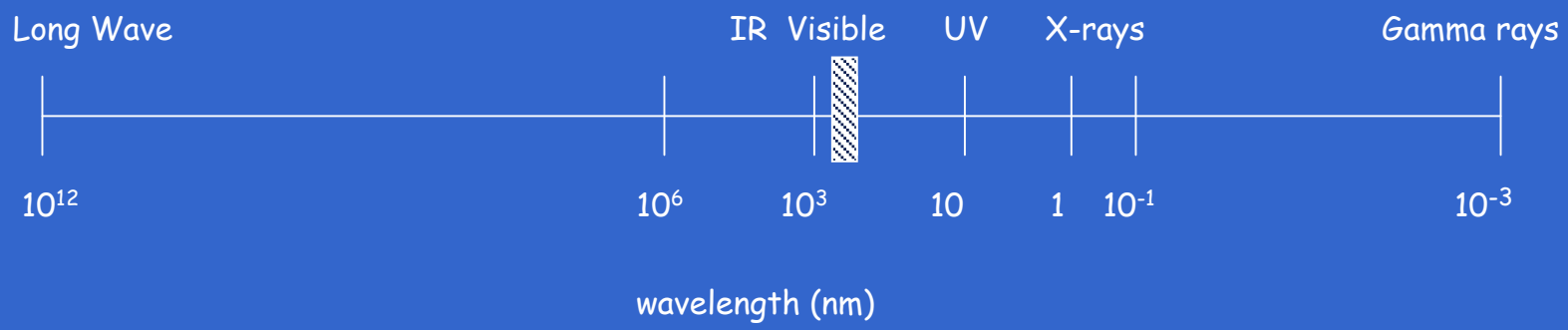
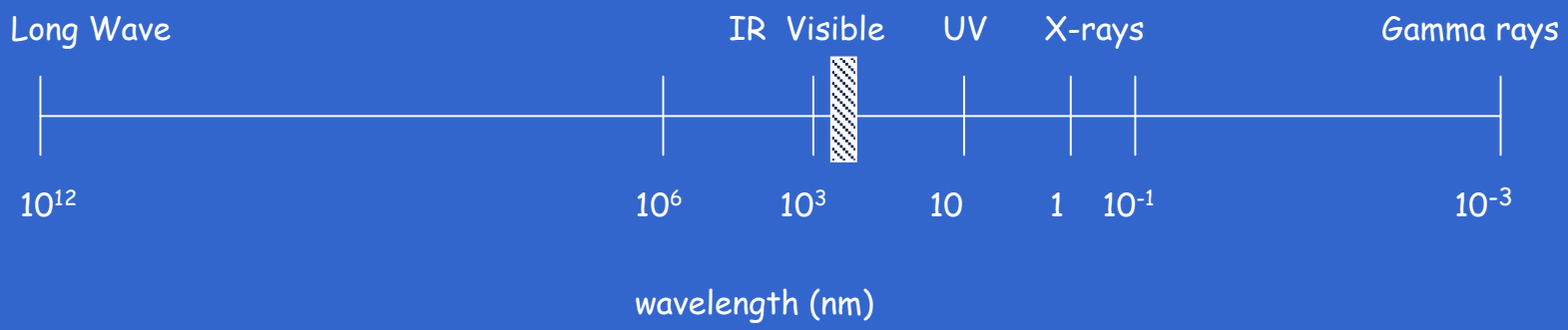
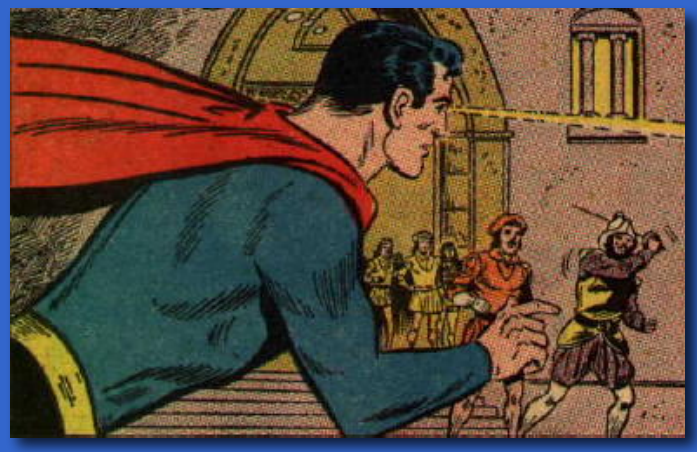


