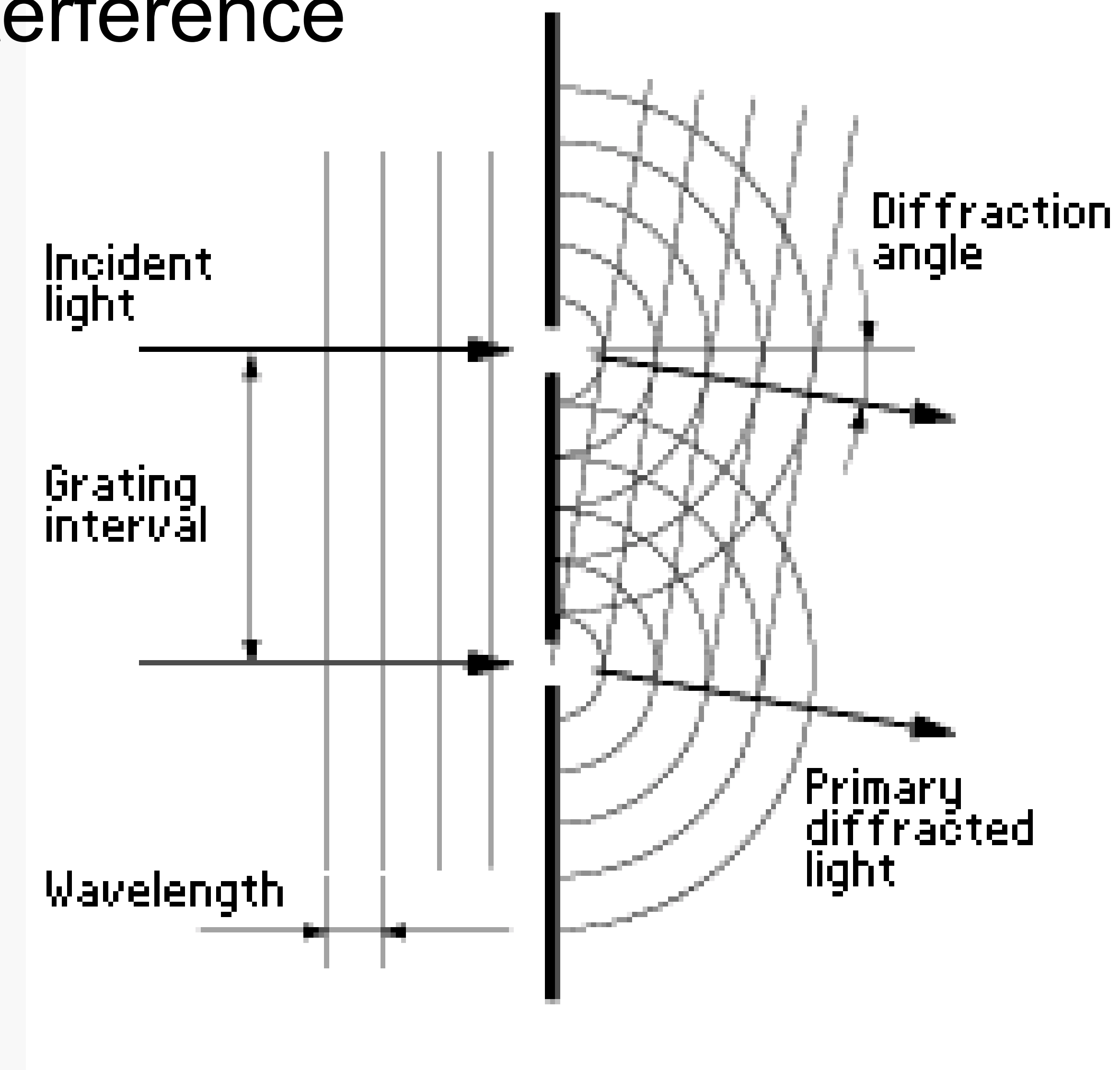
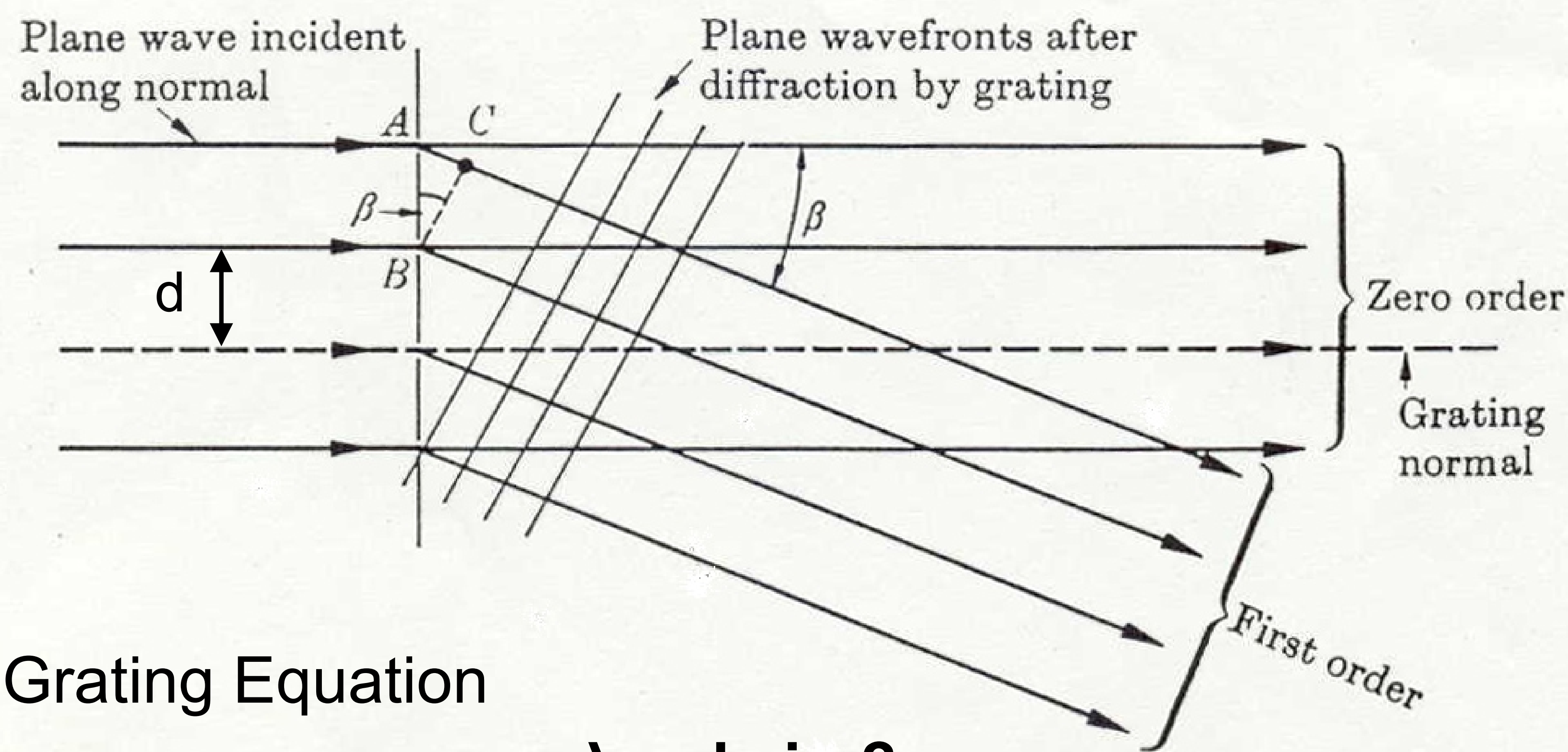
Gratings work on the principles of diffraction & interference





