AA Optics

AA Optical Components

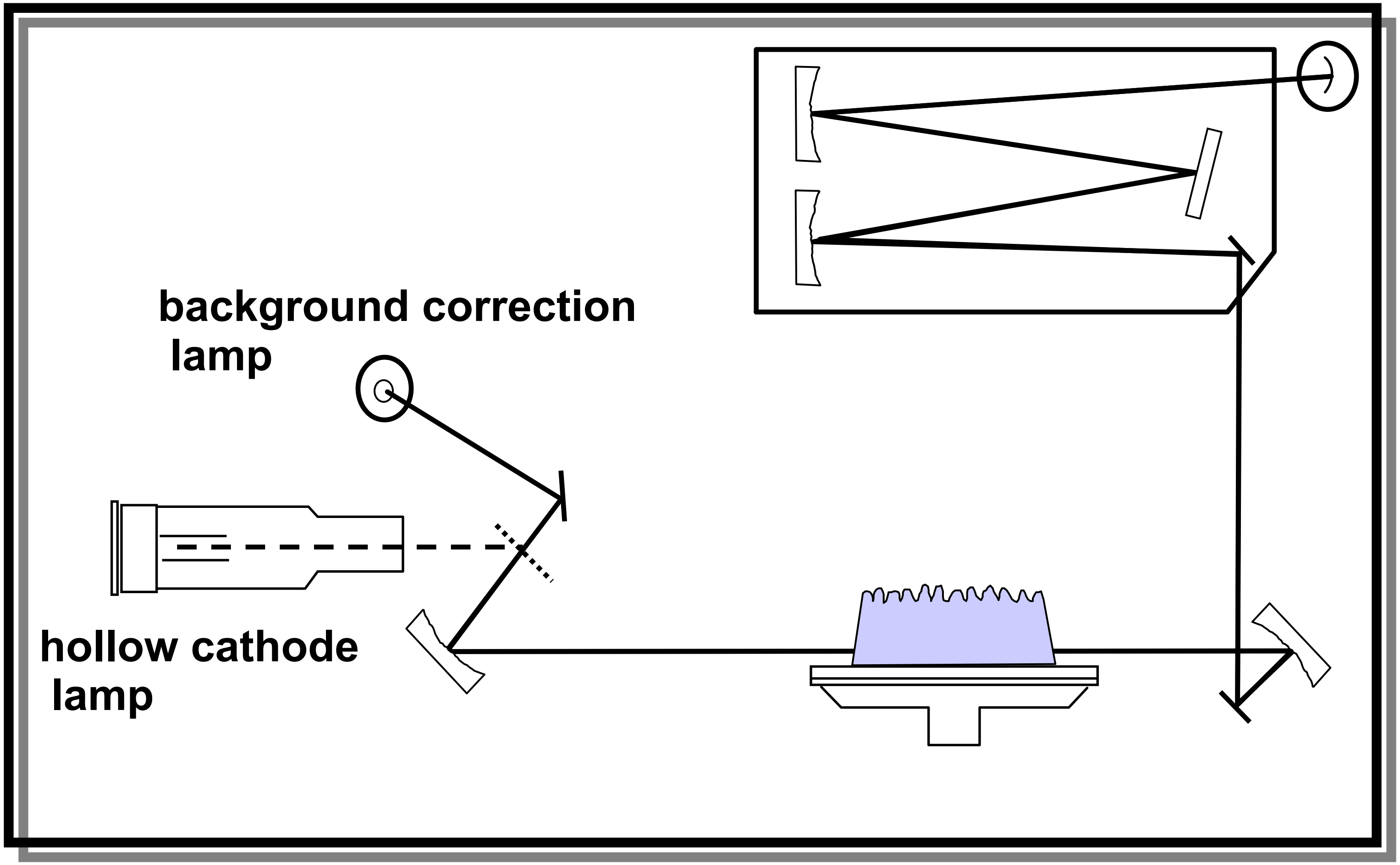
Spectrometer

- Collimates light from hollow cathode
- Isolates analyte wavelength
  - From other lines
  - From broad band emissions

Detector

- Measures light absorbed by analyte atoms
- References absorbed intensity to initial lamp intensity

Single Beam Optical Layout



Inspiring Excellence

Single Beam Optics

Light from the source traverses ONLY ONE path

Must measure Io BEFORE inserting sample

Relies on stable light source

- I_0 does NOT drift while it is measured
- Modern hollow cathode lamps sufficiently stable
  - Appropriate warm Up period
    - Element dependent
    - Typically 10 minutes
      - » Exceptions such as P, Tl, Cu/Zn multi-element
- Change in I_0 = change in baseline

Single Beam Optics

Aging lamps could drift more

- Use frequent recalibrations and reslopes
- Particularly necessary for graphite furnace

