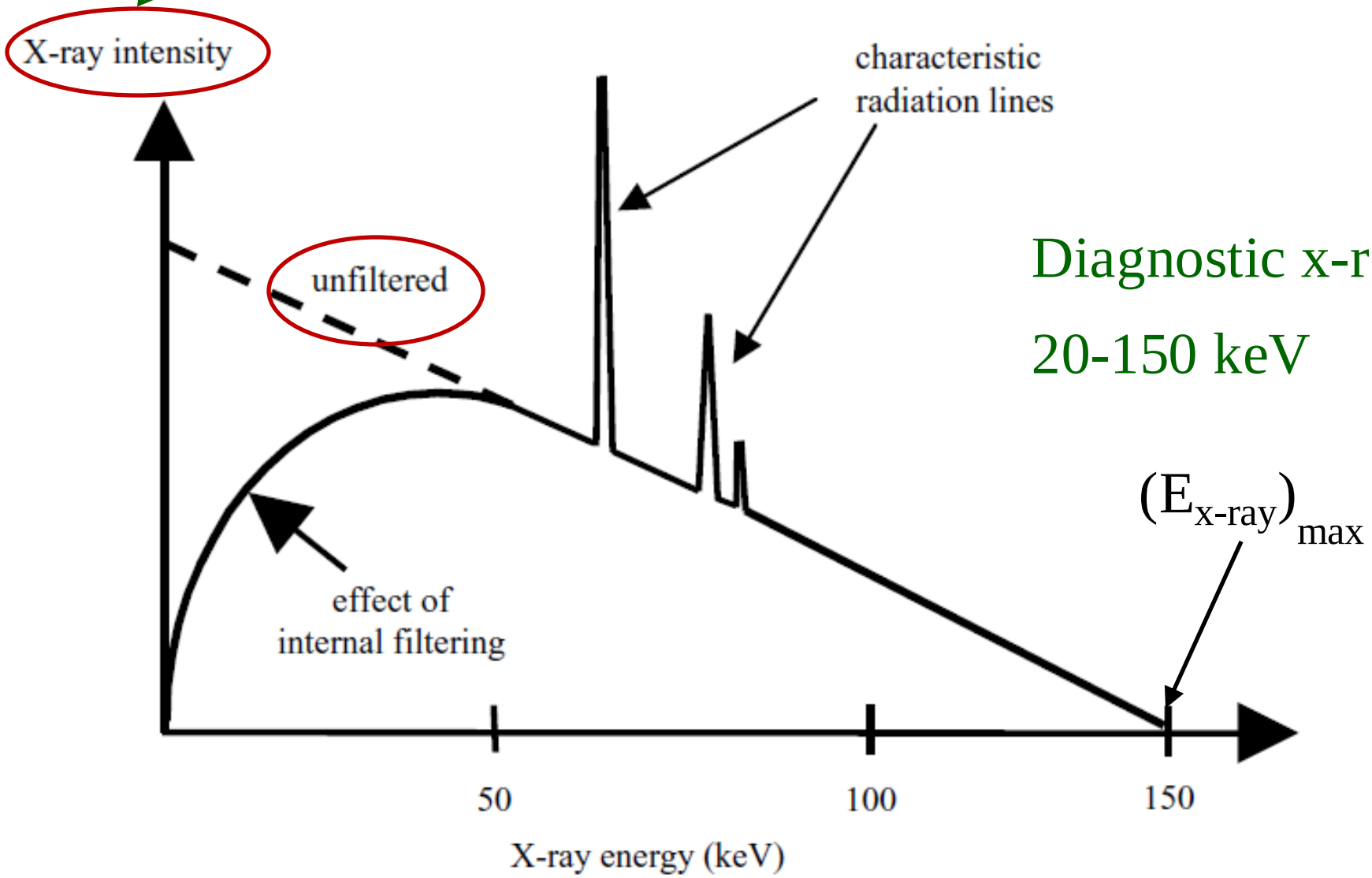
Lec 4: X-ray tube

Recap: X-ray spectrum

of photons in the beam



Diagnostic x-rays:

20-150 keV

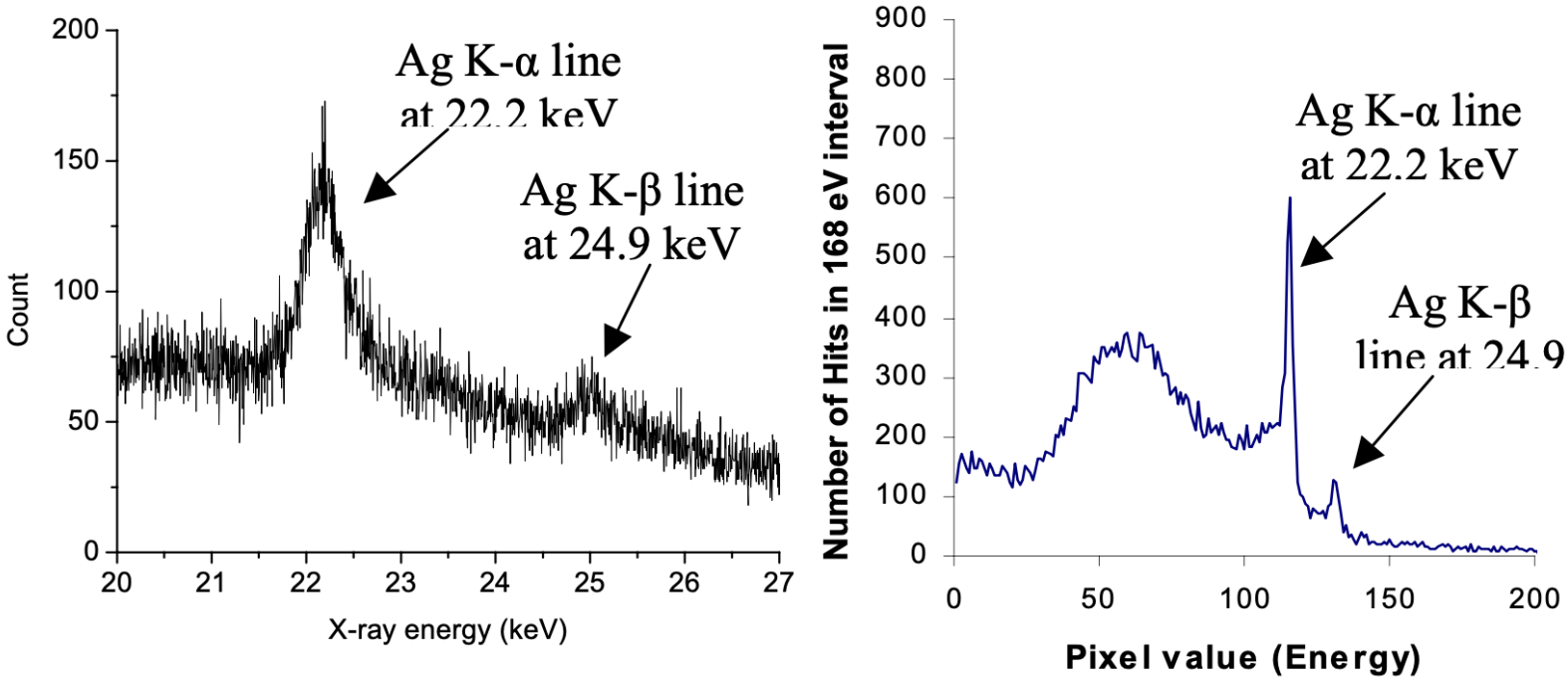
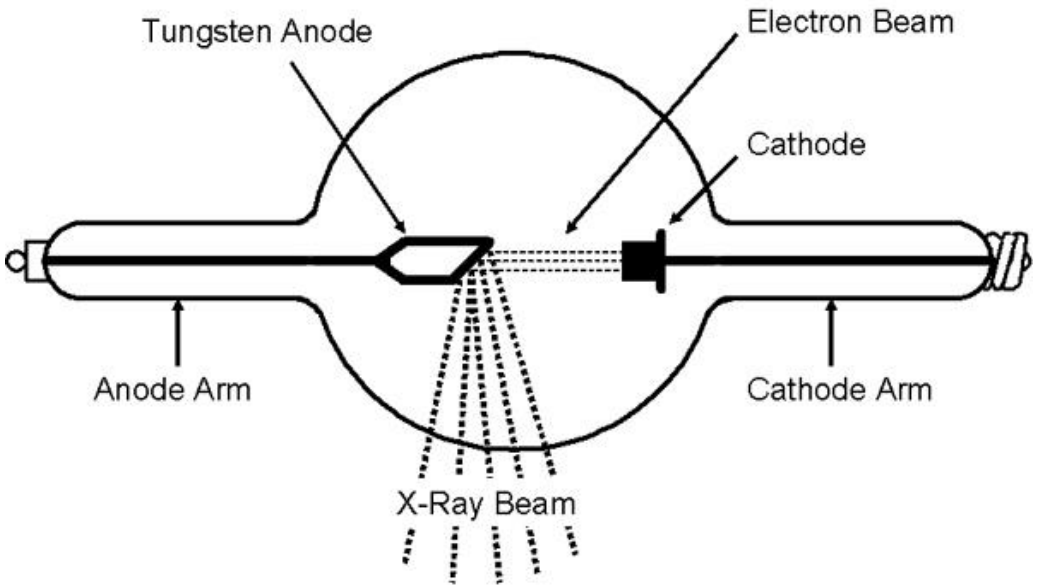