Grating Equation

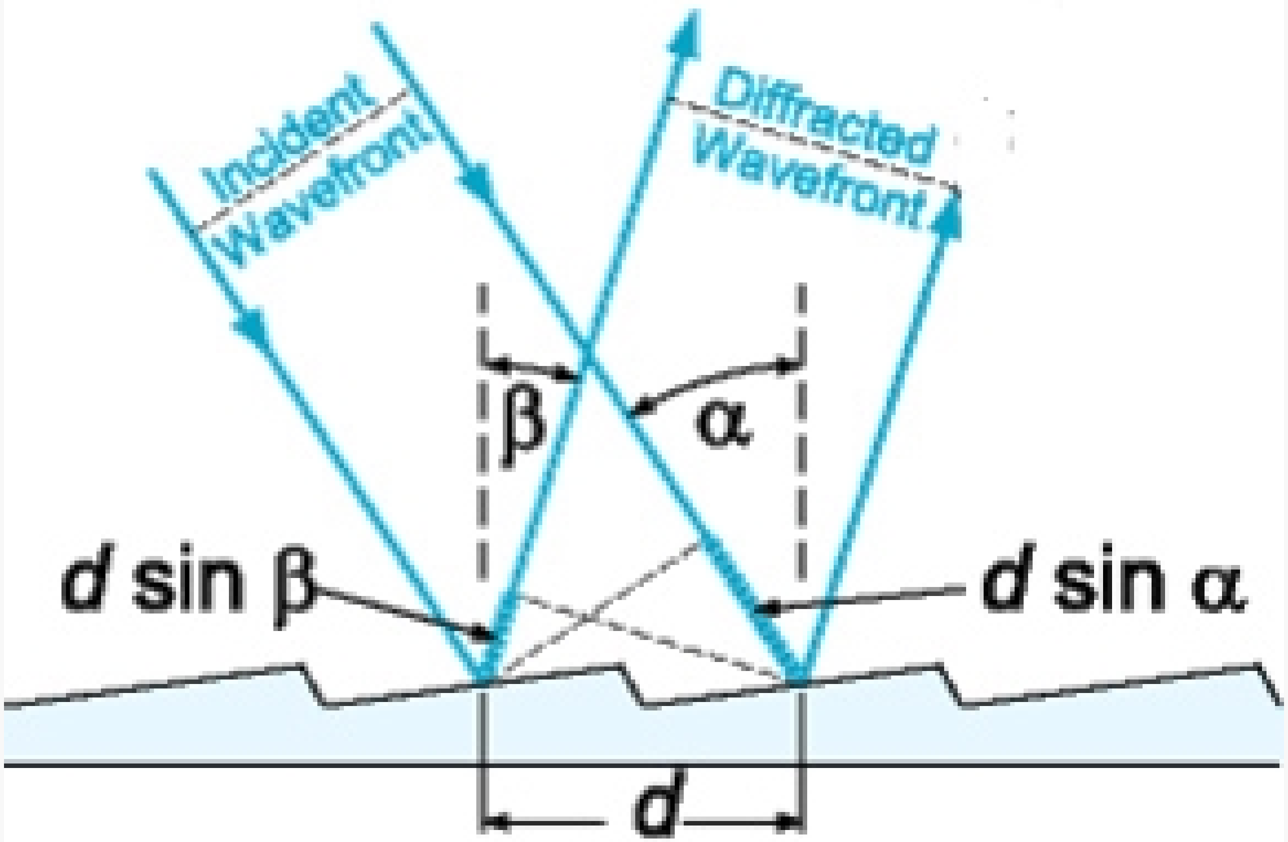
$$m \lambda = d \sin \beta$$

Condition for constructive interference

AC = extra distance light travels for first order = d sin β

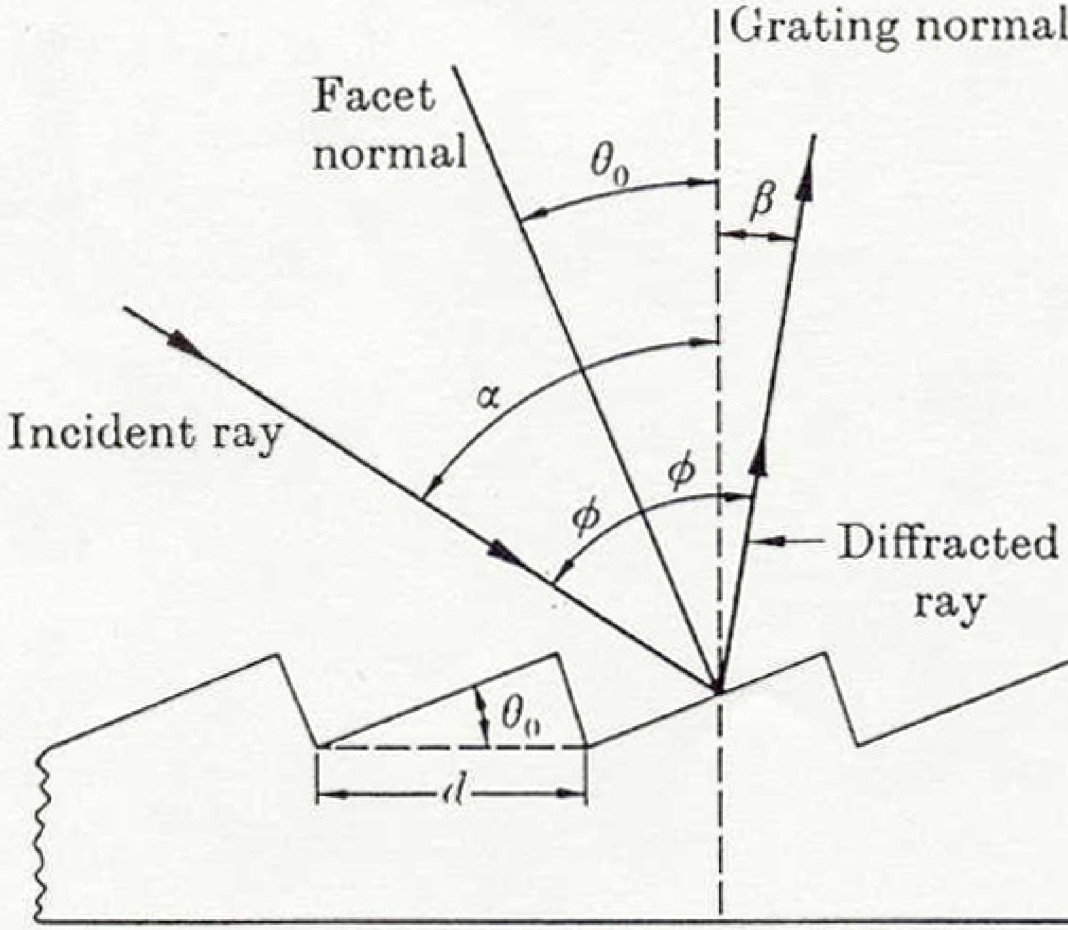
For higher orders the distance gets longer

