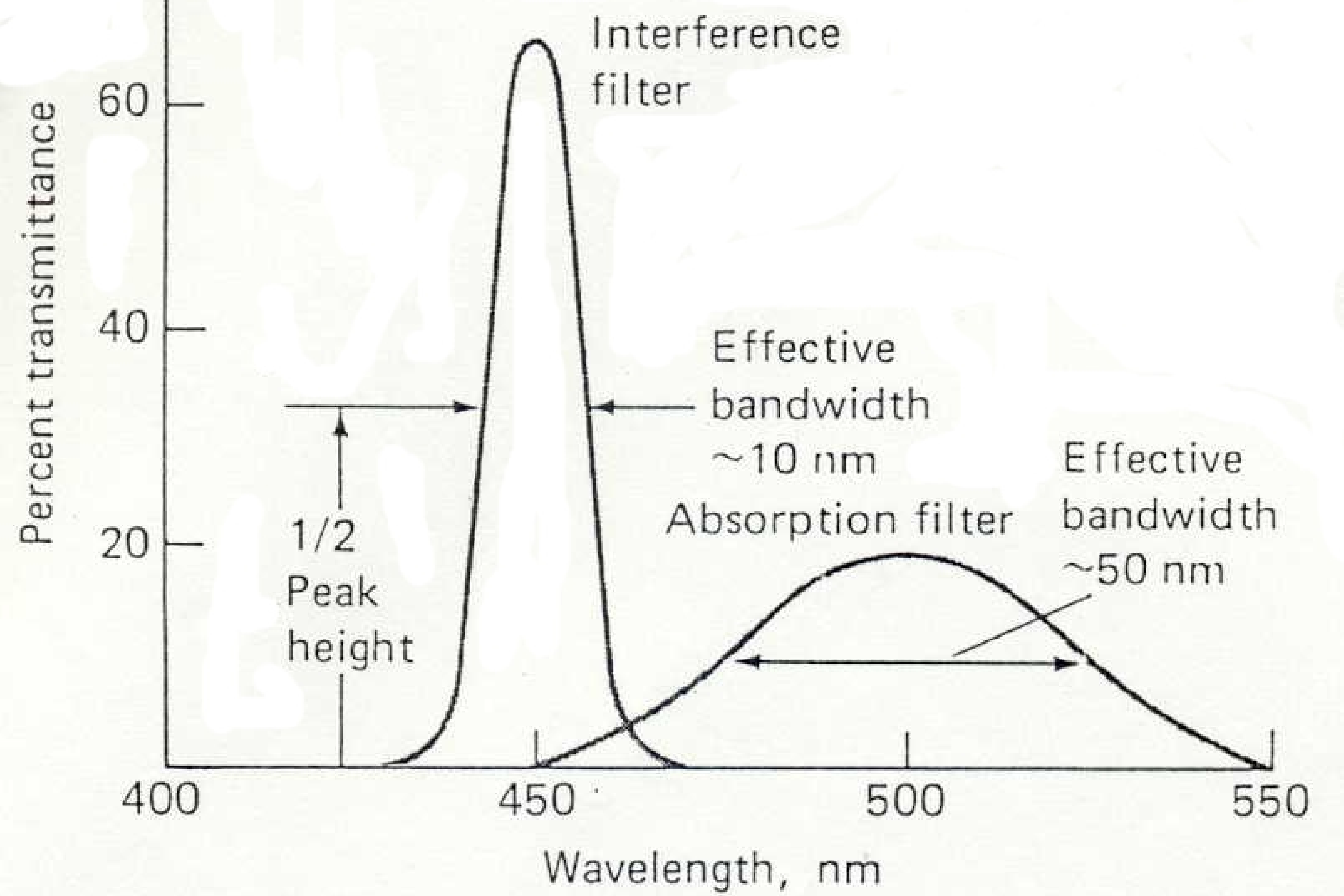
FILTERS

1) **Absorption** – colored glass, colored film, colored solutions – cheapest way