X-rays →

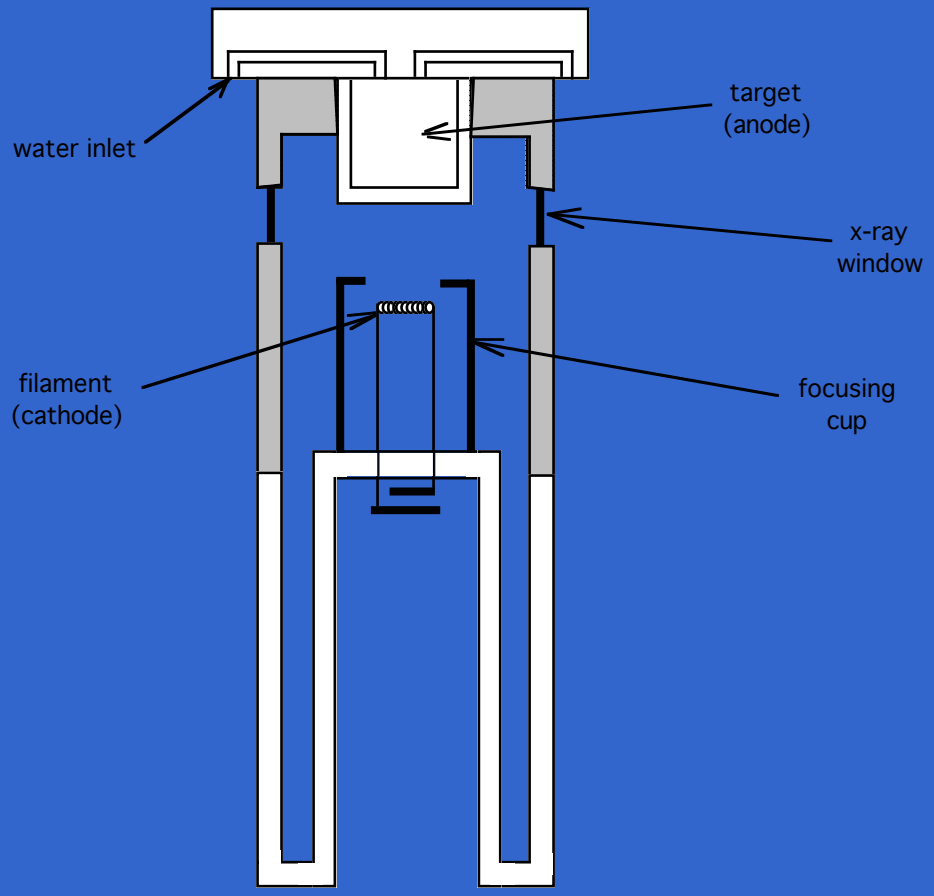
Frau Röntgen's hand


Long Wave
IR
Visible
UV
X-rays
Gamma rays
10^{12}
10^{6}
10^{3}
10
1
10^{-1}
10^{-3}
wavelength (nm)