Reflection grating with non-normal incidence



$$m\lambda = d\,(\sin\alpha \pm \sin\beta)$$

Reflection grating with non-normal incidence (another view)



Φ is fixed relative to facet (or step) normal, α & β change depending on incident radiation relative to grating normal

Preparation of reflection gratings – a master grating is prepared by ruling grooves in a reflective aluminum surface on glass (from 20 – 3000 grooves/mm or 10,000 lines/inch)

Replicate gratings can be prepared from master grating which brings down the cost

$$\text{Grating Efficiency} = \frac{\text{fraction of monochromatic light diffracted in a particular order}}{\text{fraction specularly reflected}}$$

Efficiency is maximum for situation where diffracted ray & specularly reflected ray coincide = blaze wavelength = λ_B = λ of maximum efficiency

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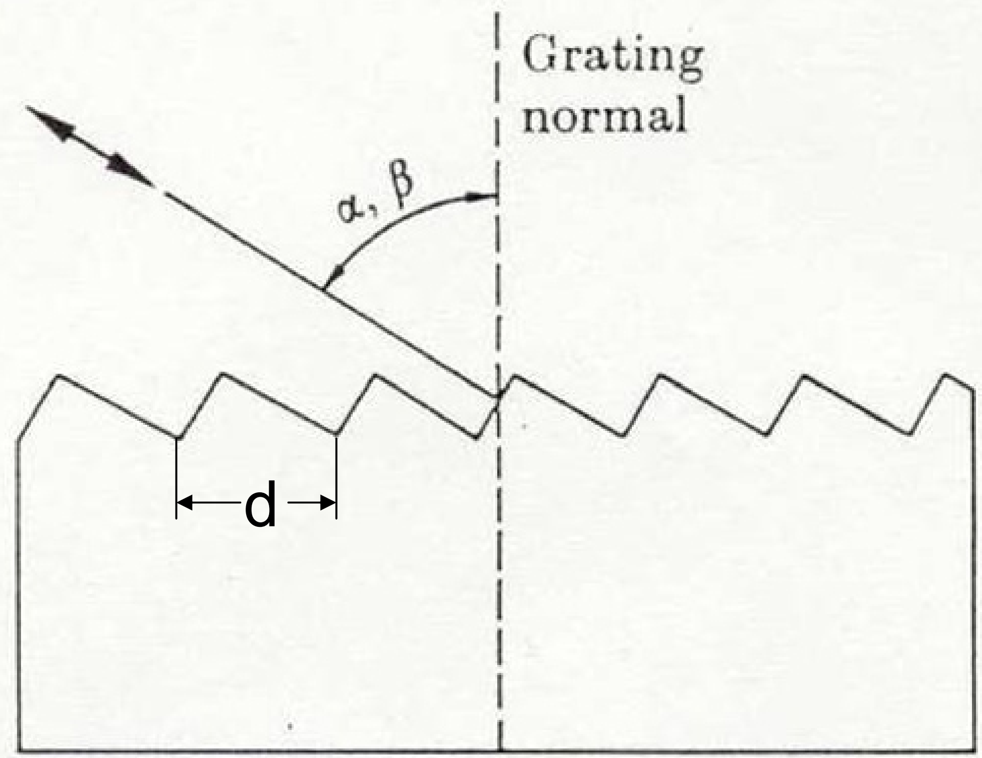
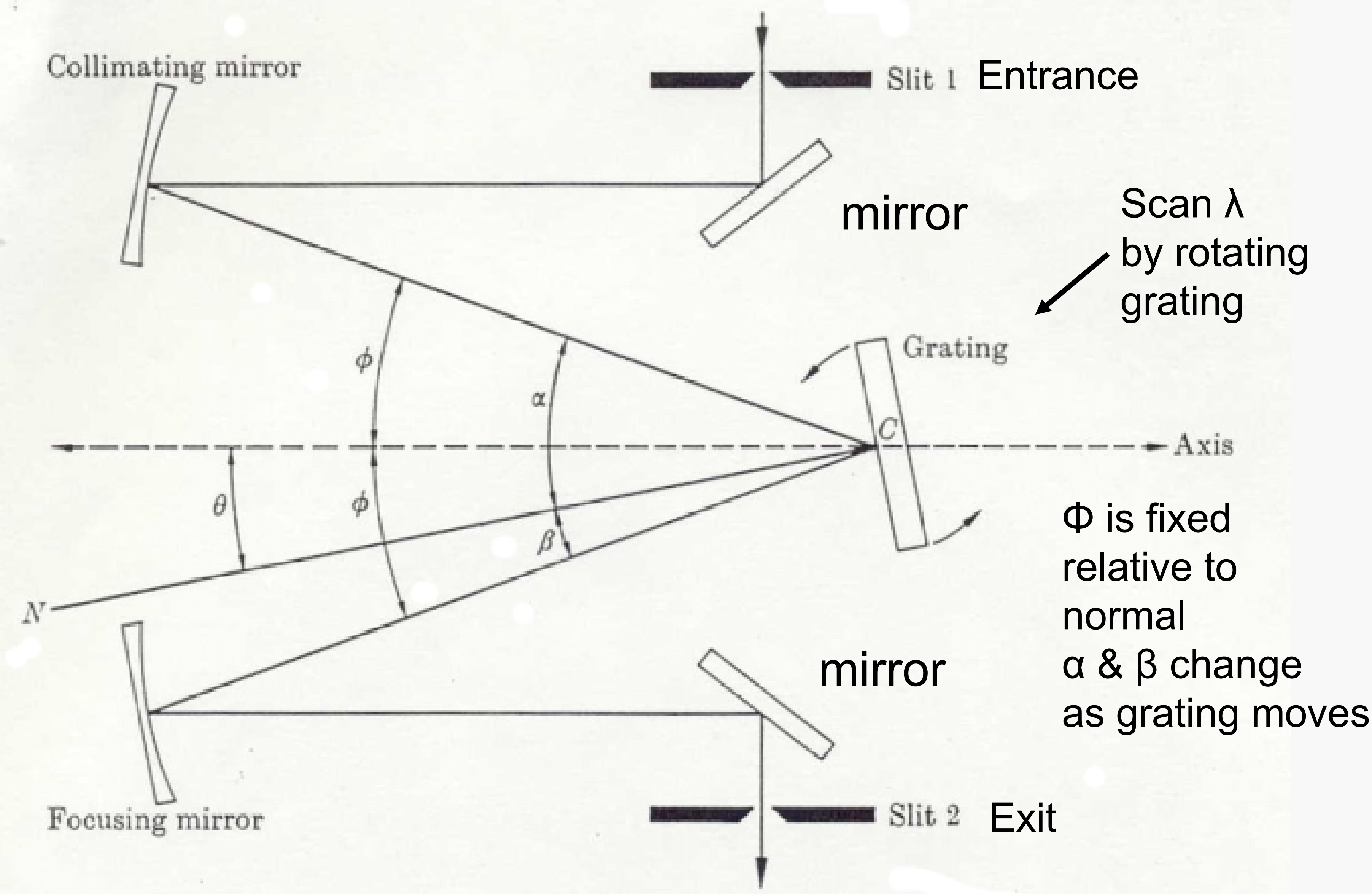
An Echelle type reflection grating has a coarse ruling (i.e. large d) and produces good spectral efficiency in higher orders making very high resolution posible

