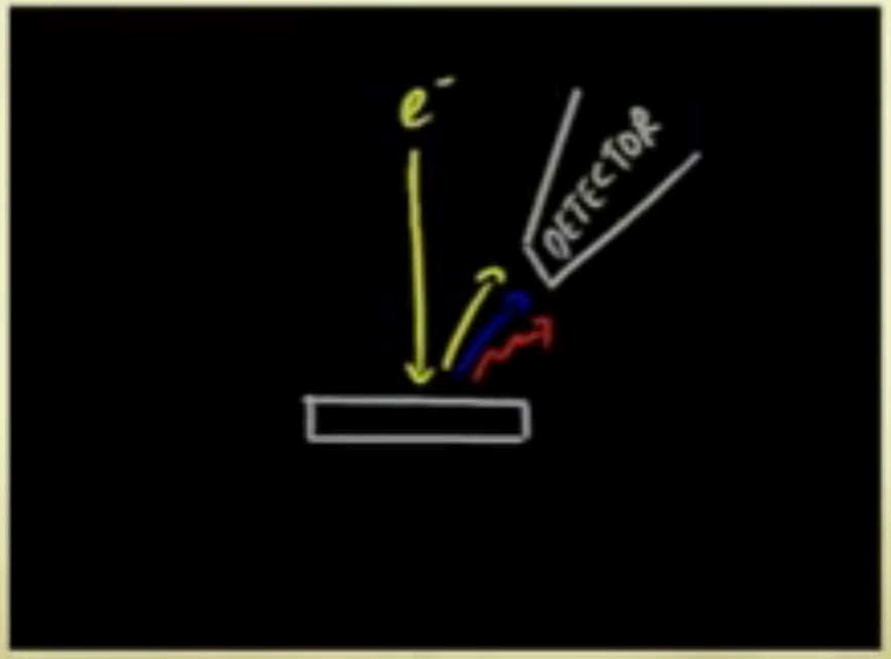
Introduction to Scanning Electron Microscopy (SEM)

GOALS

- #1 - Focus small beam of electrons onto sample
- #2 - Detect products of beam/sample interaction



GOAL #1

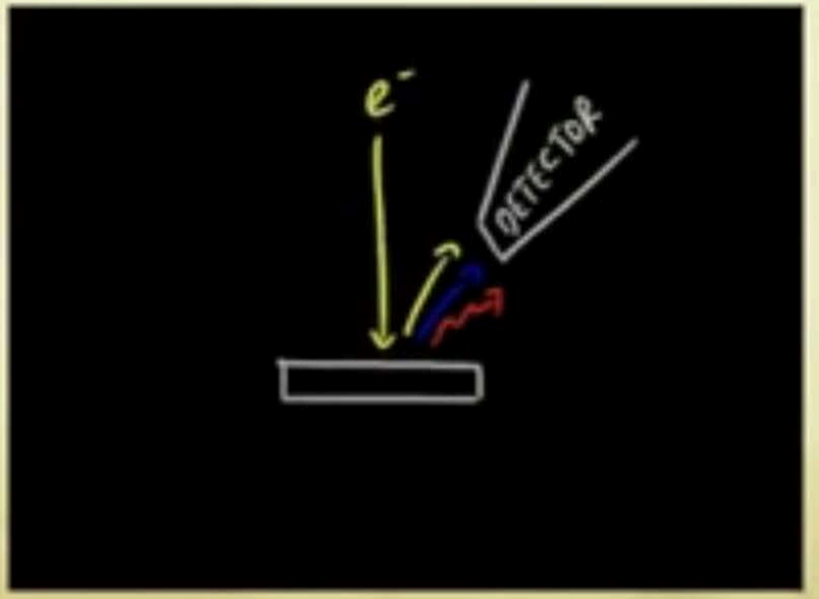
Focus A Small Electron Beam Onto the Sample

- Electron Gun
- Apertures
- Condenser Lens
- Deflection or Raster Coils
- Objective Lens