High volume graphite furnace work - Zeeman or double beam optics recommended

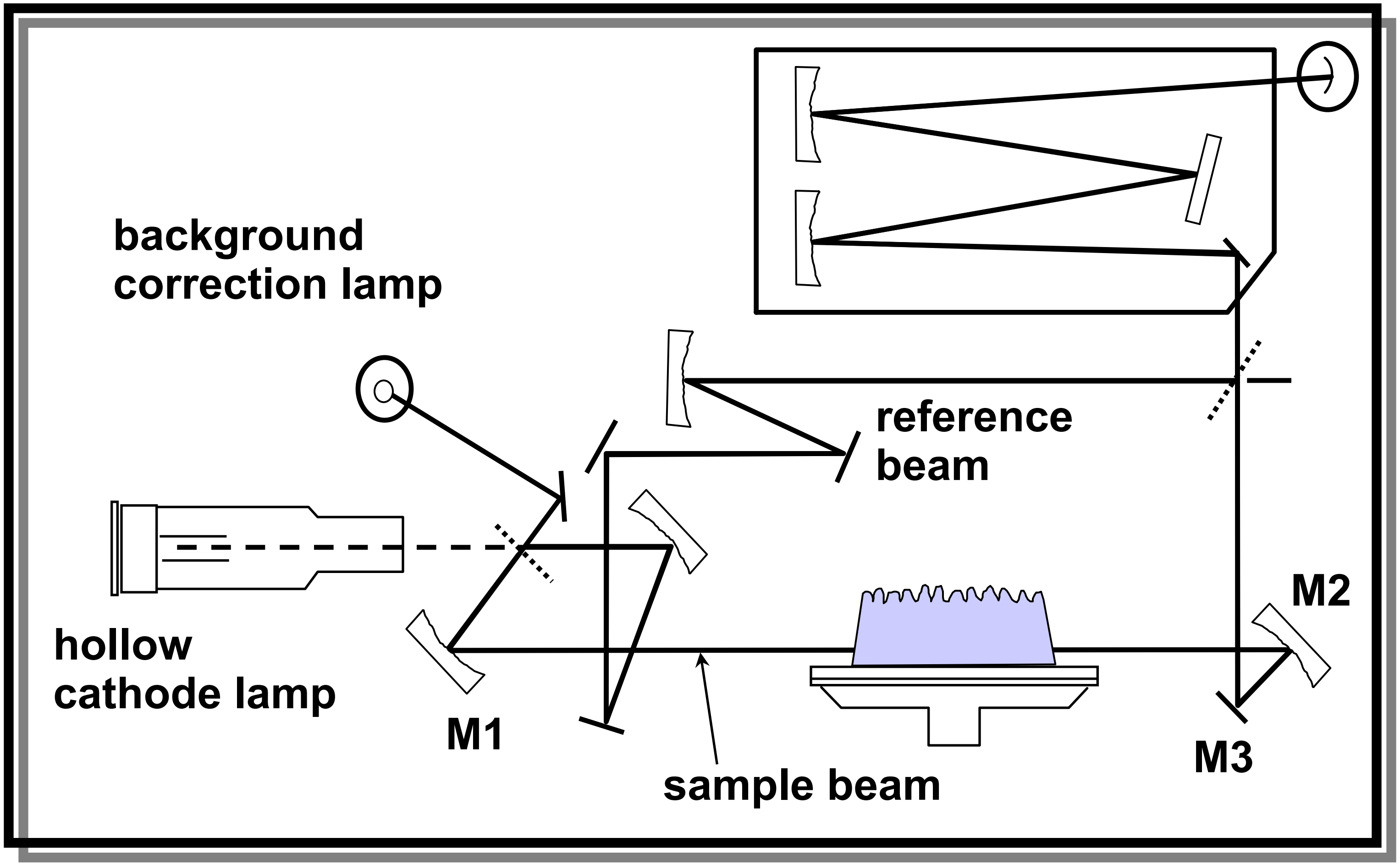
Single Beam Instruments

All of the energy from the source passed through sample cell

- Good signal to noise ratio
- SLIGHTLY improved detection limits vs double beam

If fitted with deuterium background corrector - same energy as double beam

Double Beam Optical Layout



Double Beam Optics

Designed to correct for drift in I_0

- NOT LIKE REFERENCE BEAM IN UV-VIS

Light from source is directed at a beam splitter

- Optical component designed to reflect a portion of the light energy and allow the remainder to pass though.
- Normally designed to reflect 50% - pass 50%

Beams recombined before entering monochromator

- Beams must be time separated

Methods of Time Separation and Beam Recombination

Second beam splitter with rotating perforated disk passing first one beam then the other

- 50% light loss at first beam splitter
- 50% light loss at second beam splitter
- POOR SIGNAL TO NOISE RATIO

Rotating beam combiner (RBC)

- Alternately passes
  - ALL OF REFERENCE BEAM
  - ALL OF SAMPLE BEAM
- BEST POSSIBLE SIGNAL TO NOISE RATIO

Advantages of Double Beam Optical Design

Allows intensity (I_0 and I_t) of BOTH reference and sample beam to be measured at high frequency

High frequency monitoring provides near instantaneous corrections for variation in source intensity