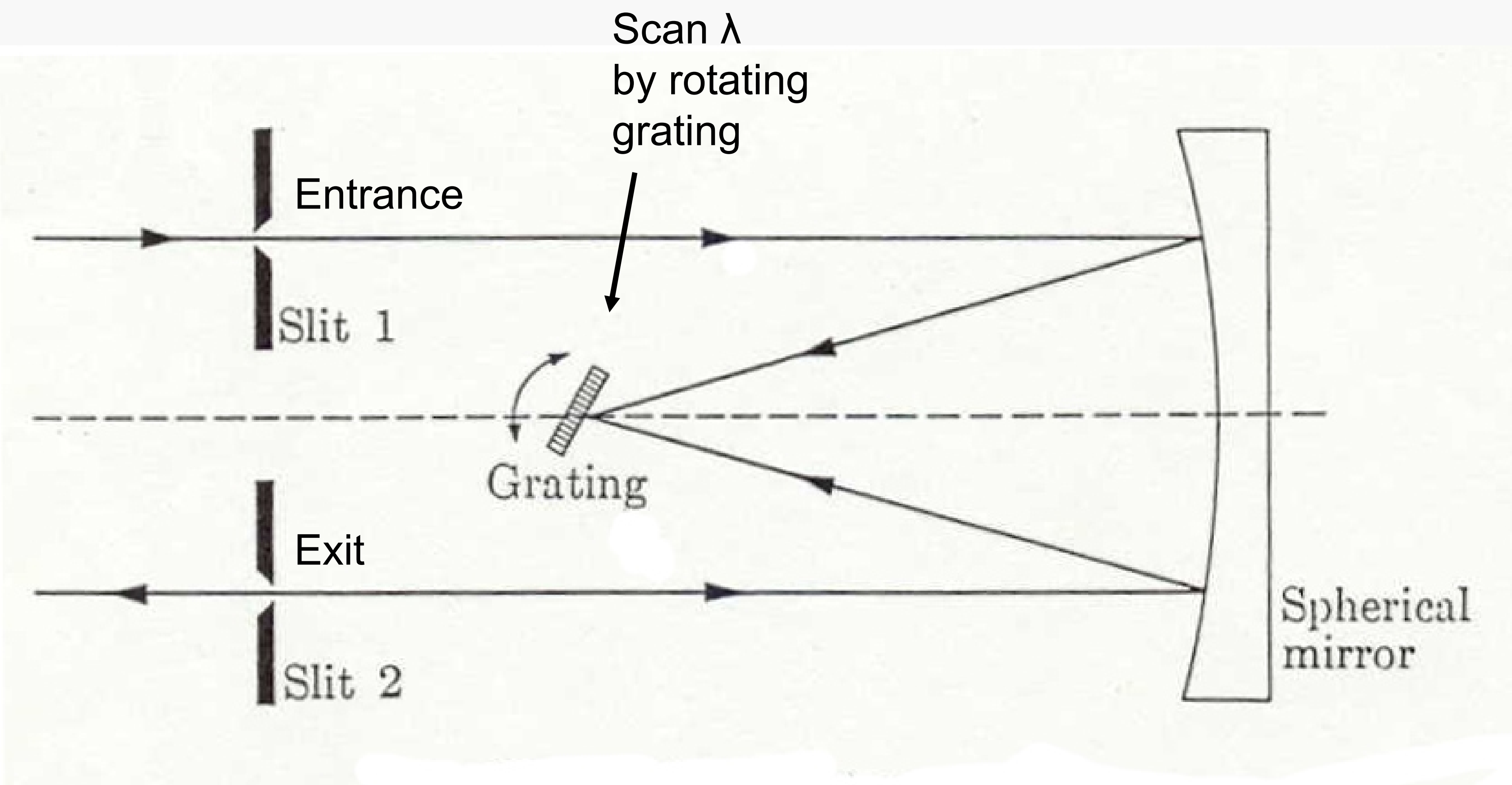


- The echellette grating concentrates most of the intensity in the first few orders
- First order efficiency at λ_B is 60 - 70 % and typically falls off by about half at 2/3 λ_B and $2\lambda_B$
- Choose angle for λ region of interest
- Echellette is the normal grating for UV, vis, IR
- Echelle grating used for atomic emission
  - Concentrates intensity in higher orders
  - Uses steeper steps

Mountings for Gratings – Czerny-Turner



Mountings for Gratings – Ebert Mounting



Littrow mounting is the same as for prism except use grating in place of prism

Grating Characteristics – Resolution & Dispersion are very high for a long, finely ruled grating

Resolution (theoretical)

$$R = m\ N$$

(m: order; N: number of rulings illuminated)