GOAL #2

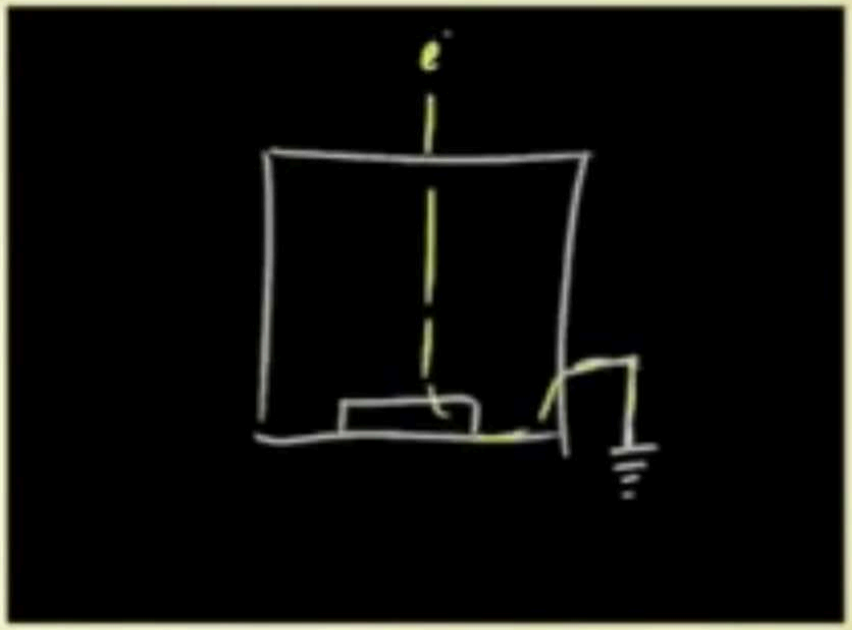
Detect Electrons and Other Particles Emanating From the Beam / Sample Interaction

- Beam/Sample Interaction
- Detectors



Major Requirements and Considerations

- High Voltage
- Low Pressure
- Sample Conductivity



GOAL #1

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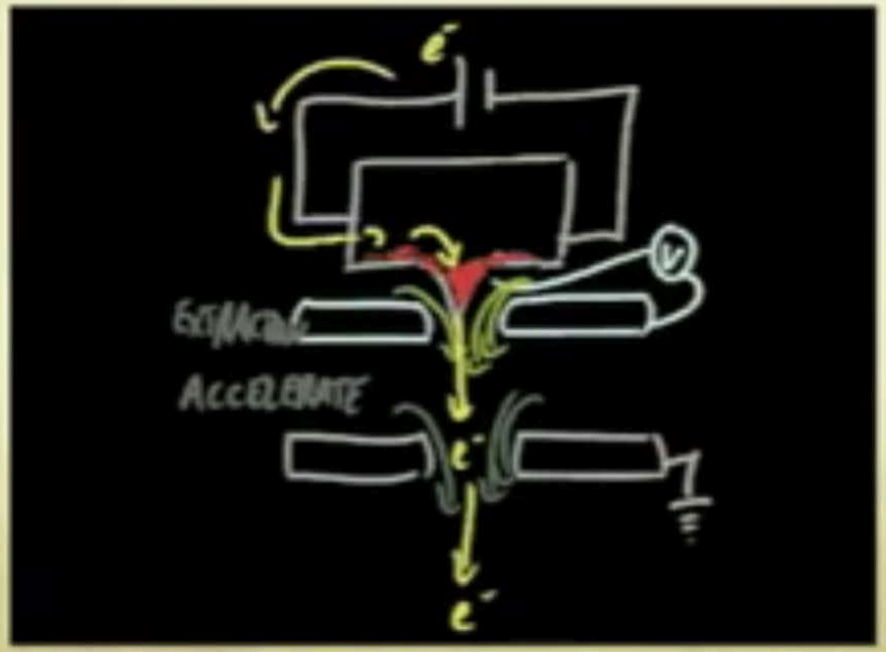
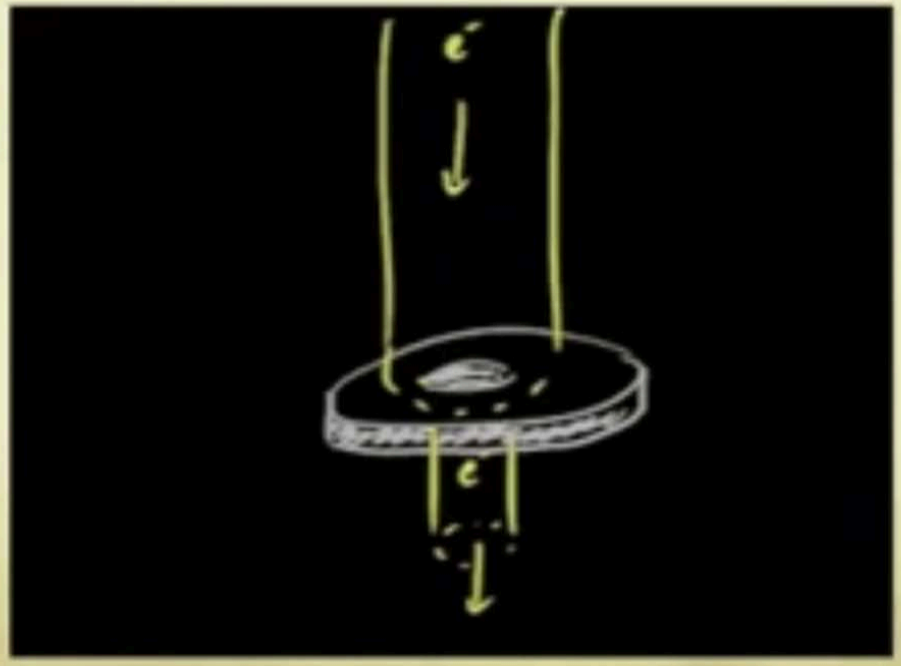
Electron Gun