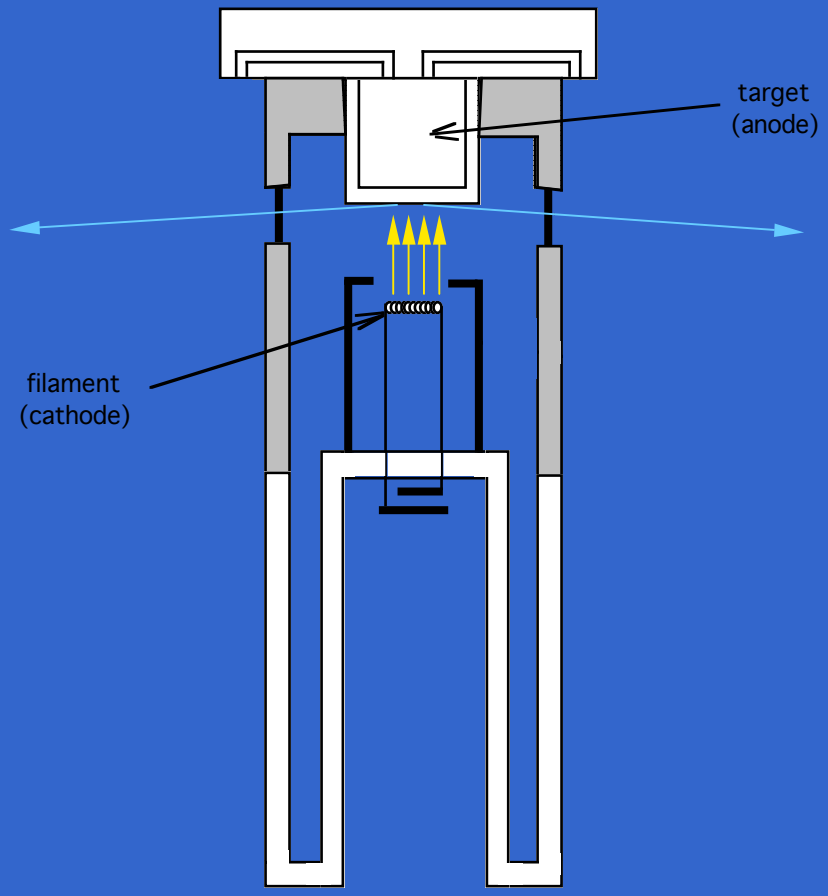
X-rays →



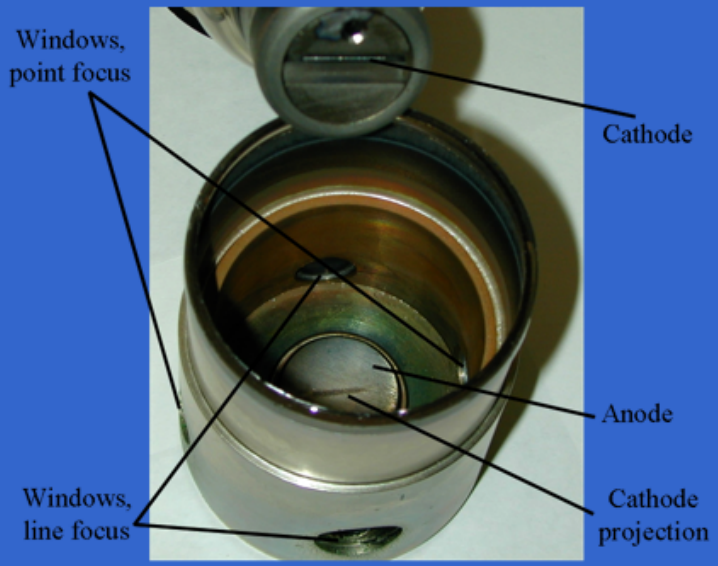
X-ray tube


water inlet
target
(anode)
x-ray
window
filament
(cathode)
focusing
cup

X-ray tube



X-rays


Windows,
point focus
Cathode
Anode