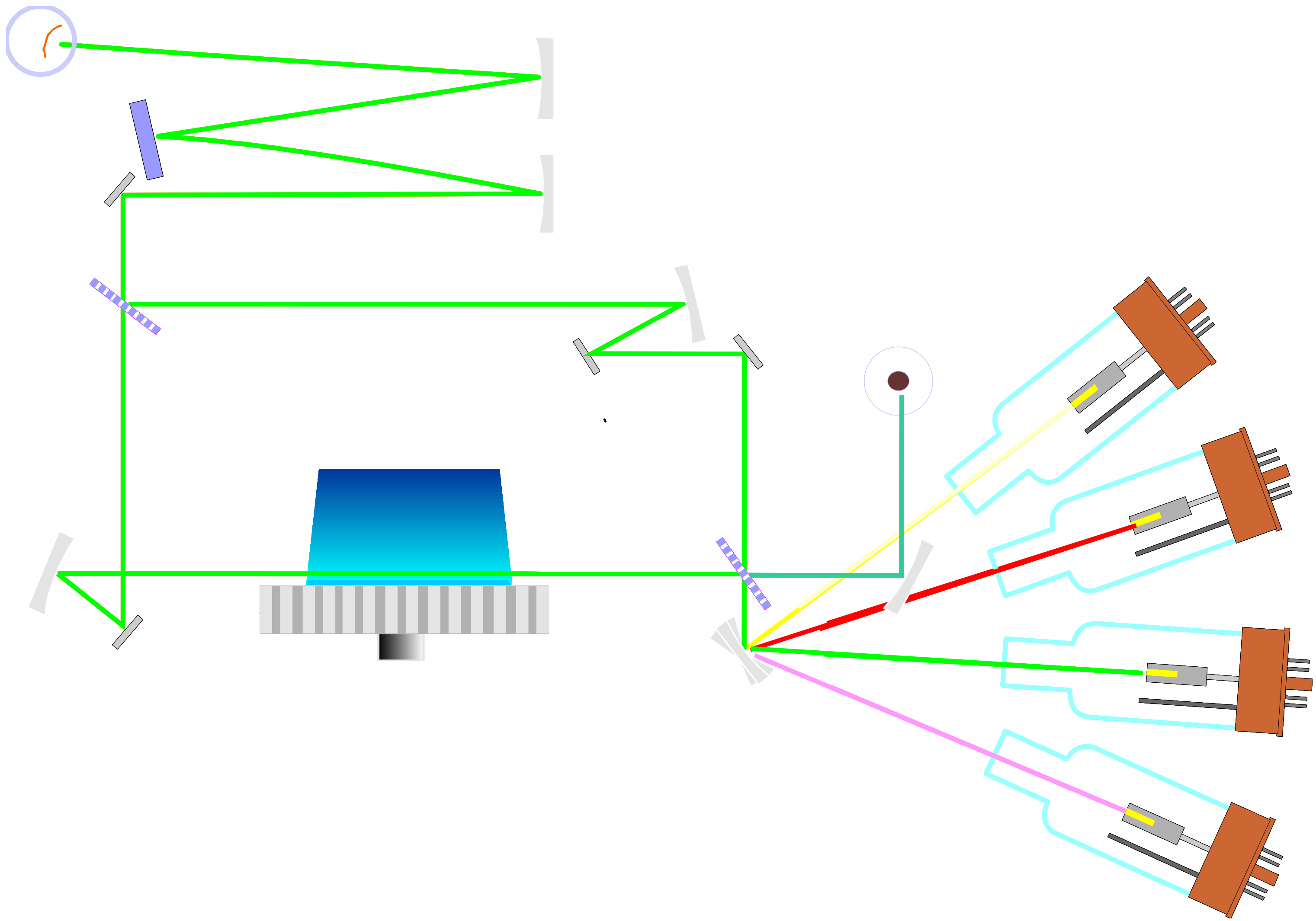
Both hollow cathode and deuterium source monitored

Double Beam Lamp Warm Up

Even with double beam optical design lamp warm up is recommended

- During warm up period emission line profile may change
- Changes in emission profile can cause small changes in the analytical signal

Fast Sequential Lamp Selection



Inspiring Excellence

Monochromator Function

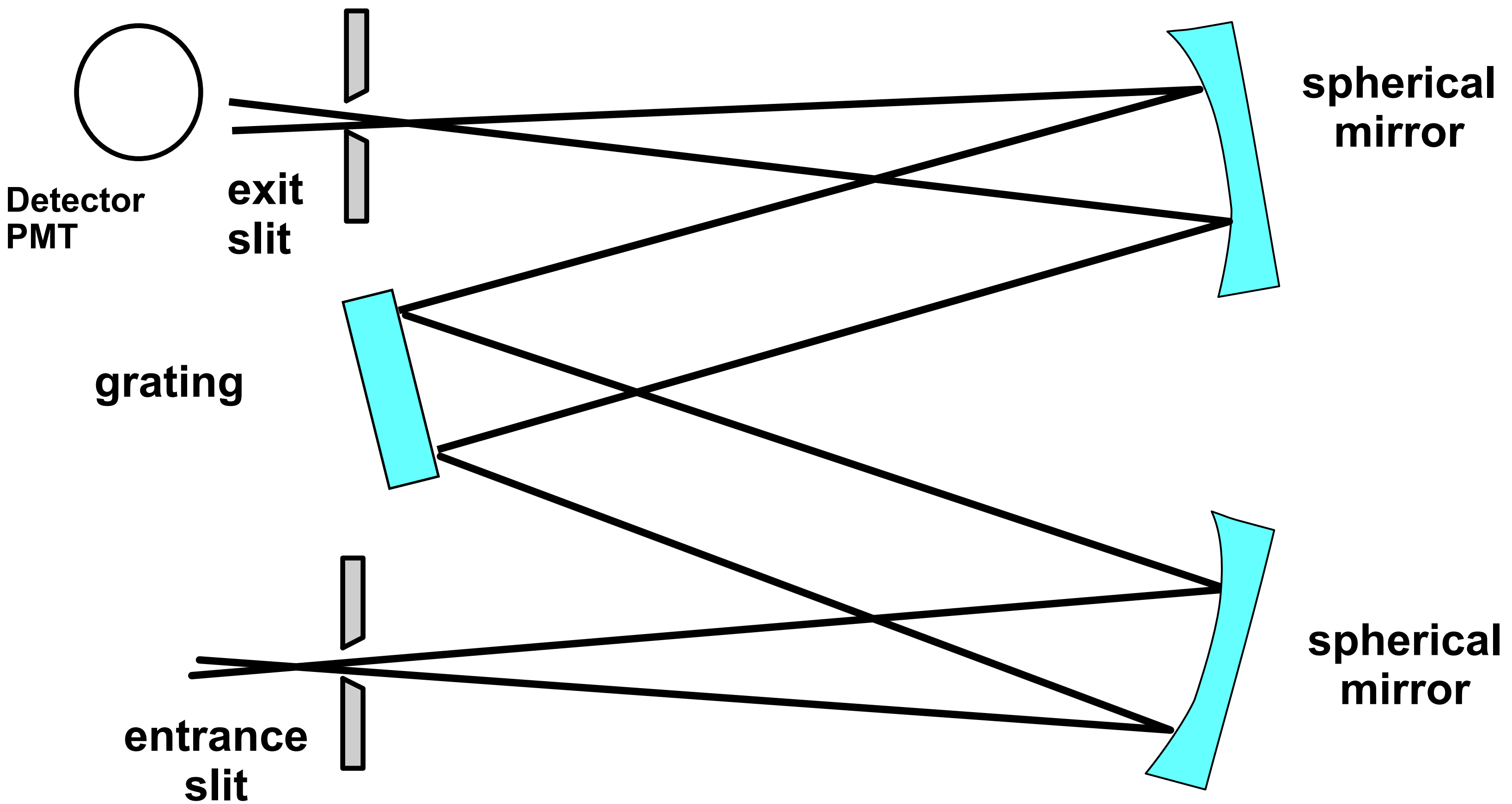
Hollow cathode lamp emits many narrow emission lines