- Source of the electron beam which is emitted and accelerated towards a sample
  - Thermionic Emission
  - Field Emission
  - 1000 to 30,000 volts



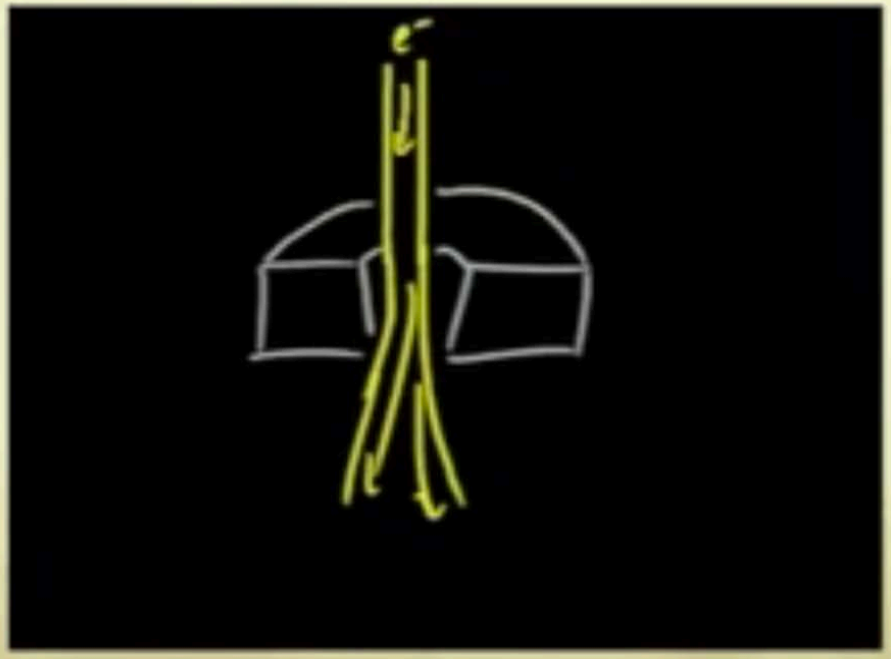
Apertures

- Small annular (donut shaped) metal discs
- Effect many parameters of final image characteristics