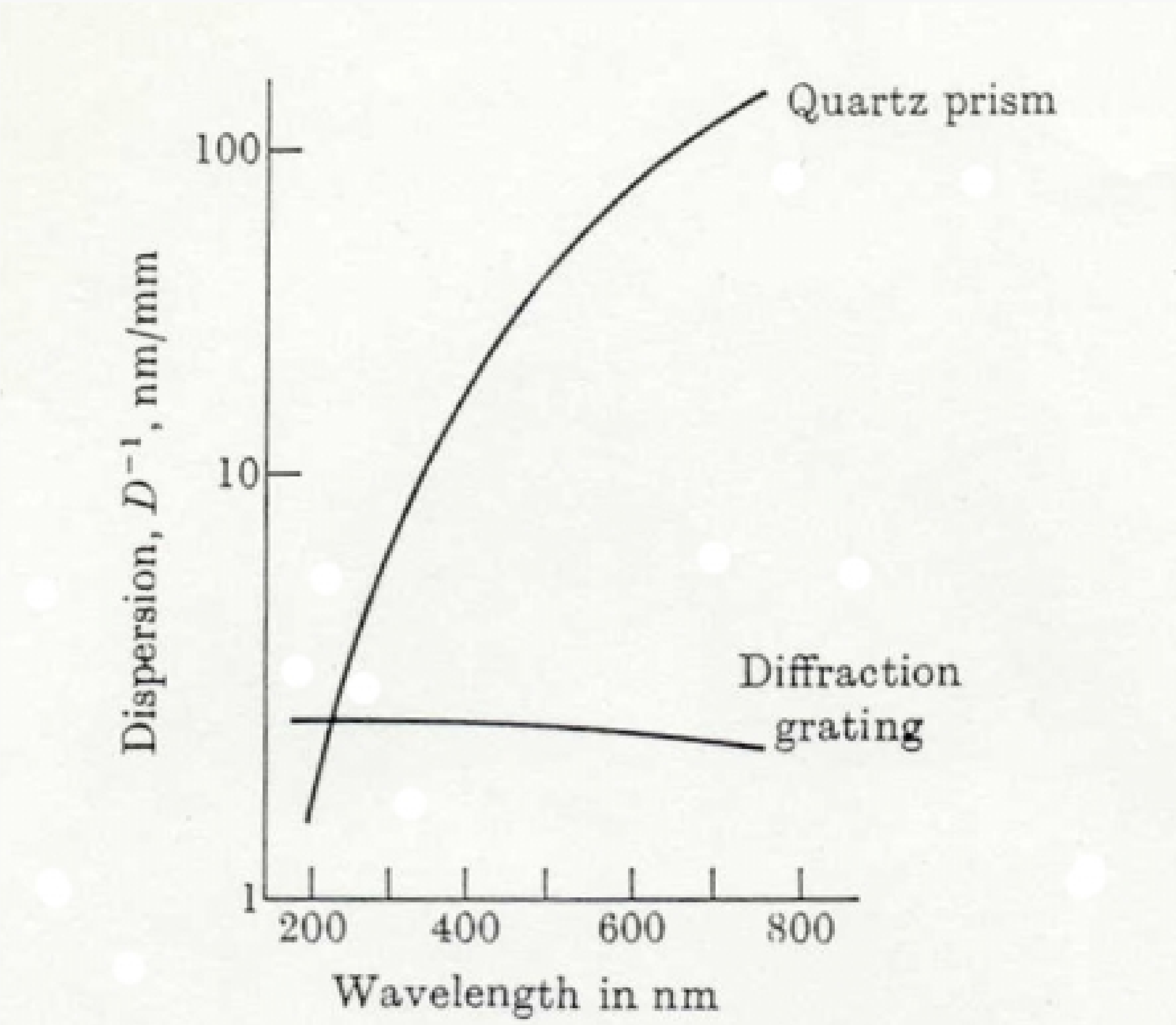
Combine with grating equation (given previously)

$$R = W\ (\sin \beta)\ /\ \lambda$$

where W (length of ruled area) = N d

The length of ruled area is important

Dispersion - almost constant with wavelength for grating (an advantage over prisms)



Don't have to change slits to get constant bandpass across spectrum

Disadvantages of gratings relative to prisms:

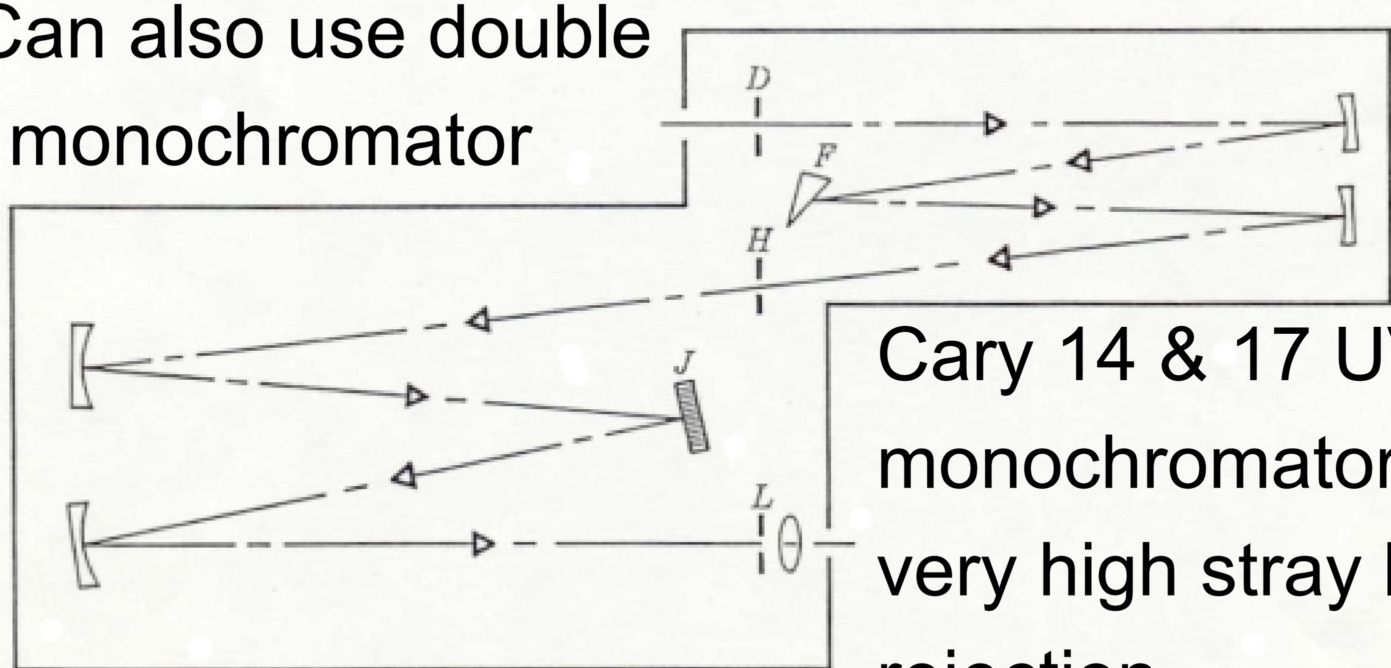
1) they are less rugged
2) they generate slightly more scattered light which is stray light → radiation present at unwanted orders
3) order overlap → multiples of λ present

Stray Radiation sources:

1) Diffracted from grating at unwanted angle
2) Diffracted from slit edges
3) Reflected from interior surfaces of filters, lenses, prisms & other components of system
4) Scattered by imperfections in optical components