Windows,
line focus
Cathode
projection

X-rays

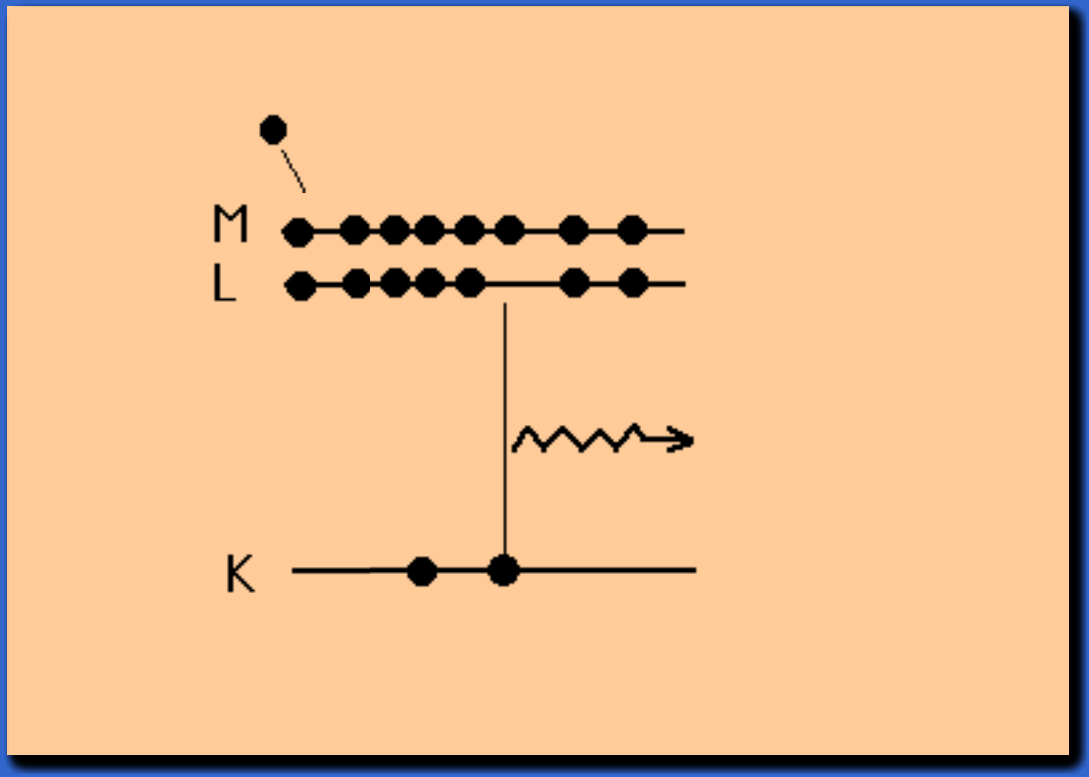
White radiation

Produced upon "collisions" with electrons in target

X-rays

Mechanism

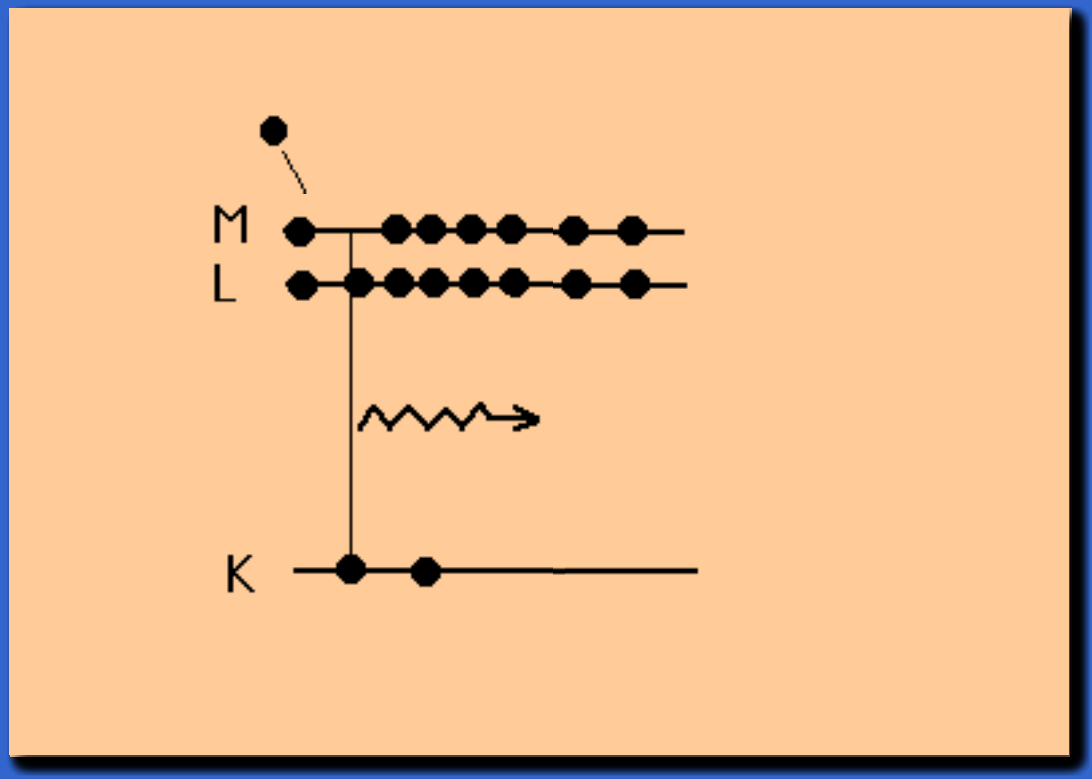