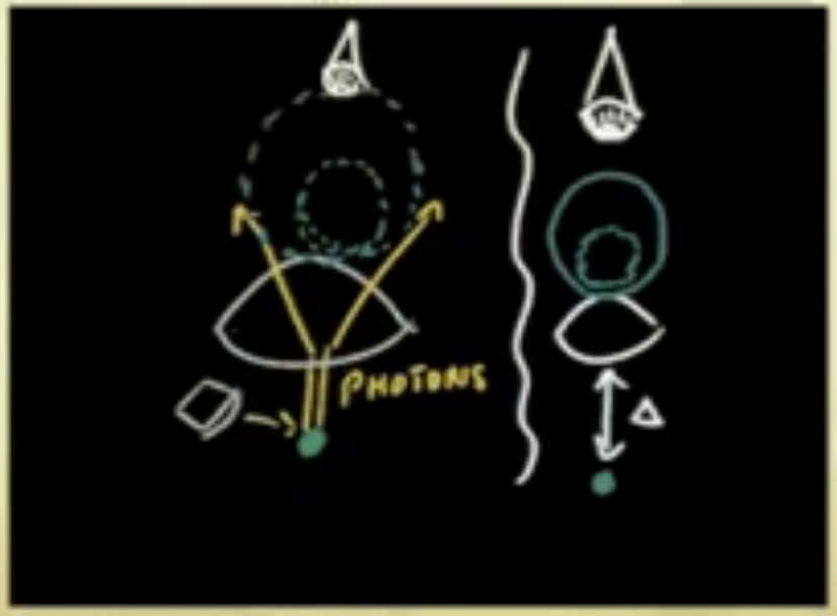
Condenser Lens

- Magnetic lens
- Controls diameter of electron beam



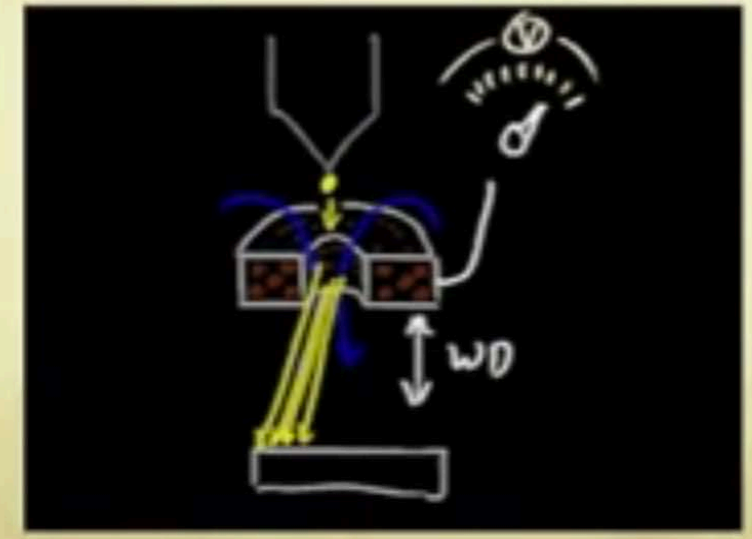
Lenses

- Glass and Optical Lenses
  - Sample ---) lens image
  - Requires light (photons)
  - Thickness ---) magnification



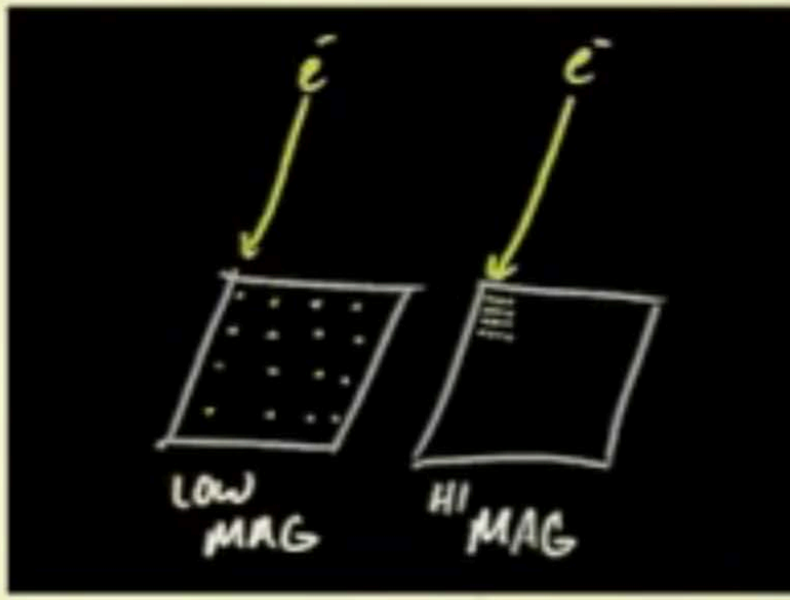
Lenses

- Electromagnetic Lenses
  - Electron beam ---) lens image
  - Requires electrons
  - Working distance ---) course focus
  - Adjustable current to lens ---) fine focus
  - Decreased raster--) increase magnification



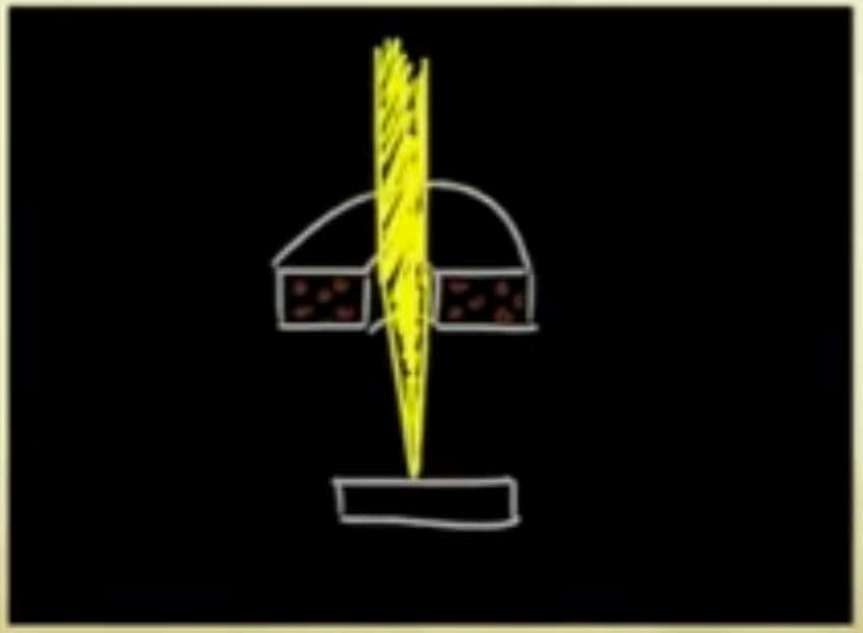
Deflector / Raster Coils

- Like independently x/y variable lenses
- Direct electron beam across the sample
- One to one correlation
- Creates 2D rastered pattern of grayscale values
- Smaller raster area ---) increased magnification