Monochromator isolates single resonance emission line from hollow cathode lamp

IDEALLY monochromator isolates ONLY ONE LINE

- Sometimes easy – Cu
- Sometimes more difficult - Fe

Czerny - Turner Monochromator



Czerny - Turner Monochromator

Uses Two Separate Mirrors

- One to Focus Incoming Light onto Grating
- One to Focus Outgoing Light onto Photomultiplier

Mirrors Have Different Optical Properties

- Reduces Aberrations
- Improves Resolution
- Improves Light Throughput

Mirrors can be Prepared with Great Accuracy

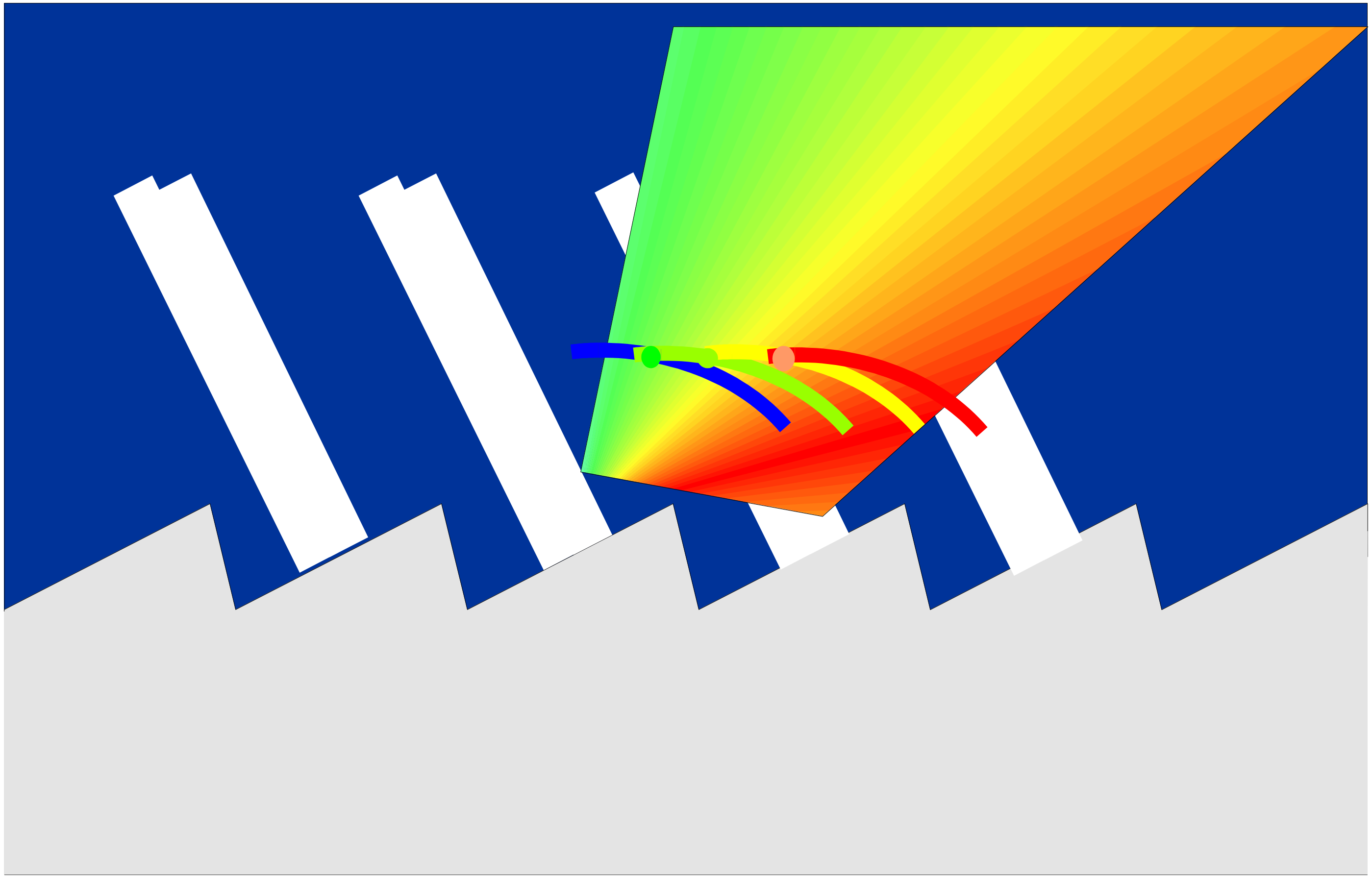
Diffraction Grating

Heart of monochromator

Light focused on grating is dispersed at different angles according to its wavelength