Decelerating charges give off radiation



X-rays

Mechanism

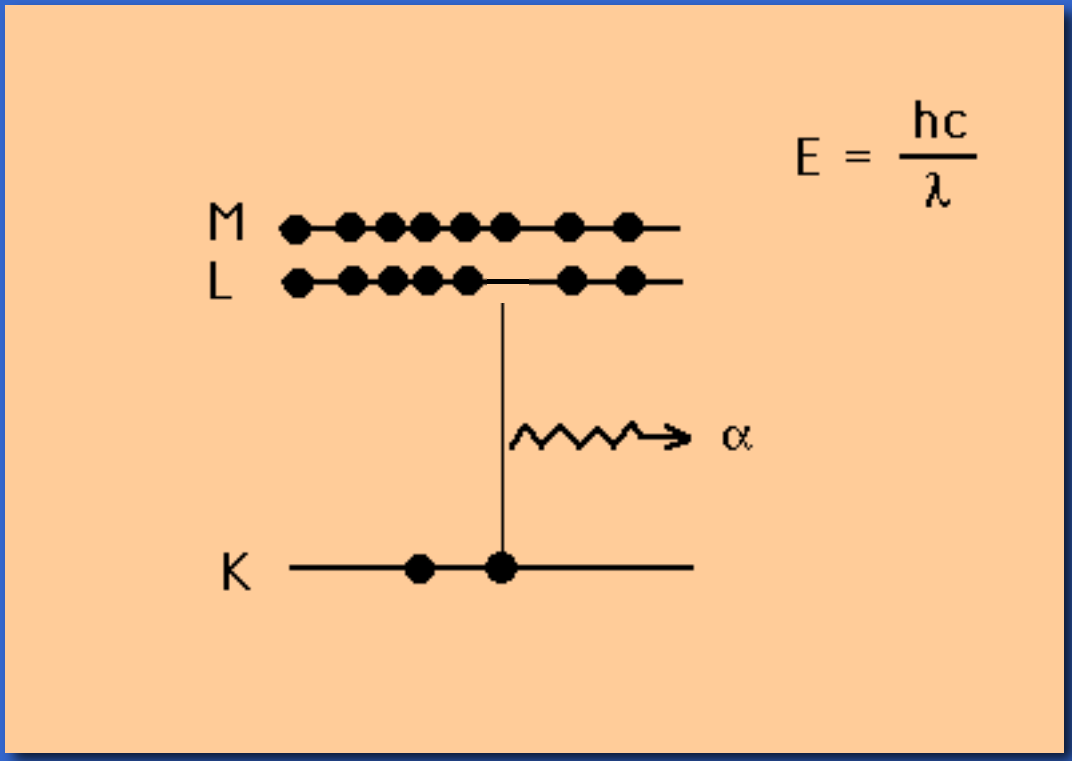
Decelerating charges give off radiation



X-rays

Mechanism

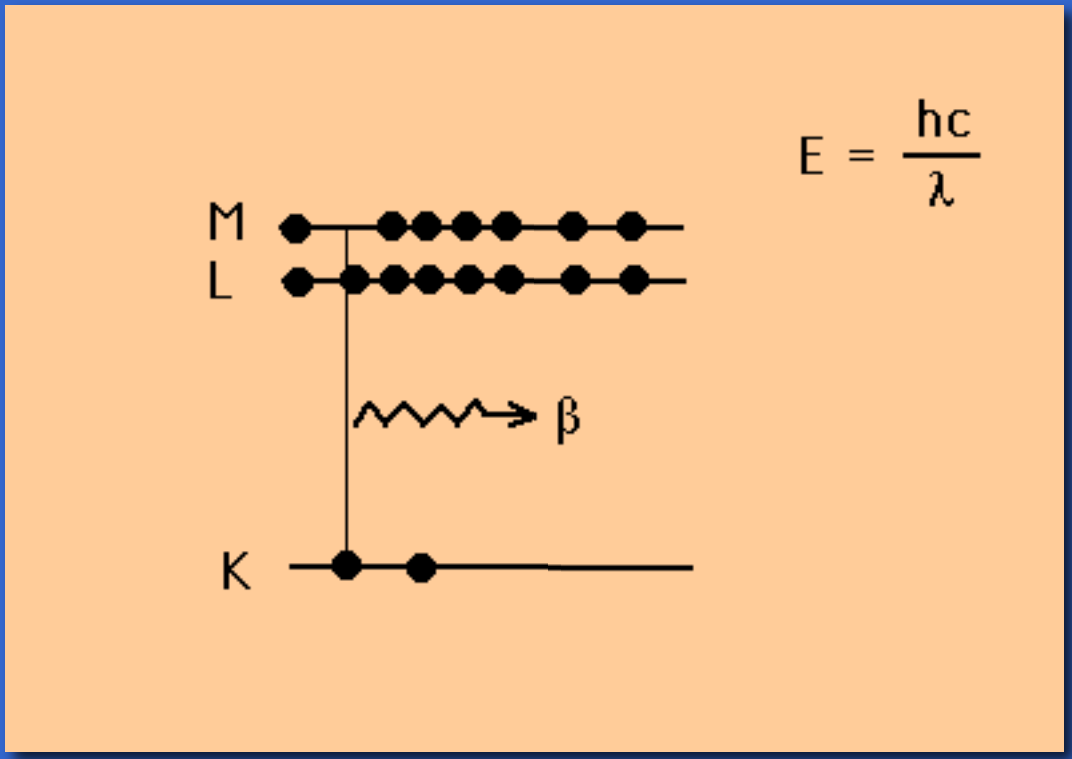
Decelerating charges give off radiation



X-rays