Objective Lens

- Serves as fine focus
- Adjusts final shape of electron beam
- Adjusts focal point to rest on sample surface



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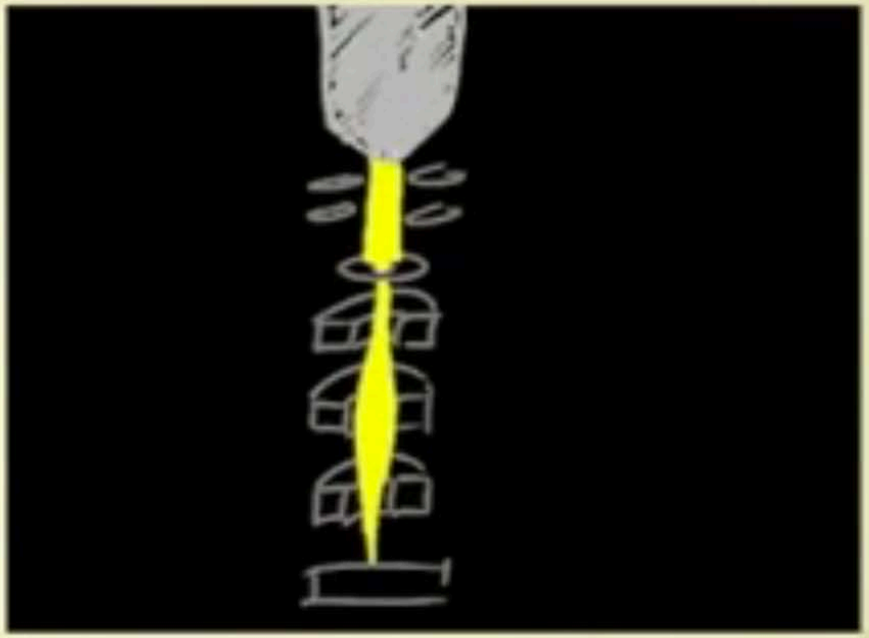
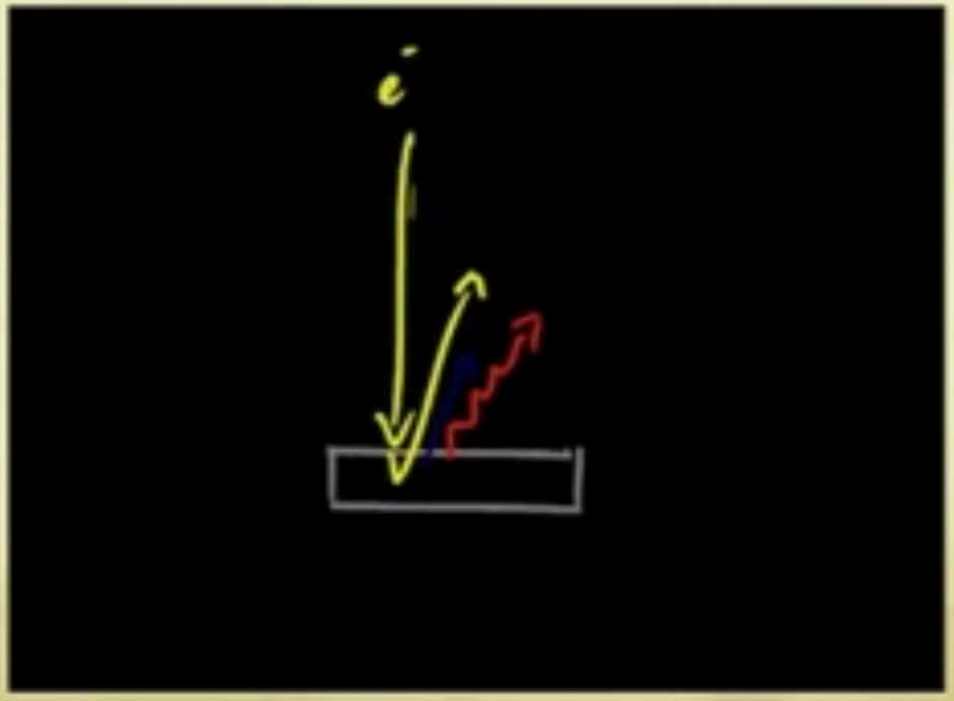


