Topic Outline

IVB. Sources

Electron Sources

- Goals
- Principles
- Accelerating Electrons
- Design
  - Schematic
  - Current Flows
  - Filaments
    - Filament Types
    - Pros and Cons
    - Tips
- Limitations

X-ray Sources

- Goals
- Principles
- Laboratory Designs
  - Schematic
  - Notes
- Synchrotron Sources
- Pros and Cons

Goals

The goals of designing an electron source are

- delta function in probe energy (electron beam kinetic energy)
- variable probe energy
- small spatial spot size at the sample
- high current (combined with above means high current density)
- stable operation (constant probe energy and intensity over the lifetime of source)

Principles

Electron emission from a metal under an applied electric field is called thermionic emission*.

Electrons can be pulled from a metal by applying a high enough field strength (voltage per unit length).

The number of electrons that can be removed at a given applied field strength increases with increasing temperature of the metal.

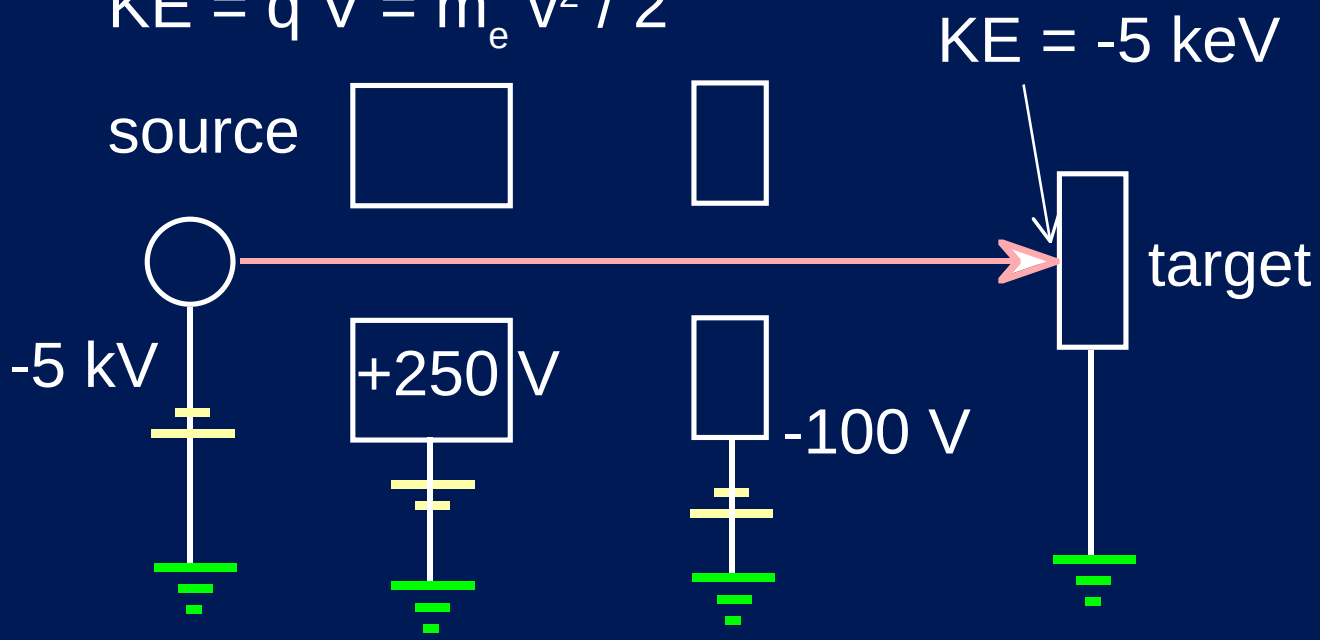
The number of electrons that can be removed at a given applied field strength increases with decreasing work function of the metal.

*The theoritical formulation is the Fowler-Nordheim relationship for an electron tunneling process.