Assortment of Glass & Quartz Optical Filters



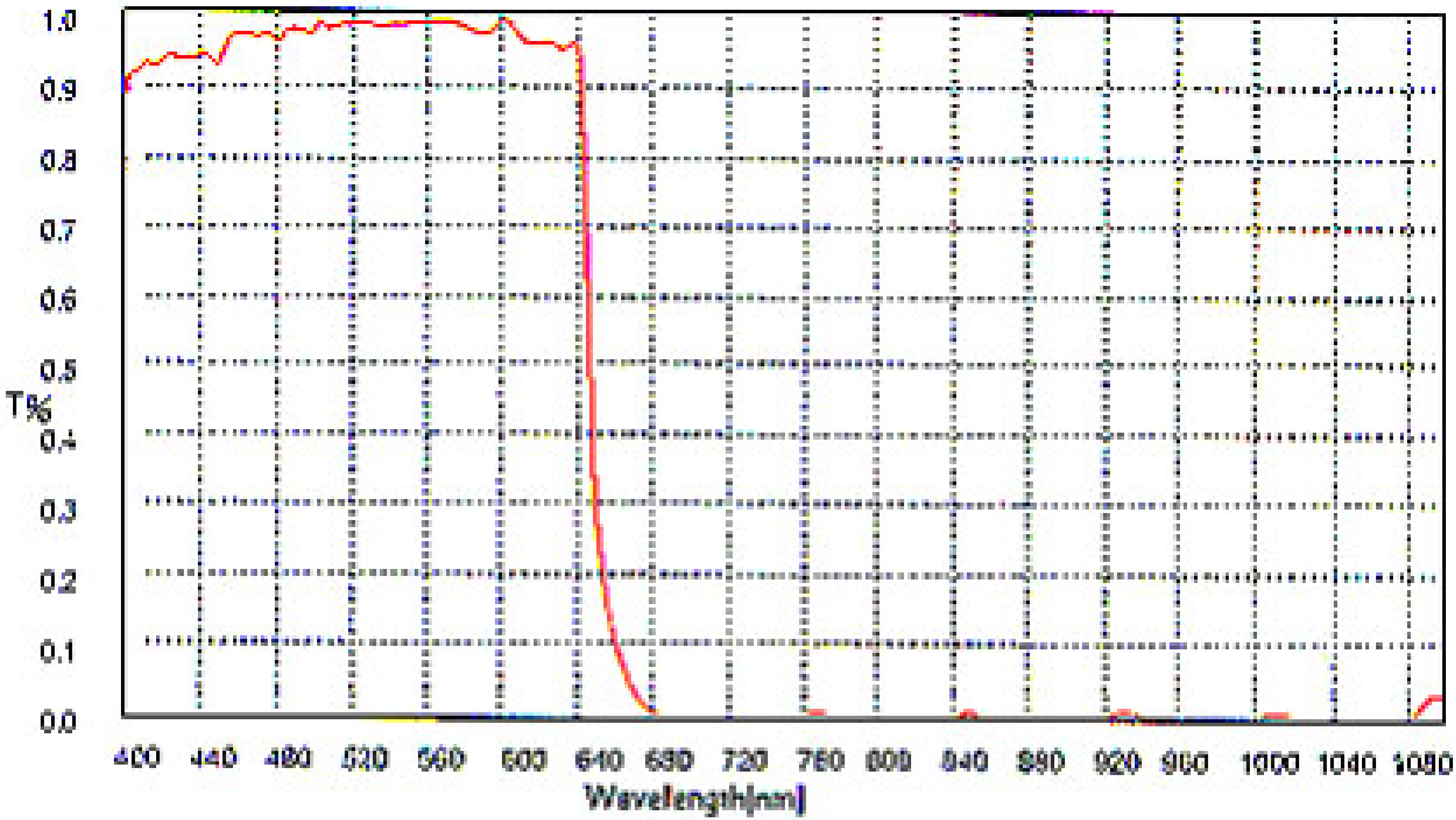
Transmittance Curves for Optical Filters



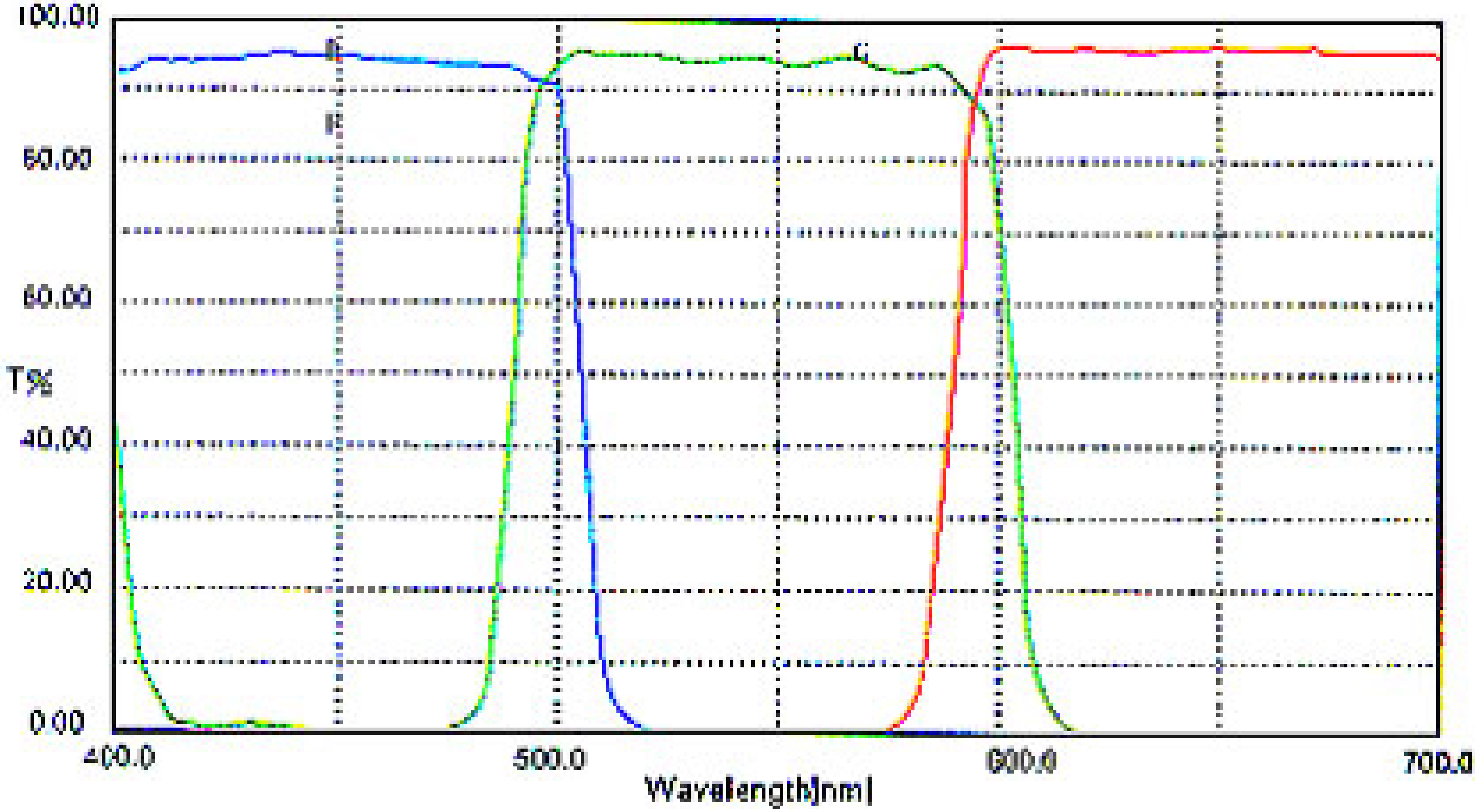
- Absorption filters are also known as bandpass filters
- Usually exhibit low peak transmittance
- Typically have a broad peak profile
- Can use two or more absorption filters together to produce desired transmittance characteristics
- Generic filters are 2 x 2 inch glass or quartz
- Relatively inexpensive