Rotating the grating focuses a specific wavelength on the exit slit

Spectrum Created by Wave Interference



Monochromator Resolution

Very important

Very high resolution needed for emission

- Complex spectra generated by high temperature plasma
- < 0.01 nm

"Medium" resolution needed for atomic absorption

- "Simple" spectral output from hollow cathode lamp
- ~ 0.2 nm

Slit Width

Affects spectral isolation of analytical line

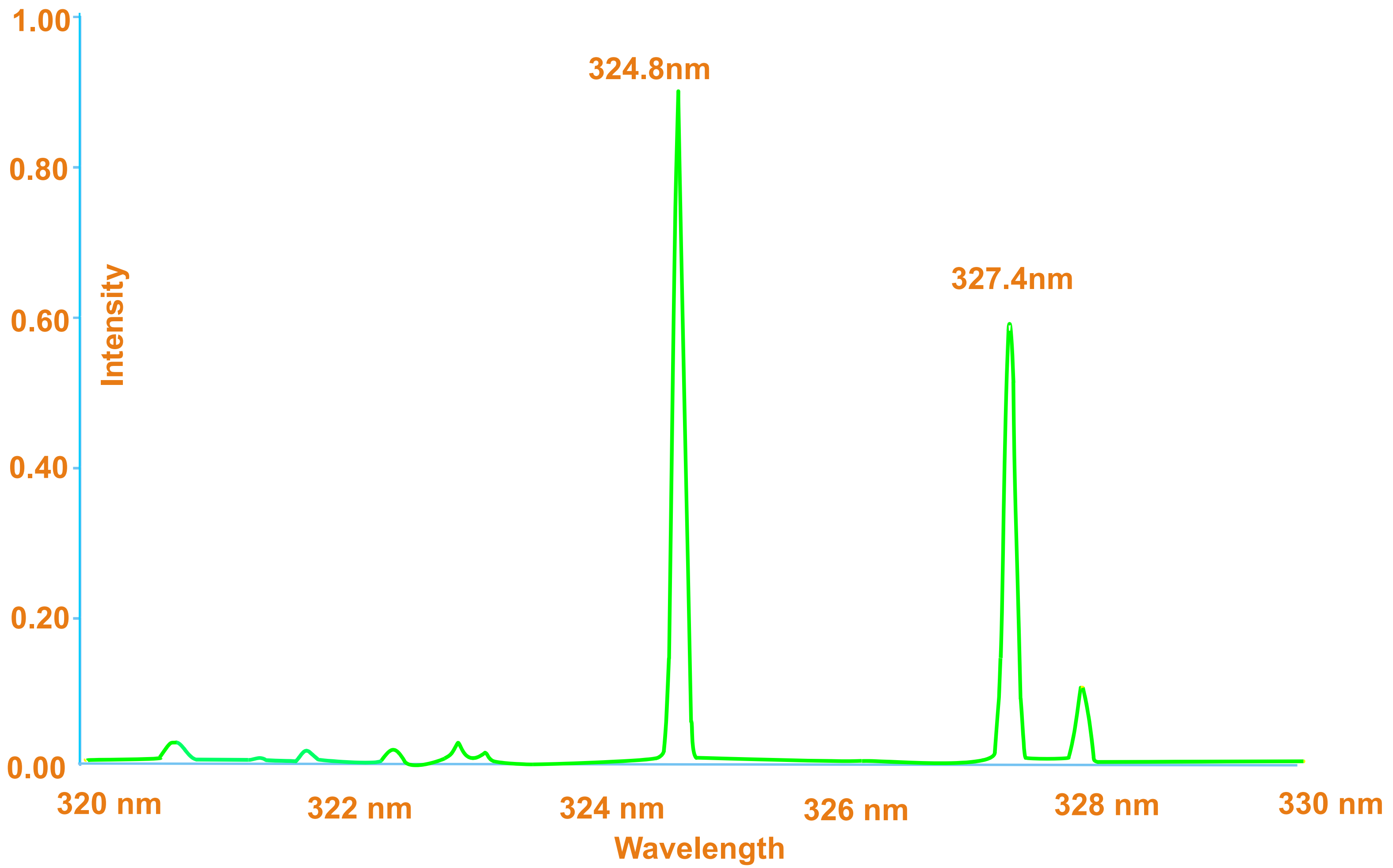
- Ability of spectrometer to resolve analytical line from adjacent lines