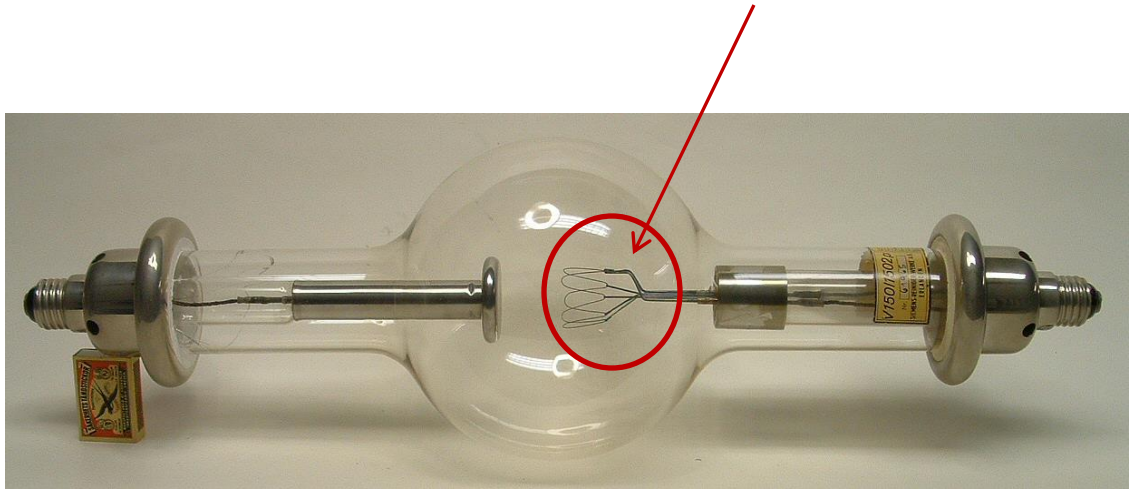
Figure 1: Typical K-alpha/K-beta spectra taken by the two single hit CCD cameras show clearly measurable K-alpha and K-beta peaks.

X-ray tube: basic parts



- Filament (or cathode): held at –ve voltage, temp. ~ 2200^{o}C for thermionic emission
- Target (or anode): held at +ve voltage (~ 150 kV)
- Housing: Vacuum tube, surrounded by oil. Lead shield, with a glass window.

Filament



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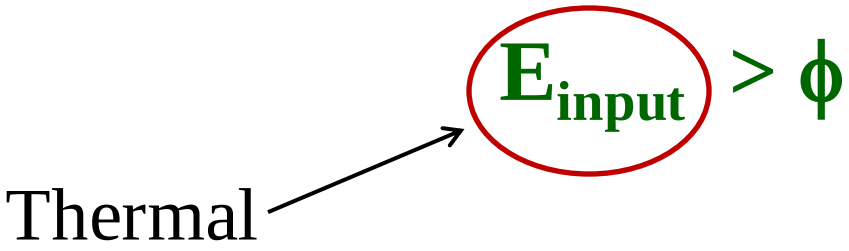
Filament current is used to heat up the cathode.

Thermionic emission: electrons leave the filament surface due to thermal energy (~ 2200^{o}C) .

Work function

Work function (ϕ): Energy needed to free a loosely-bound valence electron from the surface of the cathode.