Cut-off filters or sharp-cut filters are also available such as the 650 nm cut-off filter shown here

Cut-on filters have reverse profile

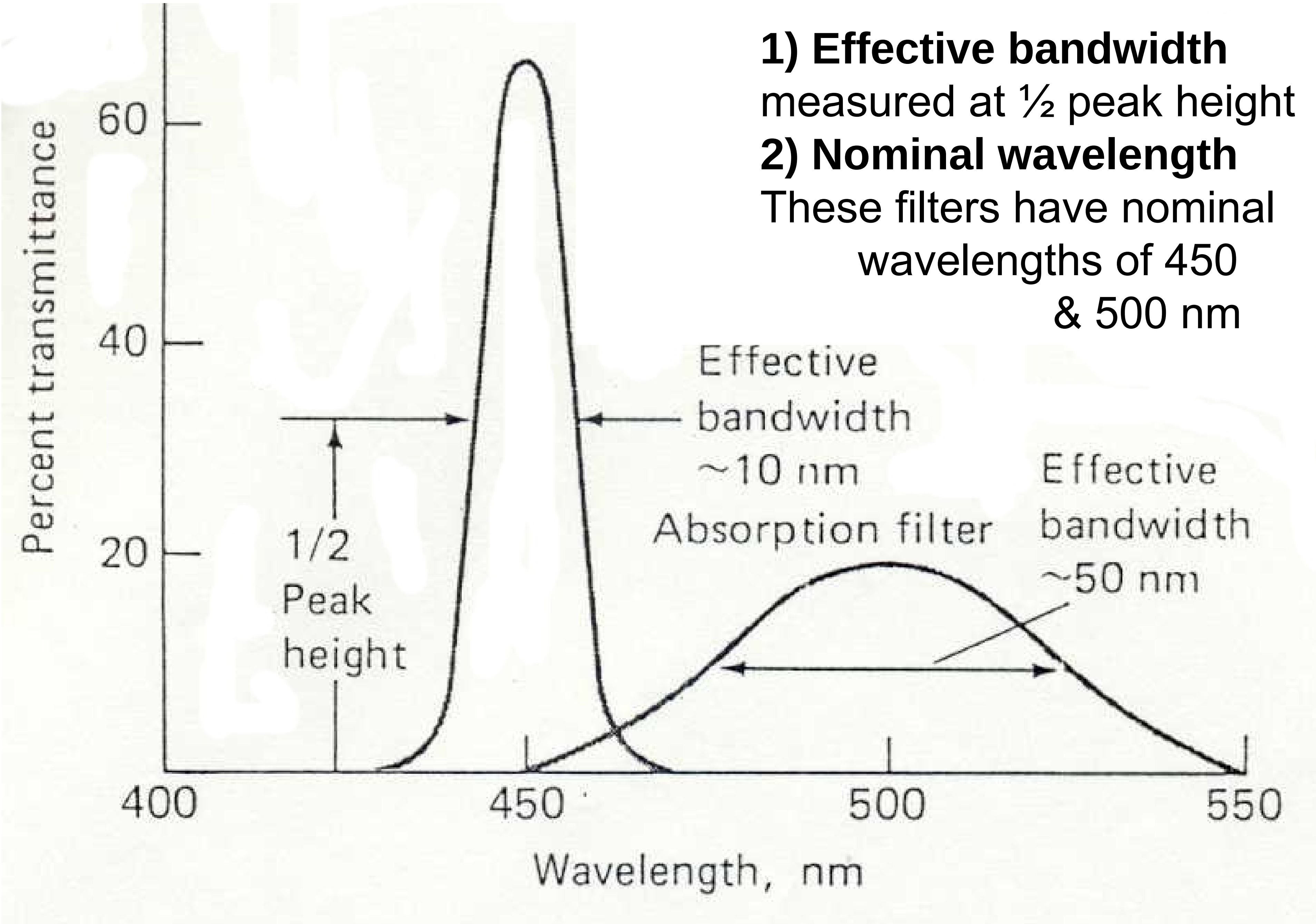


Combining two appropriate cut-off filters produces a bandpass filter. The example shown here comes from 3 filters producing bands at 500 & 600 nm.