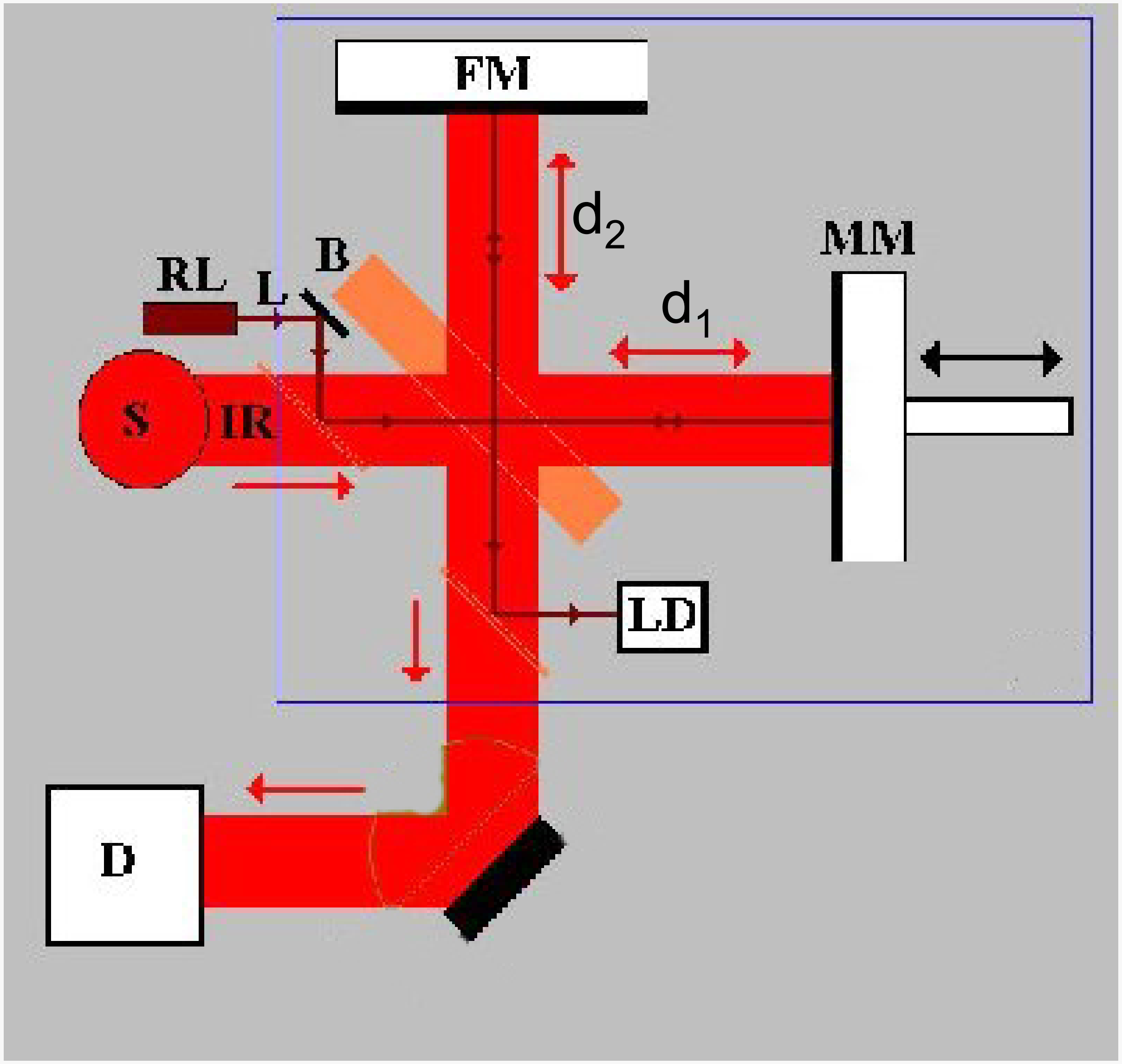
Methods of reducing stray light:

1) Paint interior black
2) Use baffles to obstruct stray radiation
3) Use high quality components
4) Keep out dust and fumes
5) Can also use double monochromator



Cary 14 & 17 UV-vis monochromator with very high stray light rejection

Michaelson Interferometer as commonly used in an FTIR



Where:

S = IR source

IR = infrared beam

D = detector

B = beamsplitter

FM = fixed mirror

MM = moving mirror

RL = reference laser

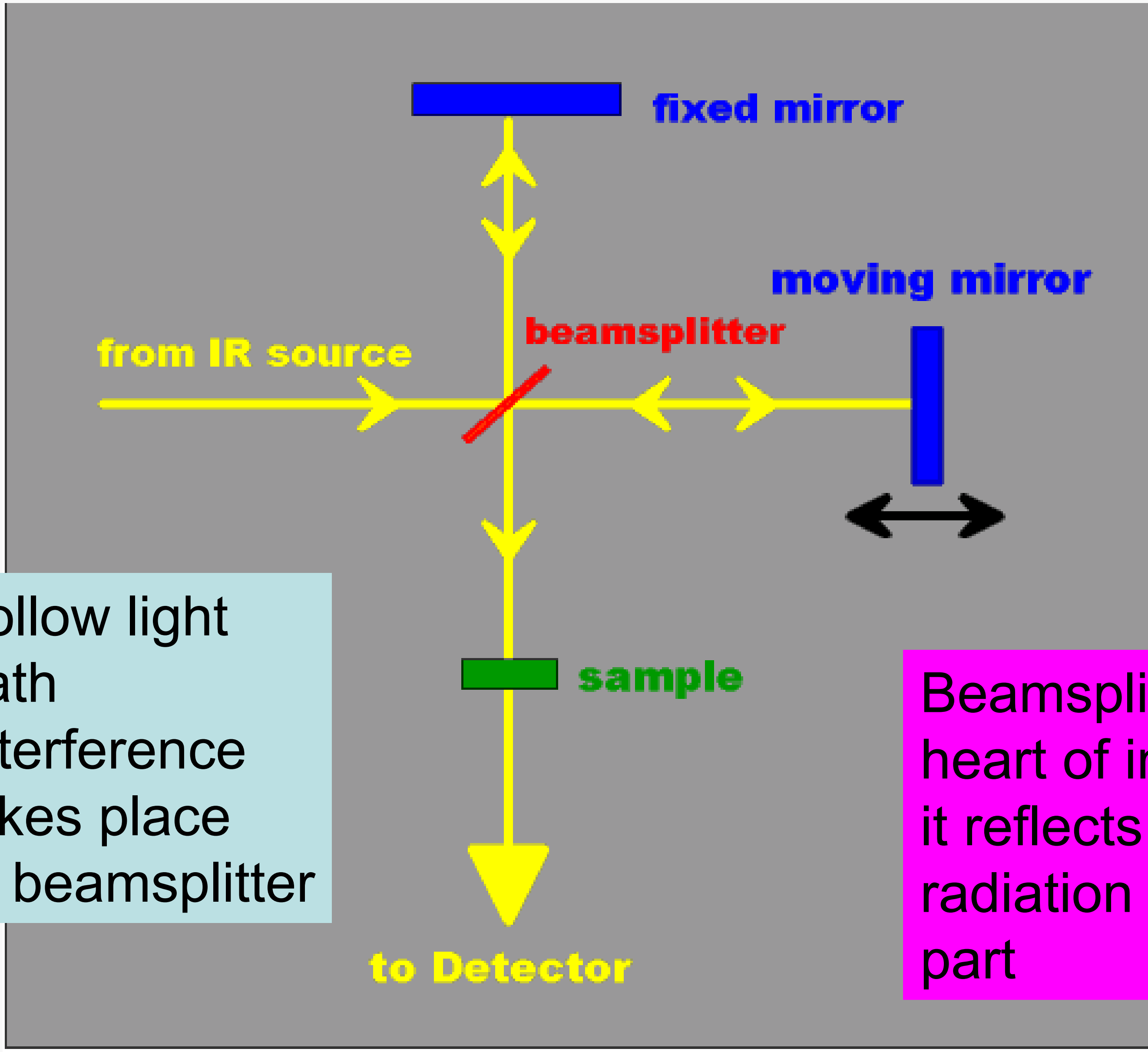
L = laser beam

LD = laser detector

d_1 = distance to moving mirror

d_2 = distance to fixed mirror

Basic diagram of a Michaelson Interferometer



Follow light path
Interference takes place at beamsplitter

Beamsplitter is at the heart of interferometer, it reflects part of the radiation & transmits part

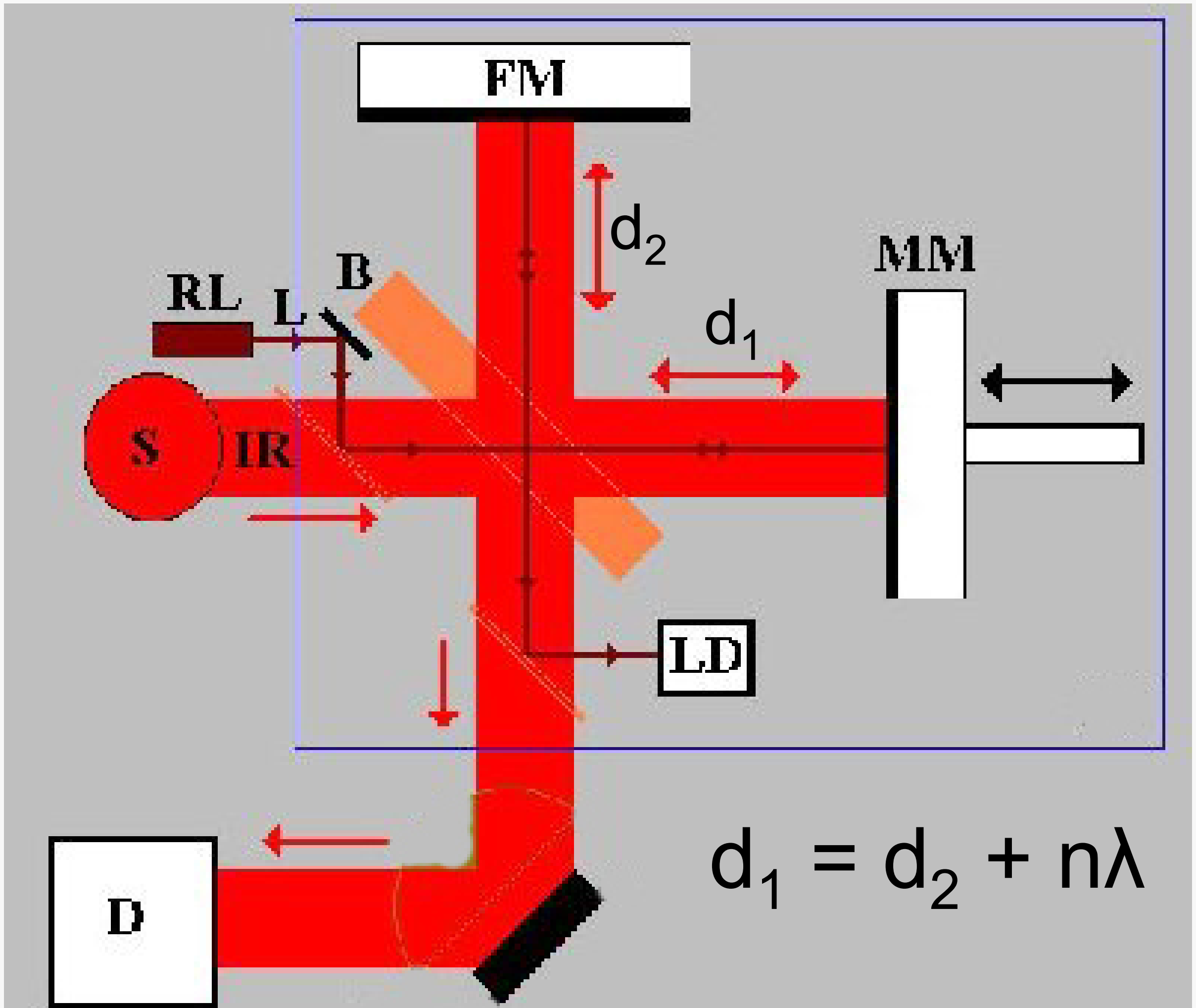
Interferometers have no slits so a wide beam of radiation can be used

Assuming monochromatic radiation

$d_1 = d_2 + n\lambda$ → for maximum constructive interference

$d_1 = d_2 + n\lambda + \frac{1}{2}\lambda$ → for maximum destructive interference