GOAL #2

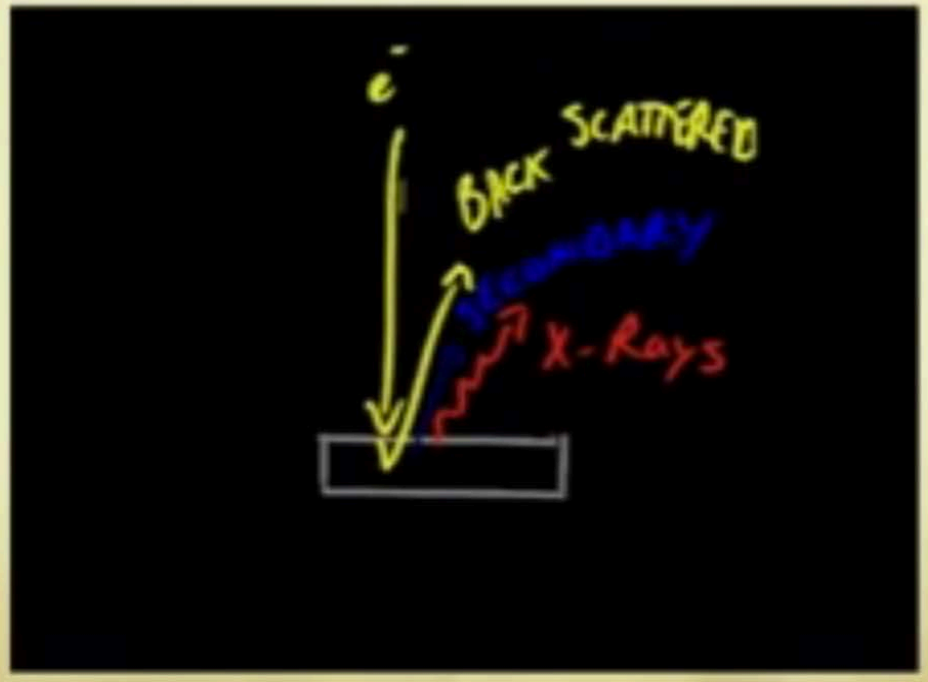
Detect Electrons and Other Particles Emanating From the Beam / Sample Interaction

- Beam / Sample Interaction



Beam / Sample Interactions

- Backscattered electrons (BSE)
- Secondary electrons (SE)
- X-Rays

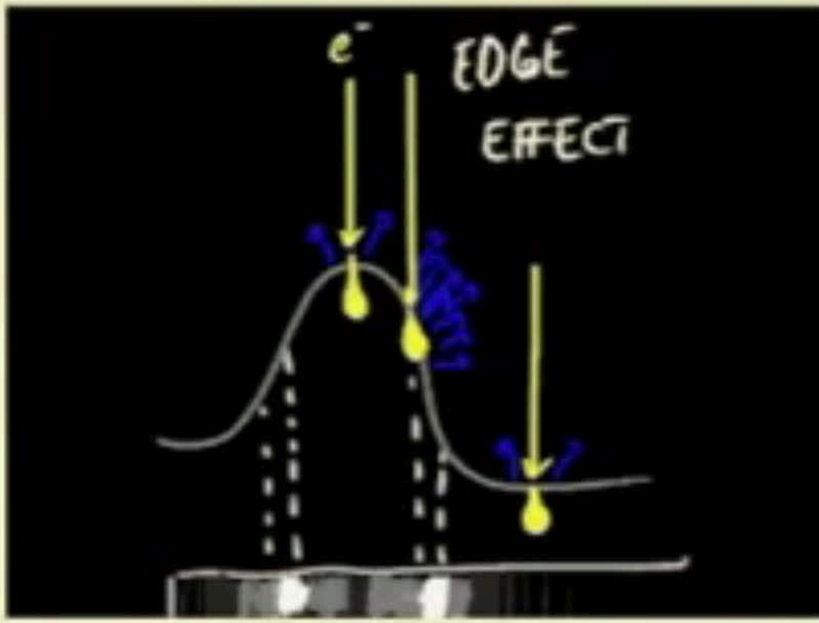


Backscattered Electrons

- Incident beam electrons ---) BSEs
- Elastic event ---) high energy
- Large escape depth
- Atomic number ---) compositional contrast

Secondary Electrons

- Sample electrons ---) SEs
- Inelastic event ---) low energy
- Shallow escape depths
- Edge effect ---) topographic contrast