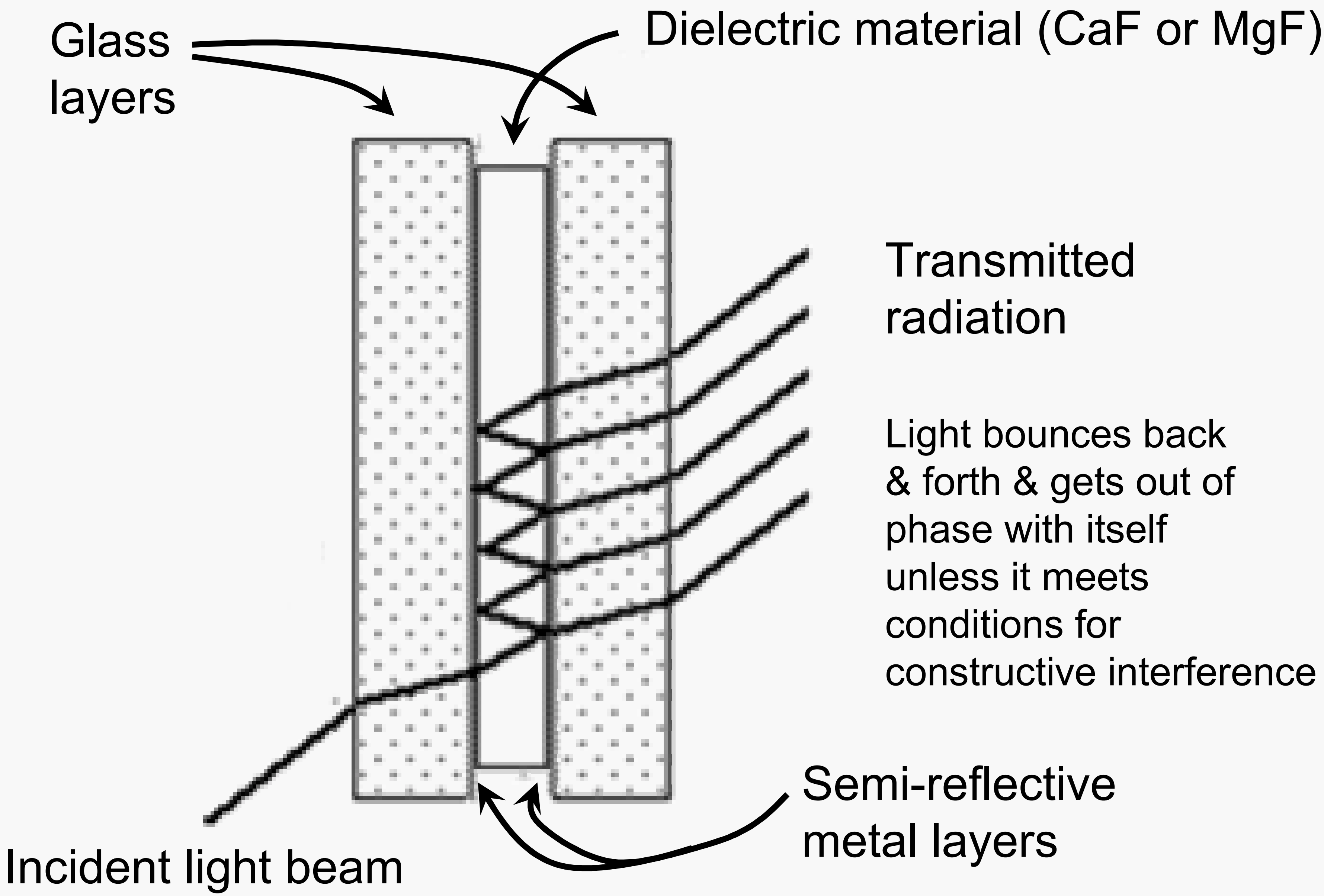


Two terms associated with optical filters are:

1) Effective bandwidth
measured at ½ peak height
2) Nominal wavelength
These filters have nominal wavelengths of 450 & 500 nm



2) **Interference filters** – usually Fabrey-Perot type



Condition for constructive interference

$$2d = \frac{m\lambda}{\eta}$$

order of interference

refractive index of dielectric

distance between semi-reflective layers

- If distance (d) is multiple (m) of wavelength (λ) then it won't be interfered with
- Concept of Order – constructive & destructive interference causes waves with different phase angles to be eliminated except if they are multiples of each other