Michaelson Interferometer as commonly used in an FTIR



$$d_1 = d_2 + n\lambda$$

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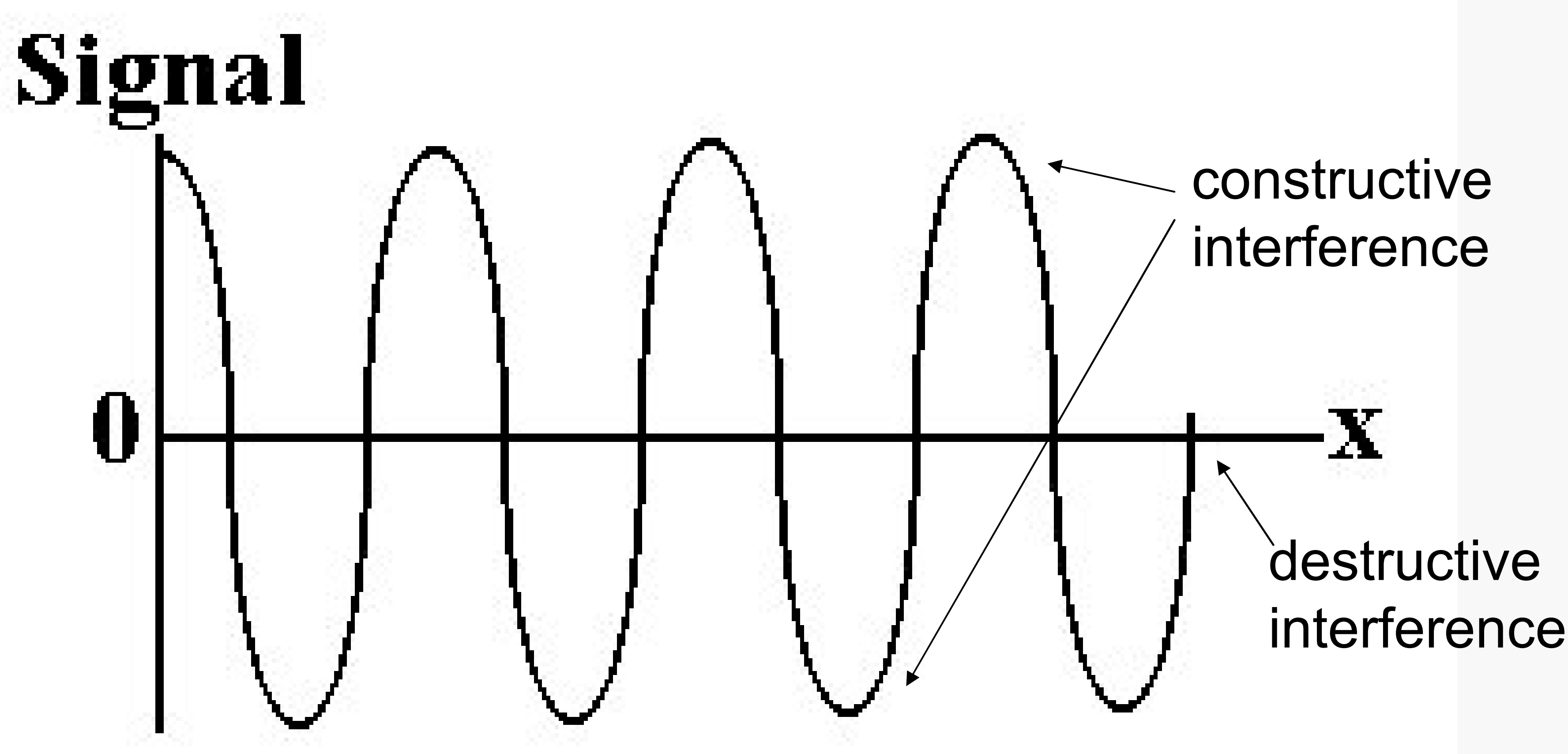
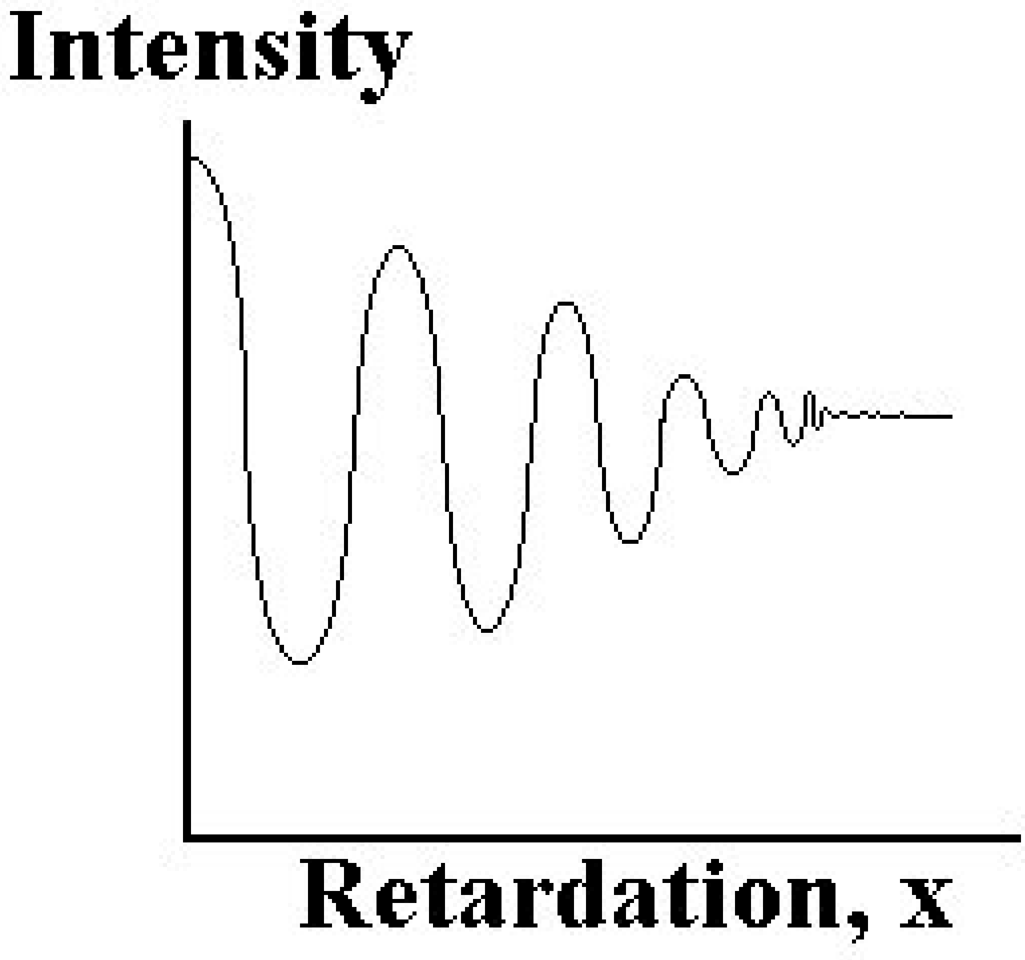
Reference laser signal as it passes through the interferometer



This allows the position of the moving mirror to be determined accurately

Interferogram is a plot of energy vs mirror displacement from zero (i.e. $d_1 = d_2$)



This is for polychromatic radiation

Mechanical specifications for mirror movement are very exacting → gets worse as λ gets shorter, therefore interferometers are used in the IR region but are not very feasible in the visible and UV regions

Extracting a conventional spectrum (i.e. I vs λ) from interferogram involves the complex mathematics of the Fourier integral also known as Fourier Transform → need computer to do calculations

Advantages of Interferometers:

1) Energy throughput is much grater than for monochromators → better signal to noise ratio because there are no slits – this is particularly important in IR where the sources are relatively weak
2) Multiplex Advantage – all signals are viewed simultaneously

Disadvantage: Mechanical tolerance for mirror movement is severe – can’t do interferometry in the UV-vis region, λ too short