Filament current

Filament current density: $J = AT^2 e^{-\varphi/kT}$

(Richardson-Dushman equation)

$$A = \frac{4\pi emk^2}{h^3} = 1.2 \times 10^6 \mathrm{A/m^2K^2}$$

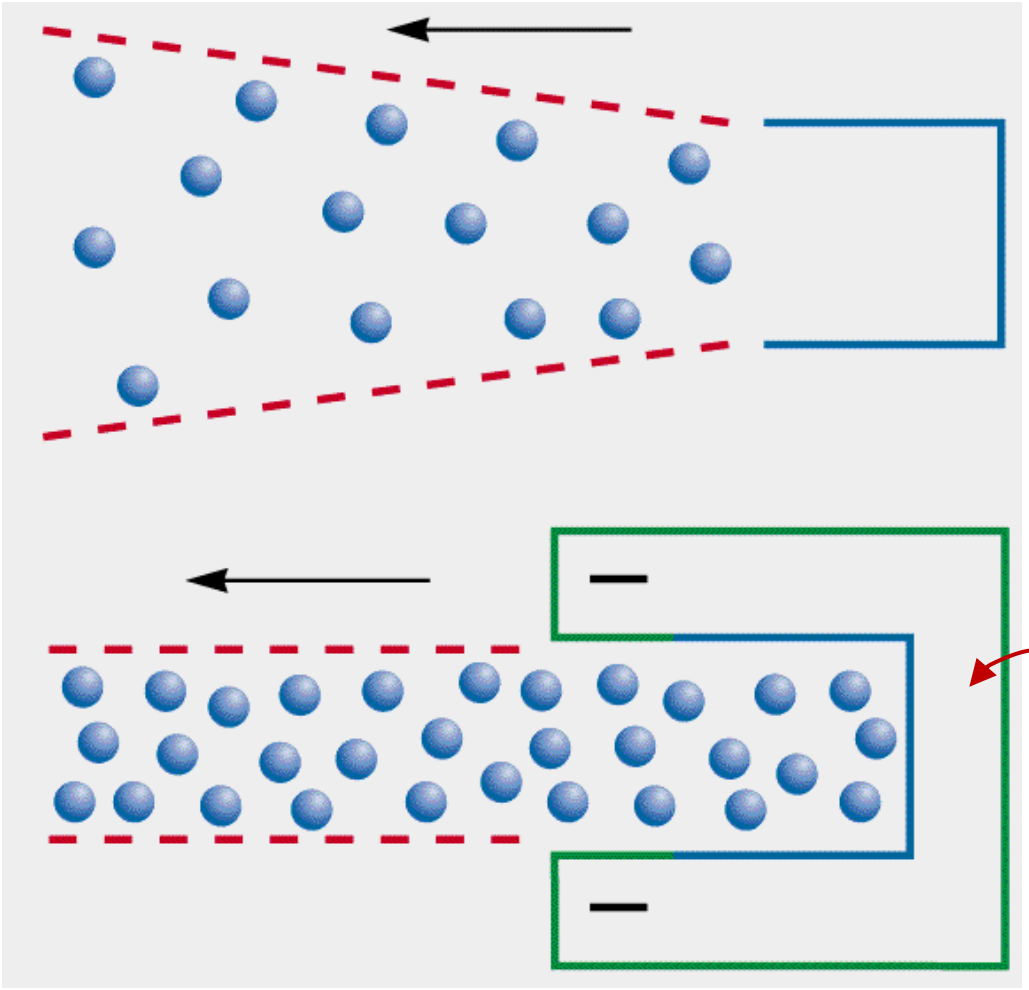
Nobel prize to Richardson in 1928
for thermionic emission

Space charge

Cloud of emitted electrons around the filament.

Makes it difficult for further electrons to be emitted.

Cathode



Electrons without focusing

In presence of a focusing cup

Filament + focusing cup = cathode (-ve charge)

Bushong, chapter 7

“Sun burn” of the filament

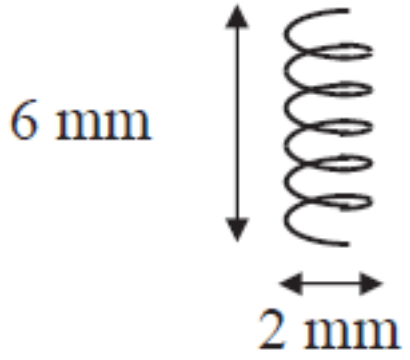
- Particles vaporize under high heat and solidify on the glass.
- Destroys the vacuum integrity of the tube.