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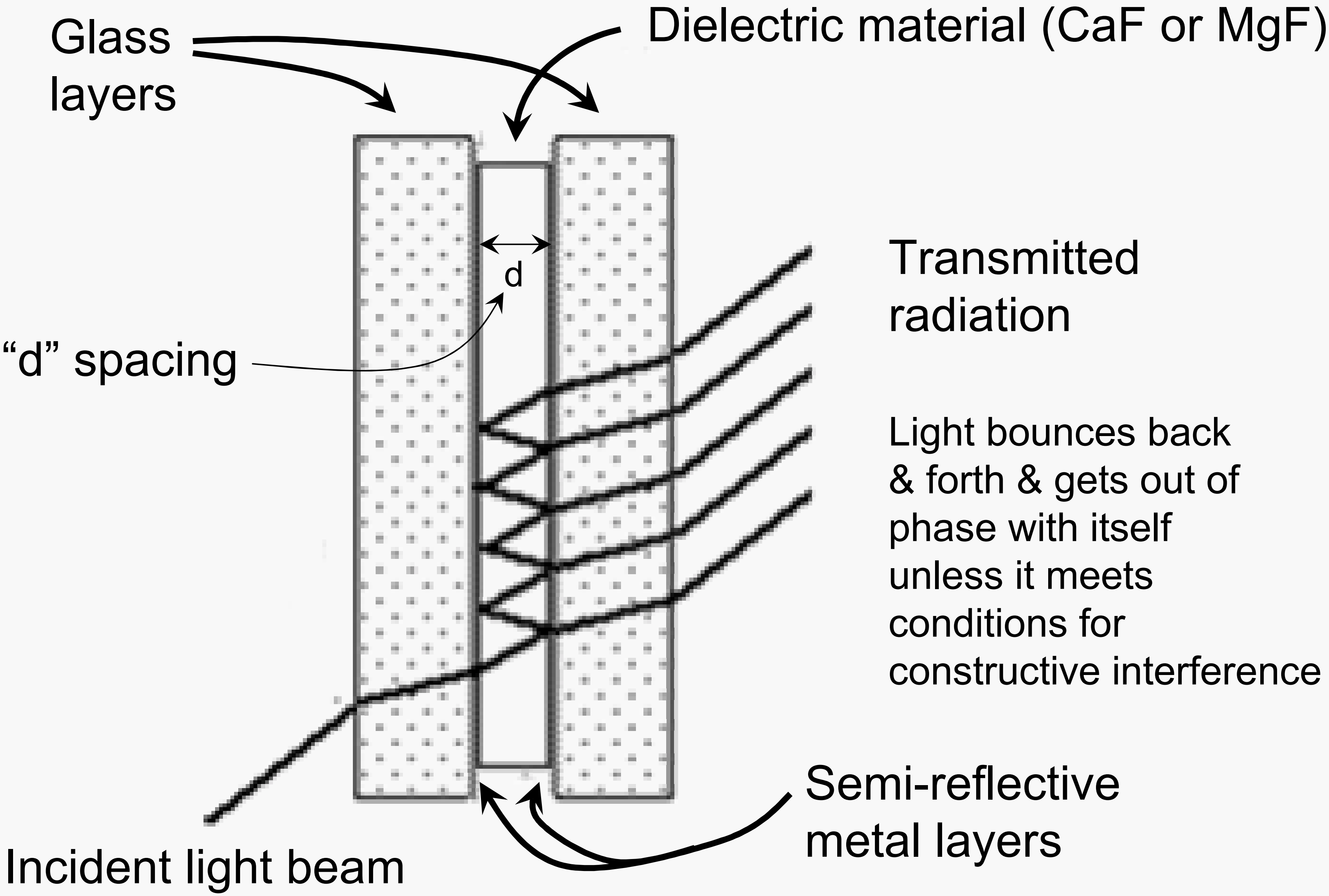