X-Rays

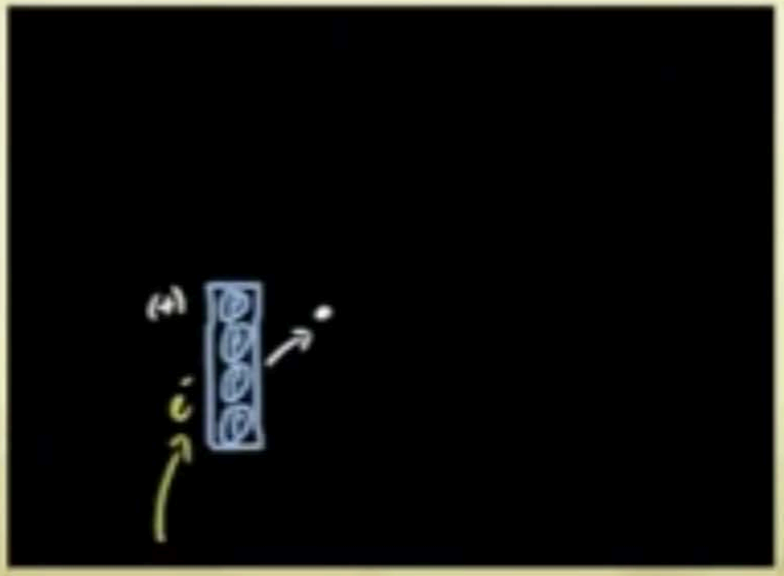
- Photon of light
- Emitted when high energy electrons "fall"
- Huge escape depths
- Unique emission spectra
  - Elemental analysis
  - Elemental contrast and mapping

Detectors

- Scintillator
- Light guide
- Photomultiplier

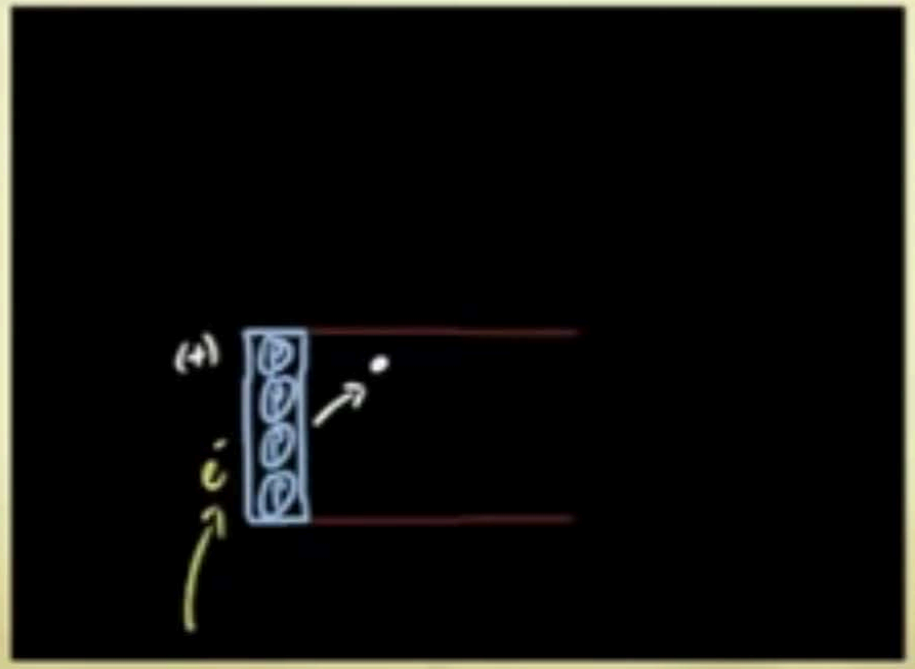
Scintillator

- Phosphorescence
- Energetic electron ---) fluorescence ---) photon
- 1 electron ---) 1 photon
- Scintillator bias ensures operation



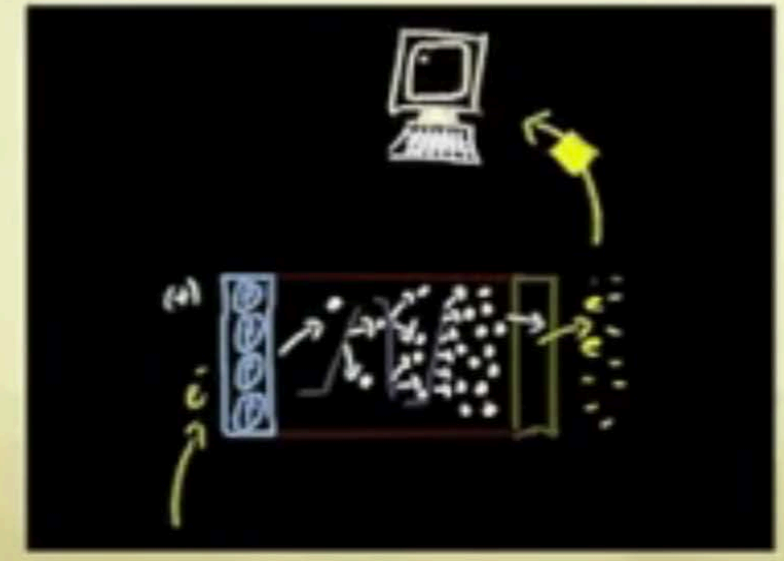
Light Guide

- Guides photons
- Scintillator ---) light guide ---) photomultiplier



Photomultiplier

- Amplifies photon signal
- Converts photon signal back to electric signal
- Sends electric signal to computer monitor
- Strength of signal represents image brightness