Normally dictated by nearest adjacent line in spectrum

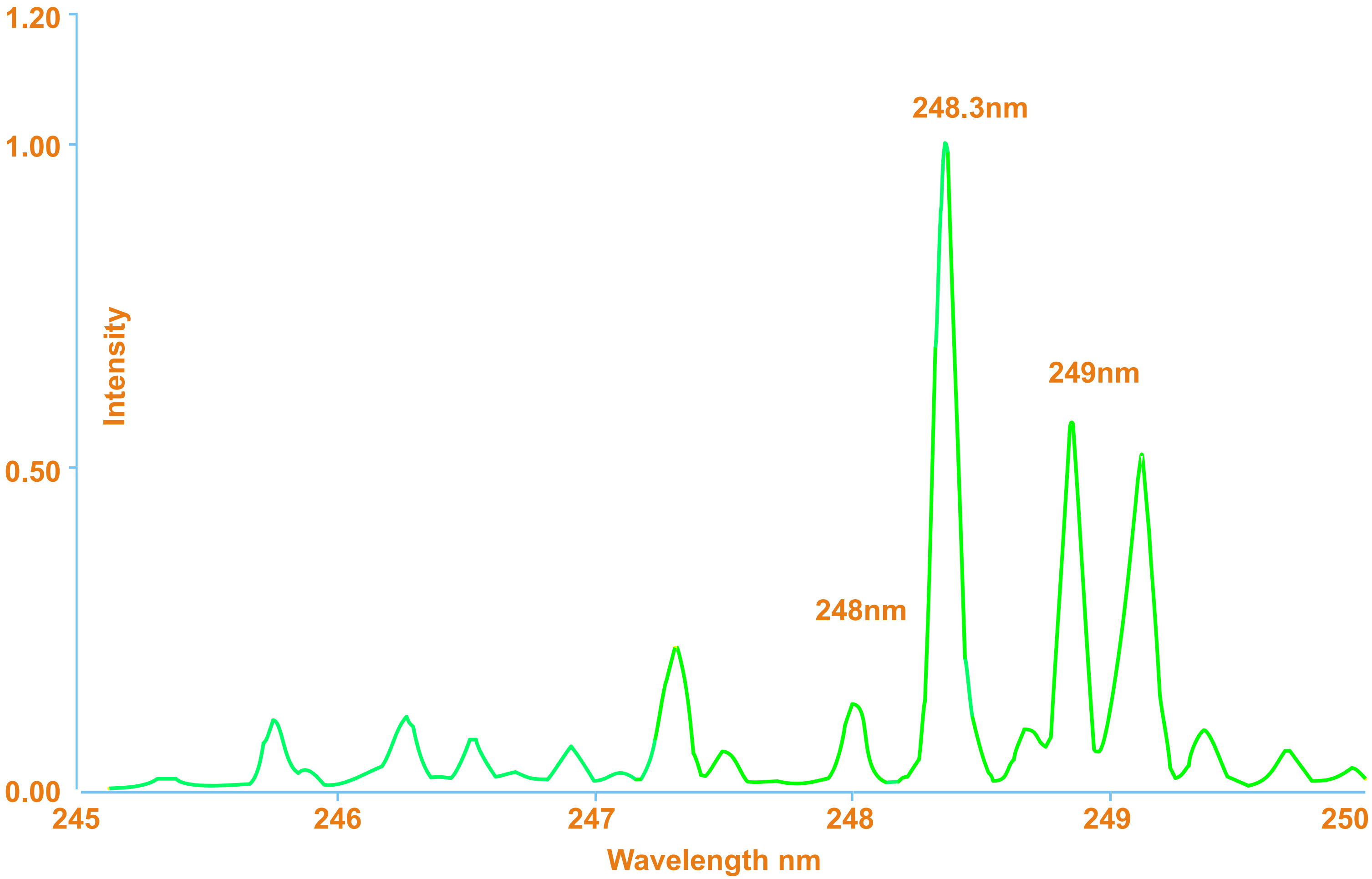
In practice setting slit width is compromise

- Wide slit
  - High energy - good signal to noise
  - Poor spectral resolution - highly curved calibration
- Narrow slit
  - Lower energy - higher noise
  - Good spectral resolution - more linear calibration