Accelerating Electrons

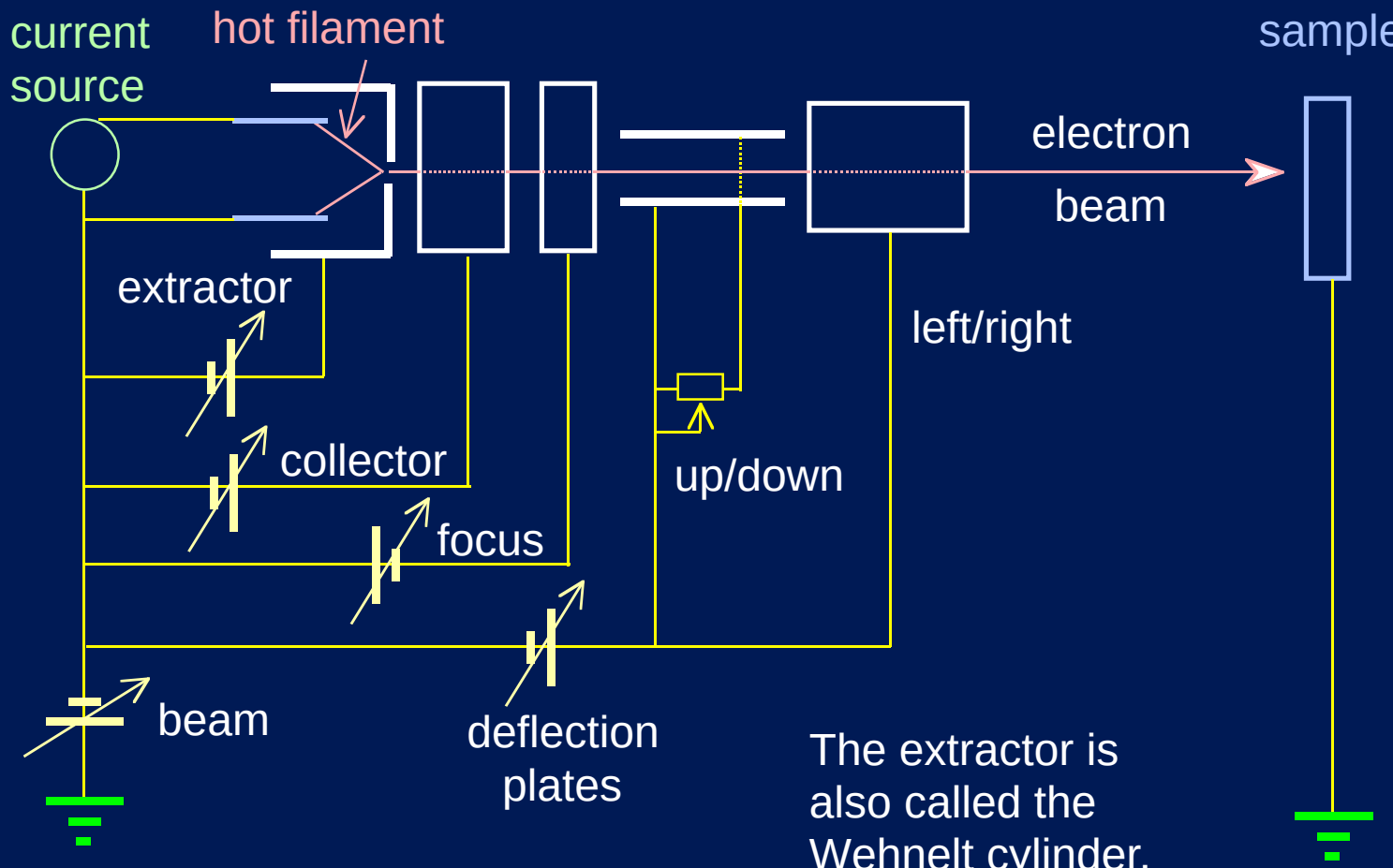
Electrons are accelerated under the application of an electrostatic or electromagnetic field. Their kinetic energy is determined by the potential difference between start and end points.

$KE = q\,V = m_e\,v^2 / 2$



Schematic

The labels denote the voltage controls.



Current Flows

The current flow ...

- through the filament is the filament current, i_F
- between filament and collector is the emission current, i_E
- between the filament and sample is the beam current, i_B
- from the sample to ground is the sample current, i_S

$i_S \quad i_B$

because the event produces electrons (current also flows away from the sample to the dectector)

We assume

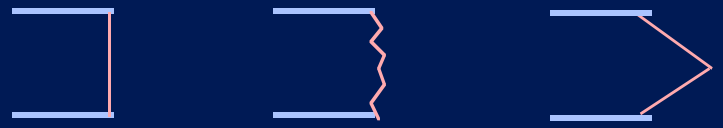
$i_B \propto i_E$

and control i_E to control i_B

Filament Types

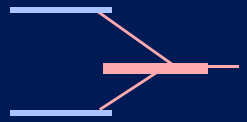
Wire Filament
Uses a W wire in one of three possible configurations.

straight curled hairpin



(most common)

Field Emitter Tip
Uses a finely pointed needle, typically made of LaB_6.