New filament materials:

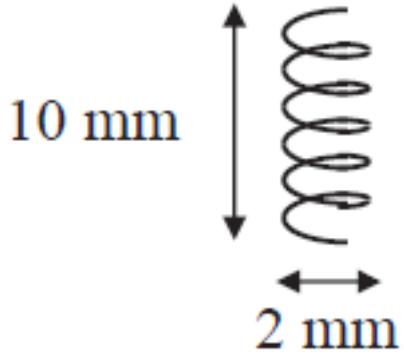
1. Reduced work function (certain oxide coatings)
2. Low sun-burn effect (add thorium to tungsten)

Dual filament

Small filament: Resolve fine features due to tight focus.

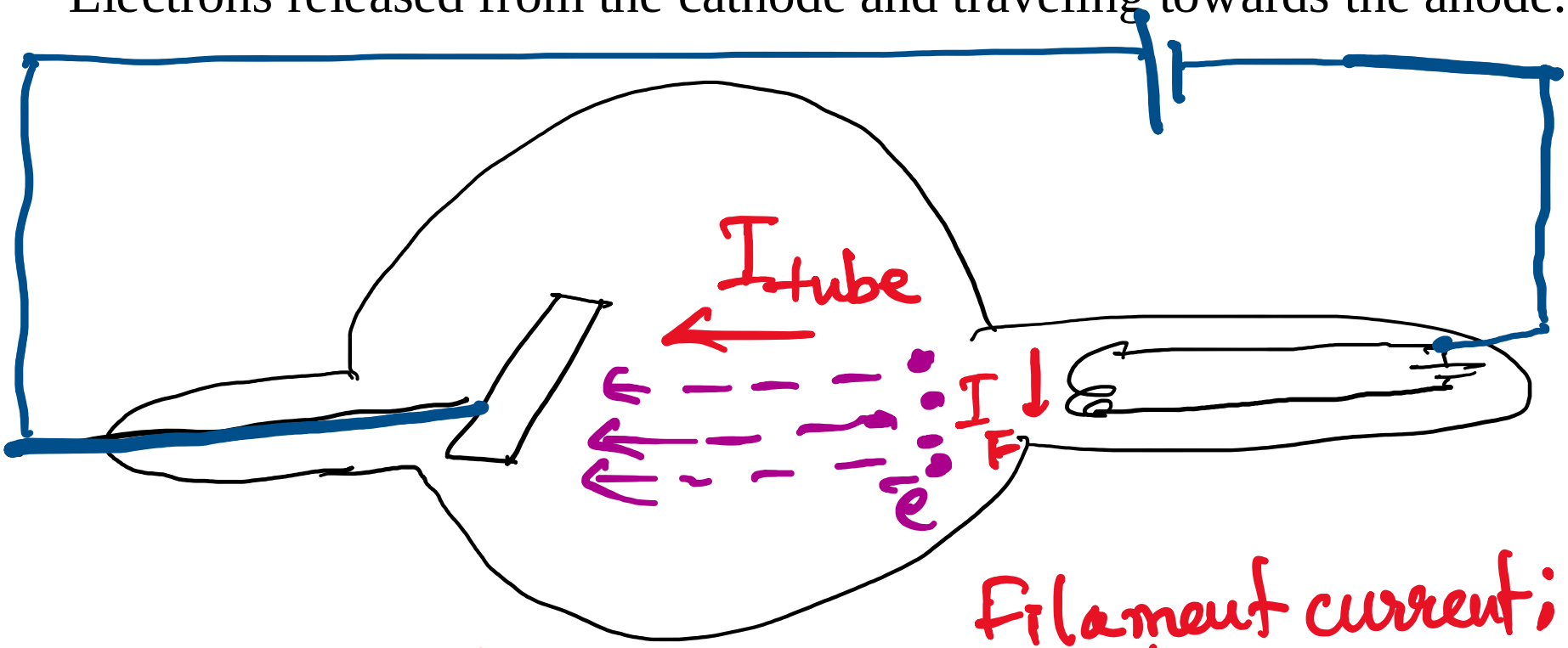


Big filament: Gives short, intense exposure (high electron emission). Useful to avoid motion blurring.



Tube current

Electrons released from the cathode and traveling towards the anode.



Tube current: leads to x-ray generation by impinging on anode

Filament current: leads to thermionic emission.