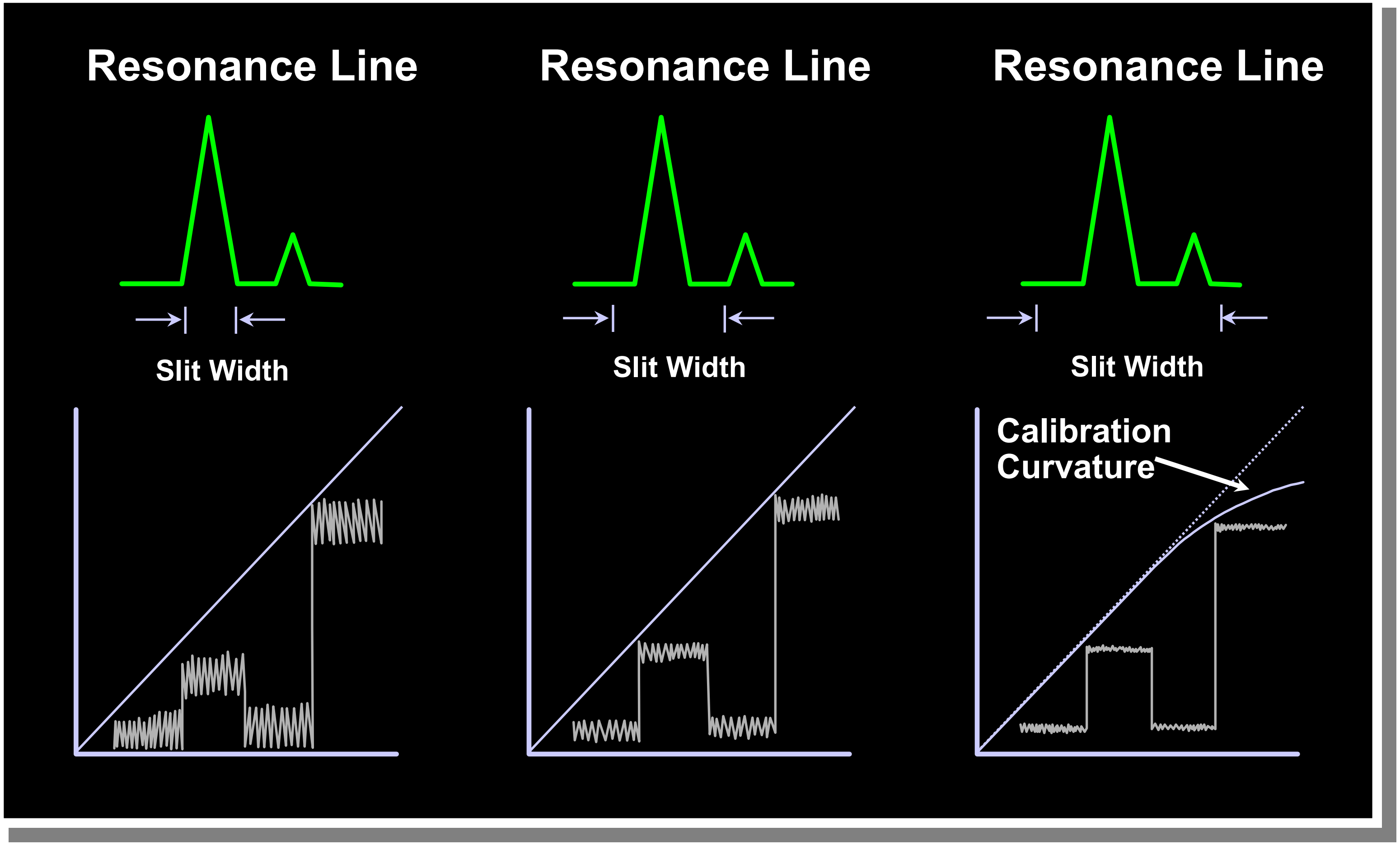
Atomic Spectrum of Cu



Atomic Spectrum of Fe



Effect of Spectral Band Width



Causes of Calibration Curvature

Detector observes non-analyte emission lines

- Hollow cathode lamp fill gas
- Non-resolved spectral lines

Detectors - Photomultiplier Tube

Vacuum tube which produces electrical signal proportional to intensity of light reaching it