Pros and Cons

W Wire

Pros

- simpler design and maintenance
- longer lifetime

Cons

- lower current densities (by about a factor of 10^5)
- larger beam diameter at sample

Field Emitter Tip

Pros

- narrower energy spread in beam for same beam energy (because it operates at lower temperature)

Cons

- higher maintenance design requires much greater care in operation

Tips

To increase the beam current from an electron source using a W wire filament, lower the work function of the filament, for example by doping it with an alkali metal (K) or thorium (thorium oxide).

Limitations

No electron source is mono-energetic because the electrons always have a Boltzman spread of energies as they are emitted from a hot filament.

All electron sources eventually reach the same current density limit in the source beam because electrons repel each other the same regardless of their source.

Goals

The goals of designing an x-ray source are

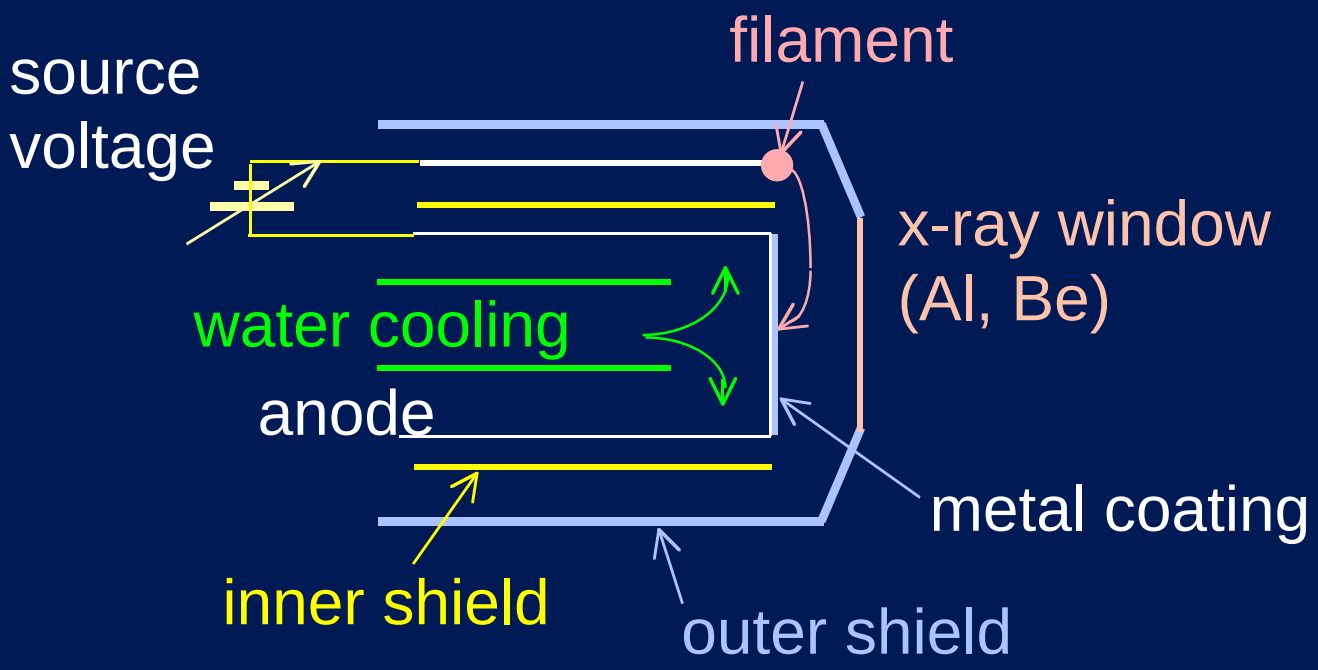
- a monochromatic source
- variable x-ray wavelength
- high x-ray flux at sample
- stable operation

Principles

X-rays are produced when electrons are suddenly stopped in a metal. This is called Bremmstrahlung ("breaking radiation").

Electromagnetic radiation ("light") is produced when electrons are accelerated. This is called synchrotron radiation.

Schematic


filament
source
voltage
x-ray window
(Al, Be)
water cooling
anode
metal coating
inner shield
outer shield

Notes

The anode is typically copper (high thermal conductivity).

Water is used to keep the anode cool.