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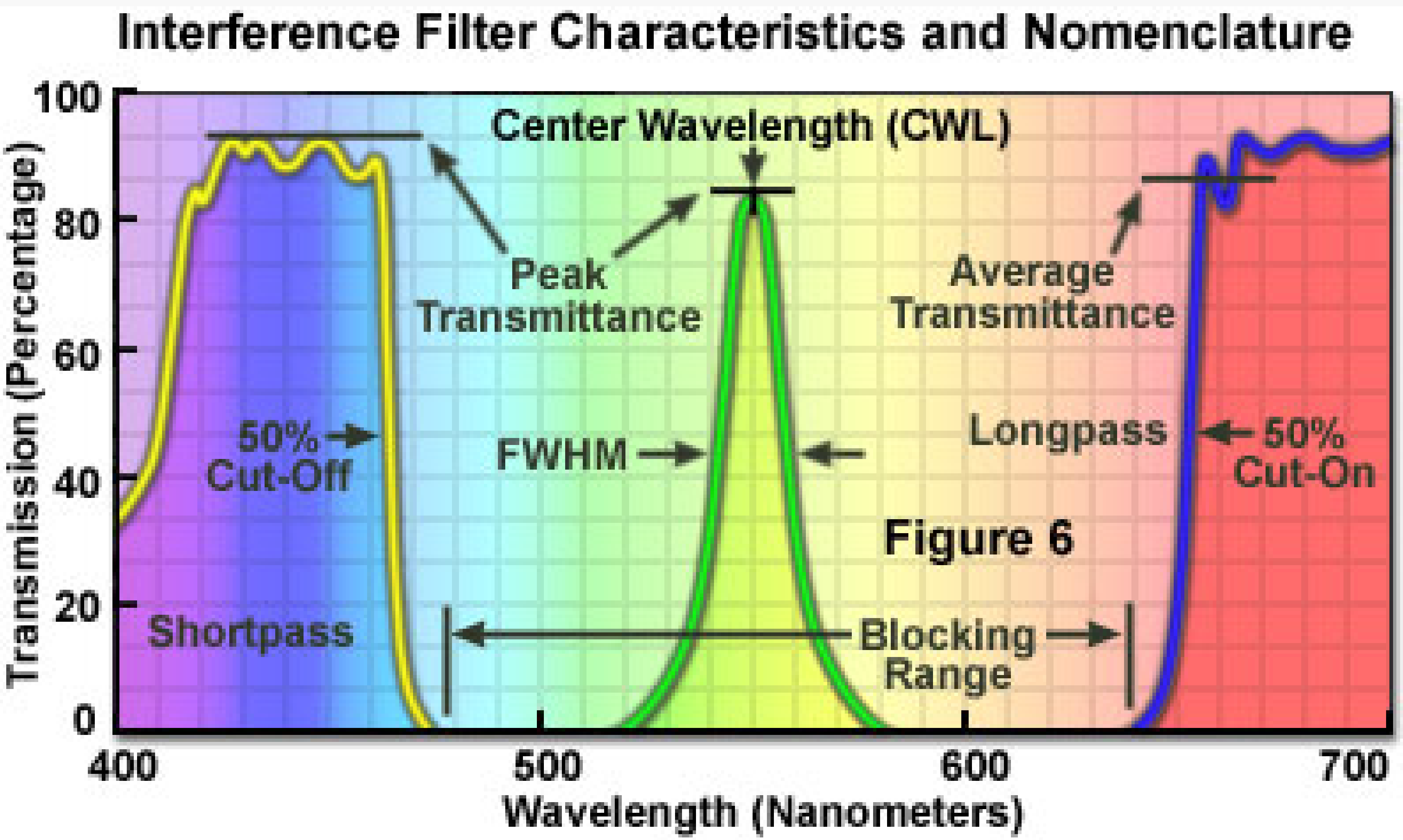