Detector Recap

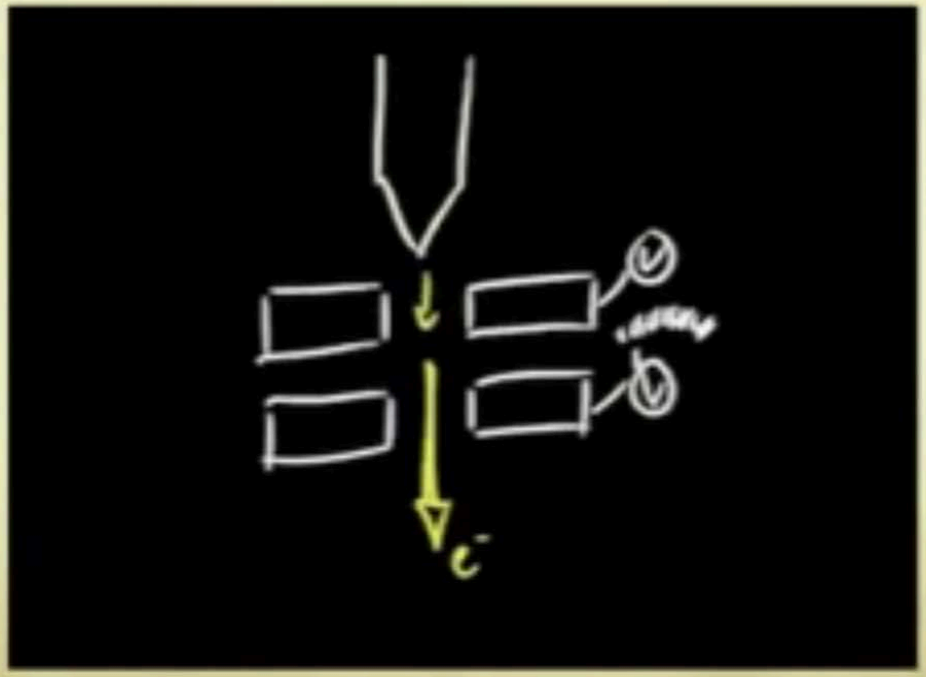
- Receives electrons
- Converts to photons
- Amplifies signal
- Converts back to electrons

Major Requirements and Considerations

- High Voltage
- Low Pressure
- Sample Conductivity

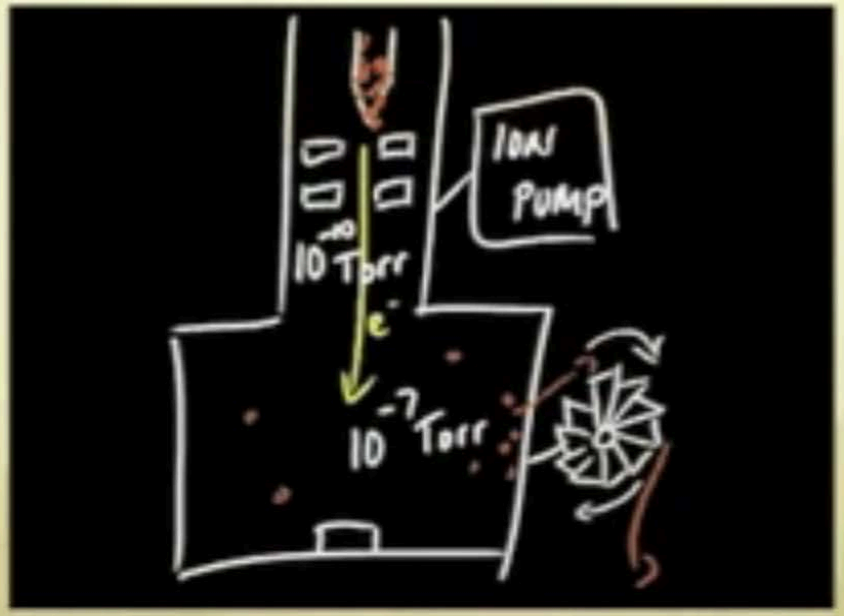
High Voltage

- Provides energy for accelerating electrons
- Must be stable, controllable, and tunable



Low Pressure

- We want to detect beam/sample electrons
  - NOT beam/air electrons
  - Specimen chamber pressure = 10^{-7} Torr
- Prolong tip life
  - Gun chamber pressure = 10^{-10} Torr



Sample Conductivity

- Grounding our sample
- Excess charge ---) noise, distortion, streaking
- Non-conductors can be coated with metal
- Balance charging with sample modification

Conclusion

- Components and Requirements
- Source, Gun, Chamber, Sample, Detector, Monitor
- Understand and Appreciate

- YOU ARE THE MOST COMPLICATED AND MOST IMPORTANT DETECTOR

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