Light enters a window and falls directly on photoemissive material

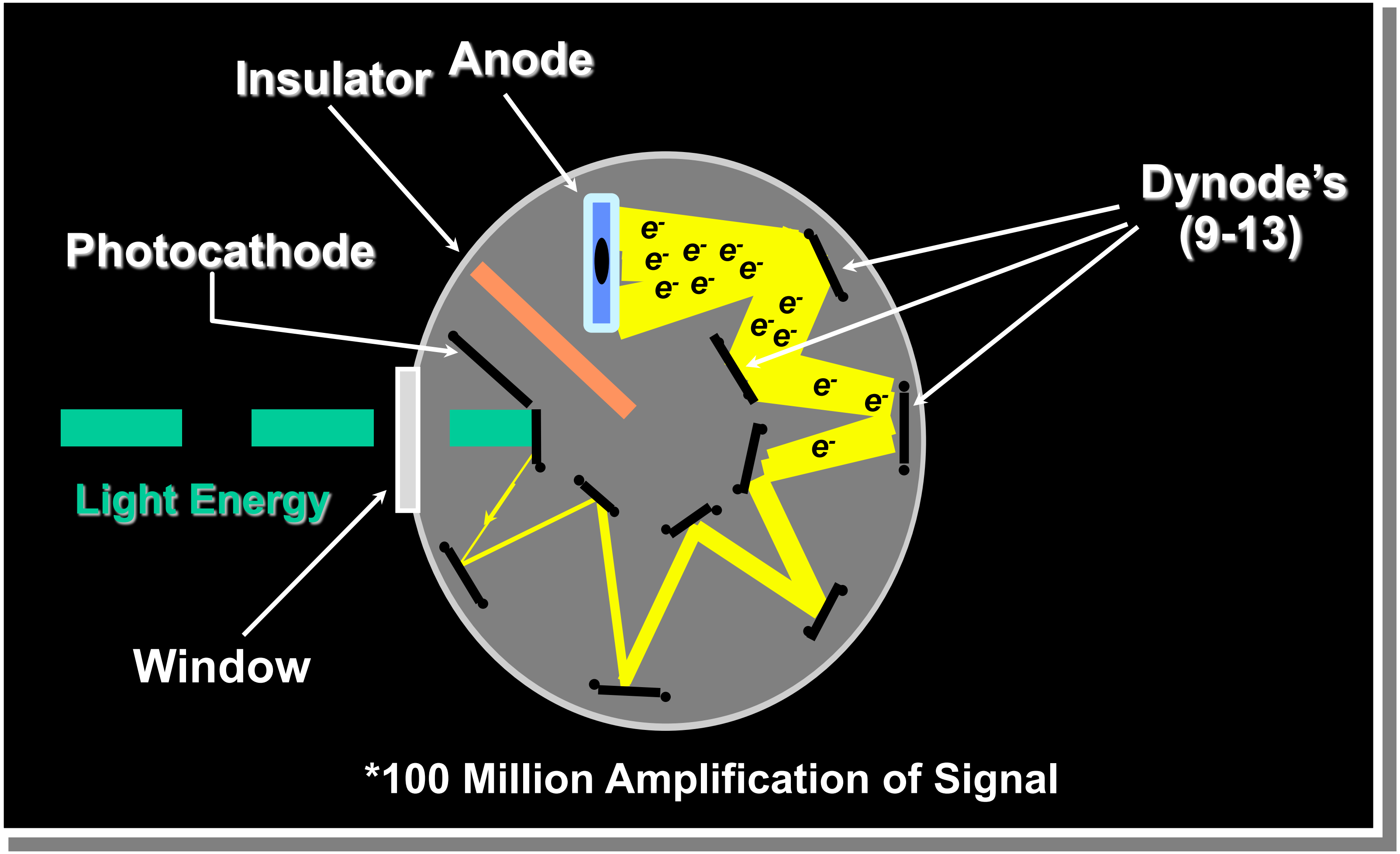
Photoemissive material emits electrons

- More light intensity produces more electrons

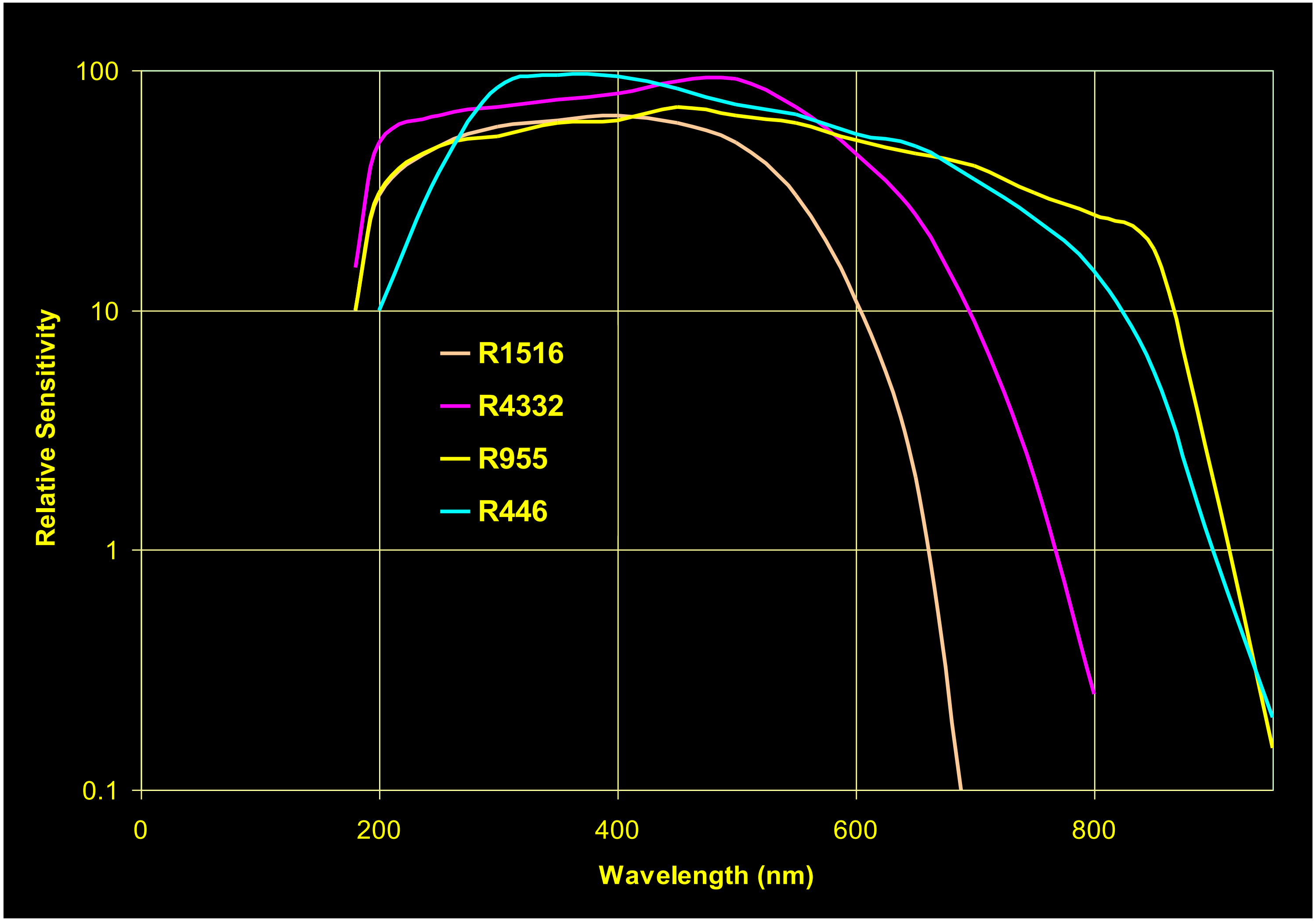
Electrons accelerated to dynodes

Dynodes emit secondary electron for each electron striking it

Photomultiplier Tube Operation



Photomultiplier Response



Factors Influencing Detection Limits

Detection limit reflects the signal to noise ratio

Factors influencing signal to noise ratio

- Optical design
- Standard deviation of blank
- Analytical sensitivity
- Unlikely to be ANY SIGNIFICANT difference between the detection limits for a double beam and D_2 corrected single beam instrument