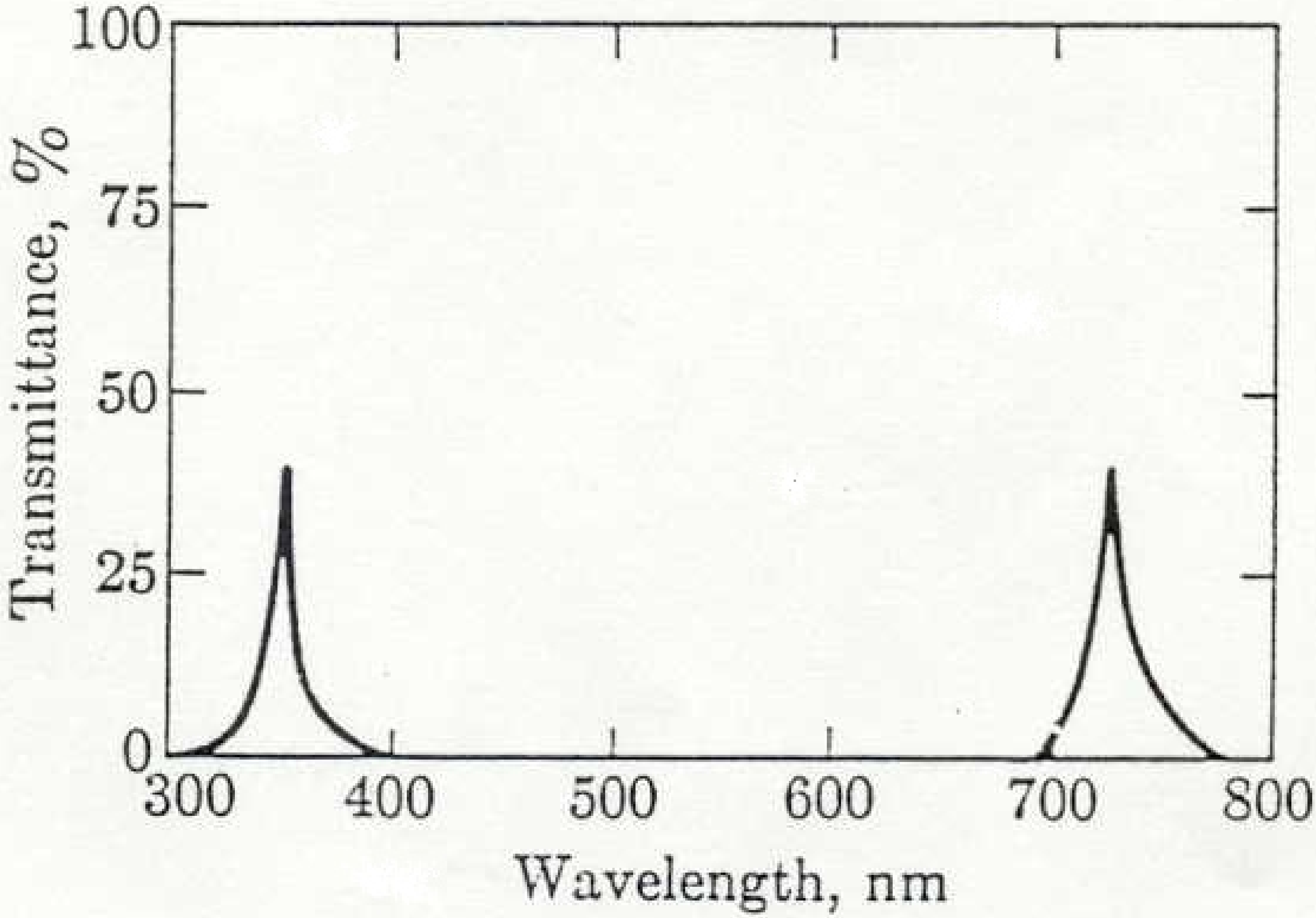
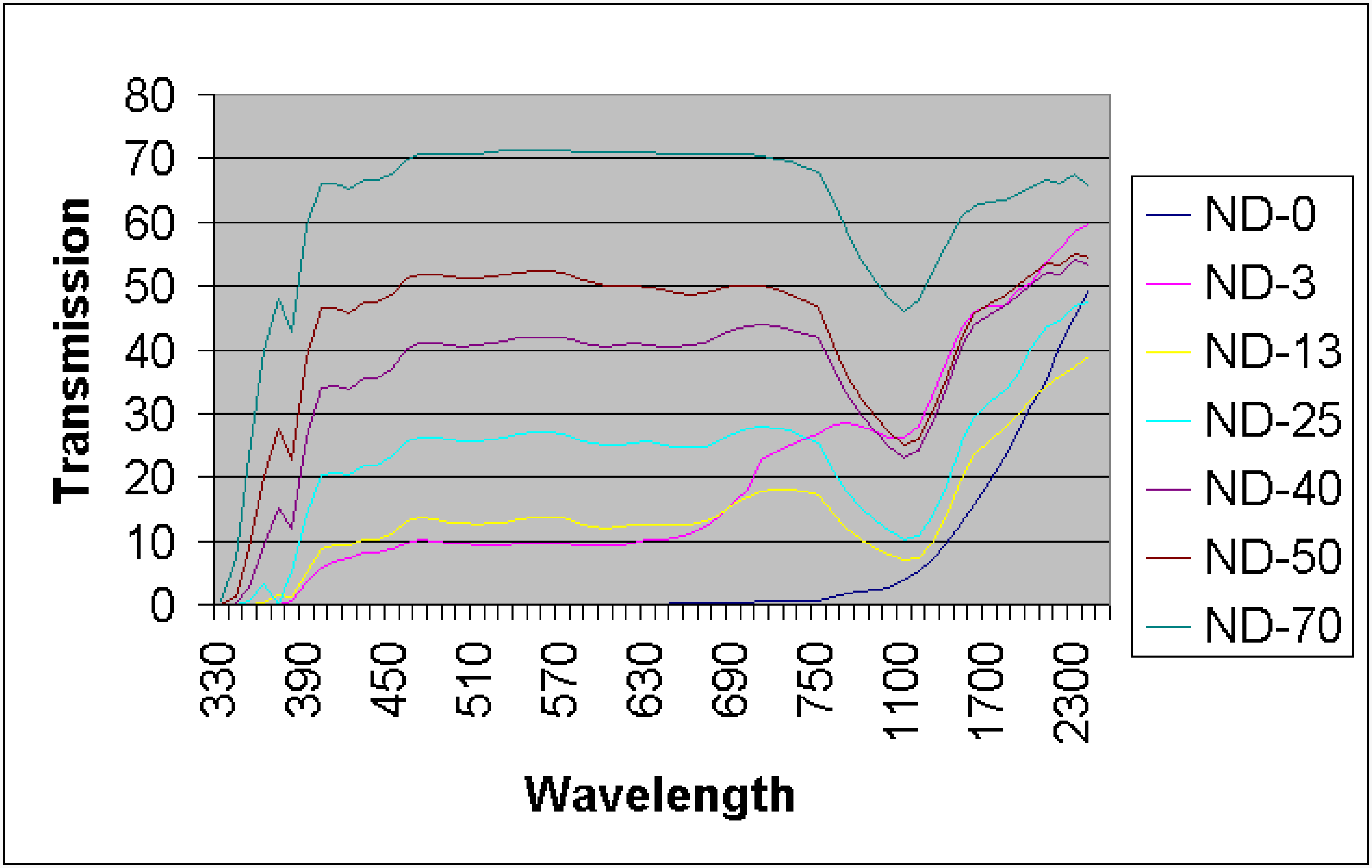