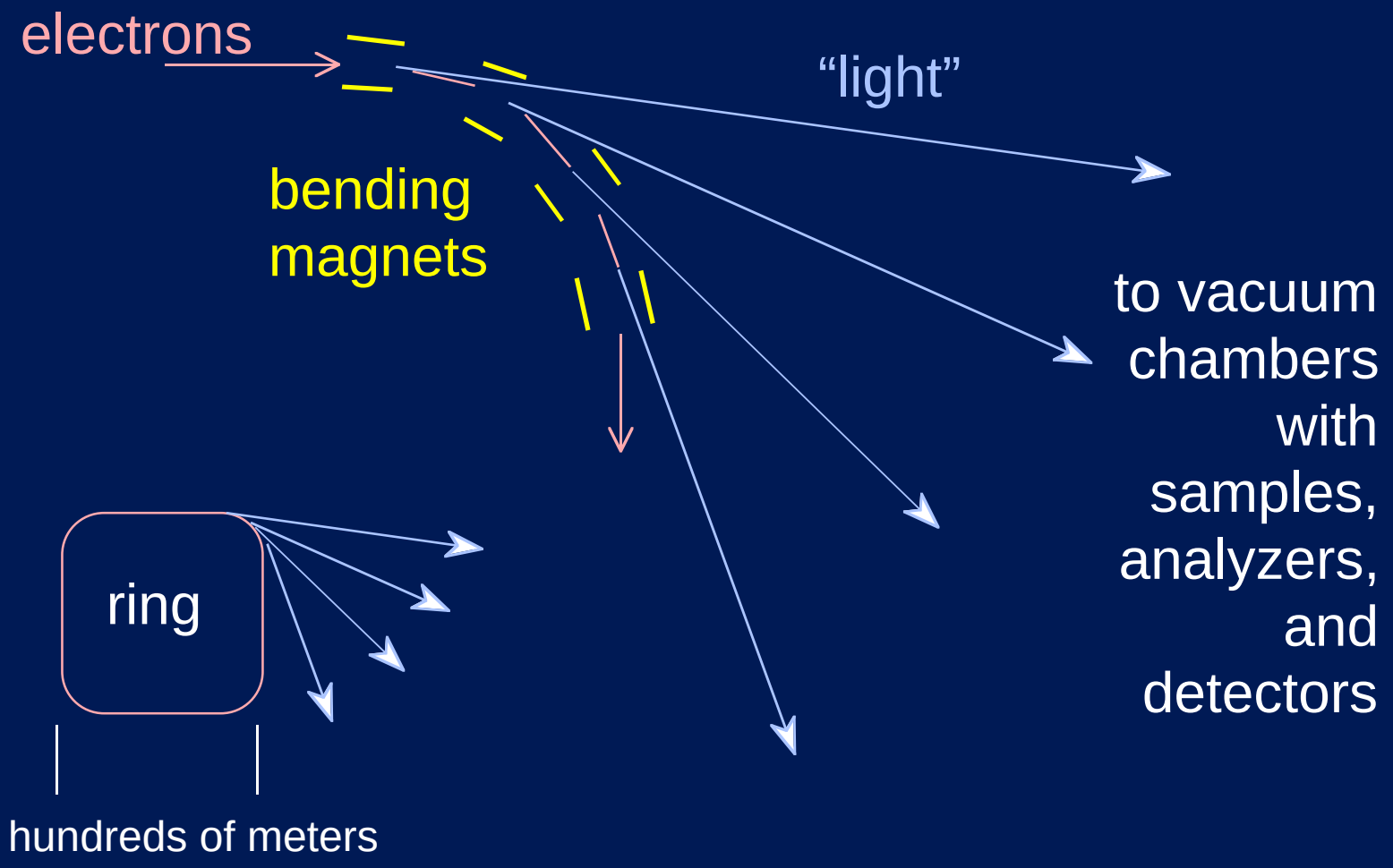
The filament is typically W (or thoriated W).

Most XPS x-ray sources use two filaments and two coatings (dual anode sources).

The x-ray window is (nearly) transparent to the x-rays at the given wavelength.

The source is operated at a given voltage and anode (emission) current or a given voltage and power (i_E*V).

Synchrotron Sources



Pros and Cons

Laboratory Source

Pros

- compact design
- lower maintenance

Cons

- source lineshape is complex
- subject to contamination by oxidation and coating loss
- only discreet energies

Synchrotron Source

Pros

- higher brilliance (intensity per unit area)
- “tunable” wavelength ranges

Cons

- specialized facilities required