FWHM – full width at half maximum

Transmittance vs. wavelength for typical Fabrey-Perot Interference filter showing first and second order λ's (m = 1 & m = 2)

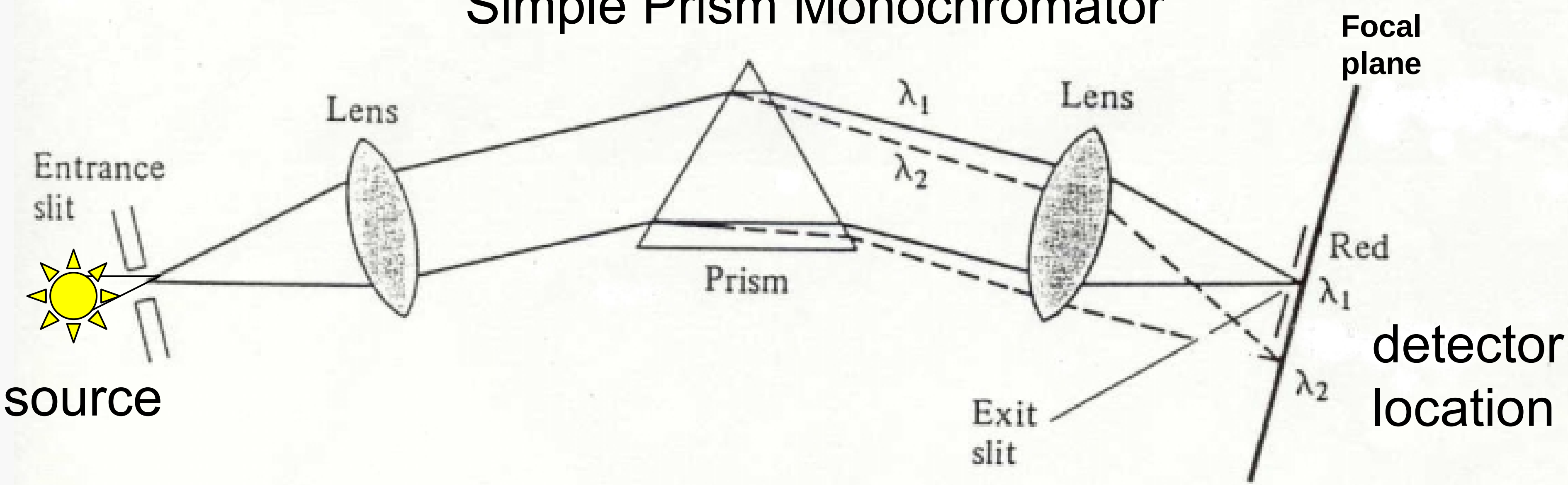


3) <u>Neutral density filters</u> – reduces intensity without any λ discrimination



II) MONOCHROMATORS

Simple Prism Monochromator



Entrance slit allows source radiation to illuminate the first lens which collimates the light spreading it across the face of the **prism**. Prism disperses radiation into component wavelengths and the second lens focuses the spectrum at the **focal plane**. An **exit slit** selects the band of radiation to reach the detector. Dispersing element can be a **prism** or a **diffraction grating**. Focusing elements can be **lenses** or **mirrors**.

- Optical Materials – need optically transparent materials for lenses, prisms & sample cells
- In visible region – can use glass down to 350 nm
- In the UV region – quartz is material of choice
- In the IR region – NaCl, KBr, etc. The heavier the atoms of the salt, the farther into the IR region (i.e., longer λ) before significant absorption occurs

Problem – sensitivity to moisture

Resolution – ability to distinguish as separate, nearly identical frequencies; measured in terms of closest frequencies $\Delta\nu$ in a spectrum that are distinguishable

$$R = \frac{\nu}{\Delta\nu} \quad \text{or} \quad \frac{\lambda}{\Delta\lambda} \quad \text{(both dimensionless)}$$

Dispersion – spread of wavelengths in space

Angular Dispersion – angular range $d\theta$ over which waveband $d\lambda$ is spread → $\frac{d\theta}{d\lambda}$ in $\frac{\text{rad}}{\text{nm}}$

Linear Dispersion – distance dx over which a waveband dλ is spread in the focal plane of a monochromator → $\frac{dx}{d\lambda}$ in $\frac{mm}{nm}$

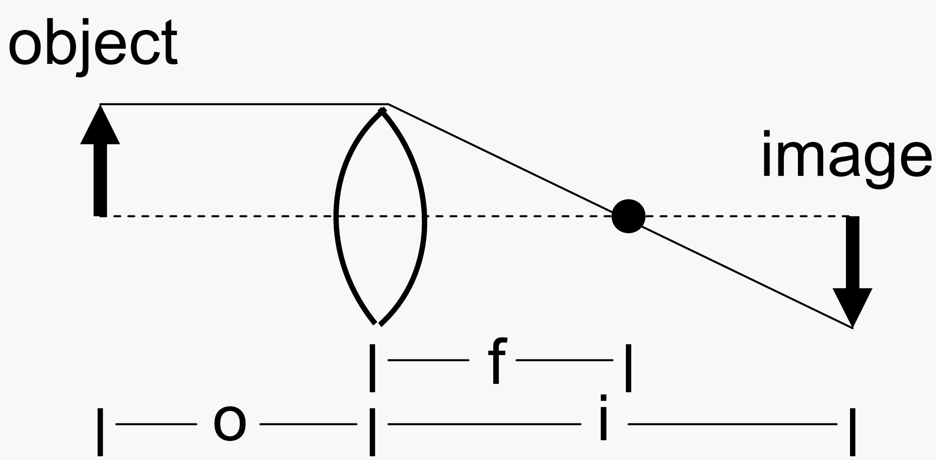
Linear Reciprocal Dispersion – range of λ's spread over a unit distance in the plane of a monochromator → $\frac{d\lambda}{dx}$ in $\frac{nm}{mm}$

Related terms **spectral slit width** or **bandwidth** or **bandpass** = range of λ's included in a beam of radiation measured at half max intensity

Lenses – lens equation (for a thin lens)

$$\frac{1}{f} = (\eta - \eta') \left(\frac{1}{r_1} - \frac{1}{r_2} \right)$$

Where
- f = focal length
- η = refractive index of lens material
- η' = refractive index of adjacent material
- r_1 = radius of curvature of first surface
- r_2 = radius of curvature of second surface



$$\frac{1}{f} = \frac{1}{i} - \frac{1}{o}$$

i: distance to image

o: distance to object