Mechanism

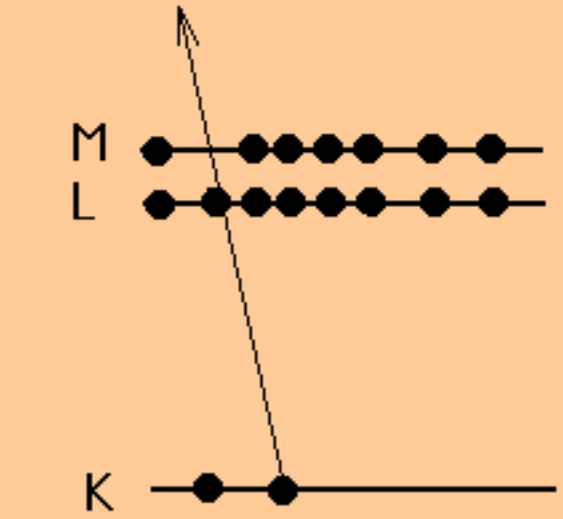
Decelerating charges give off radiation



X-rays

Mechanism

Decelerating charges give off radiation

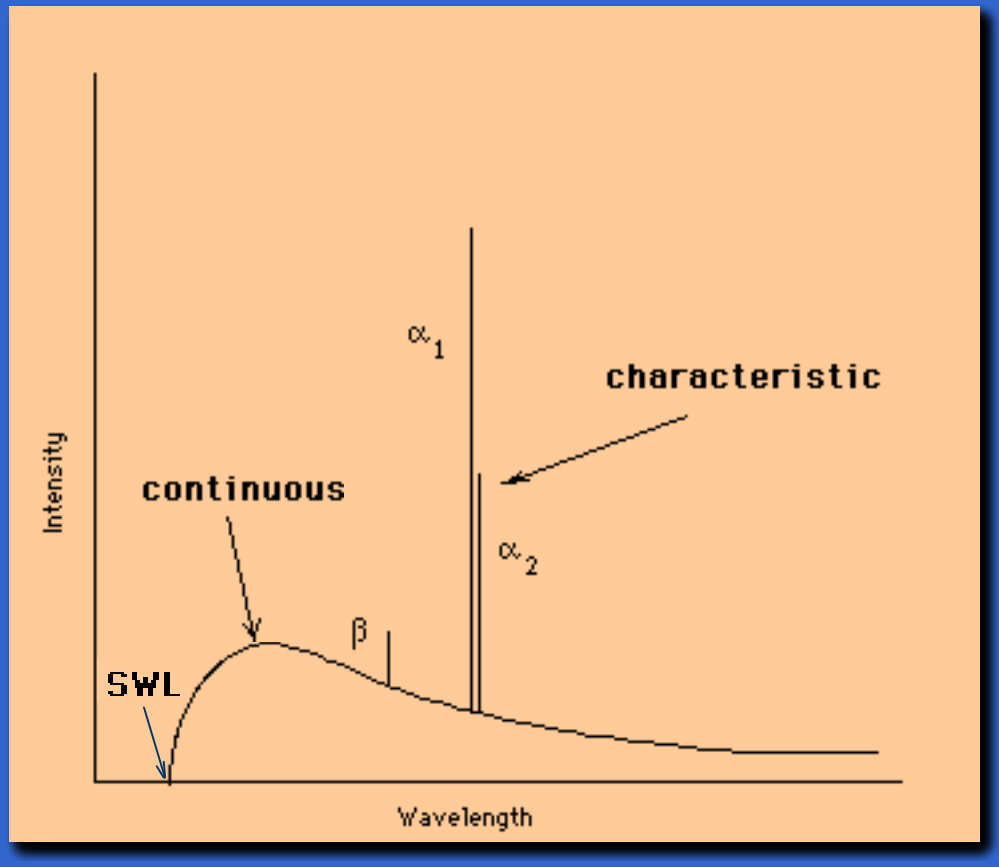


E to excite characteristic radiation

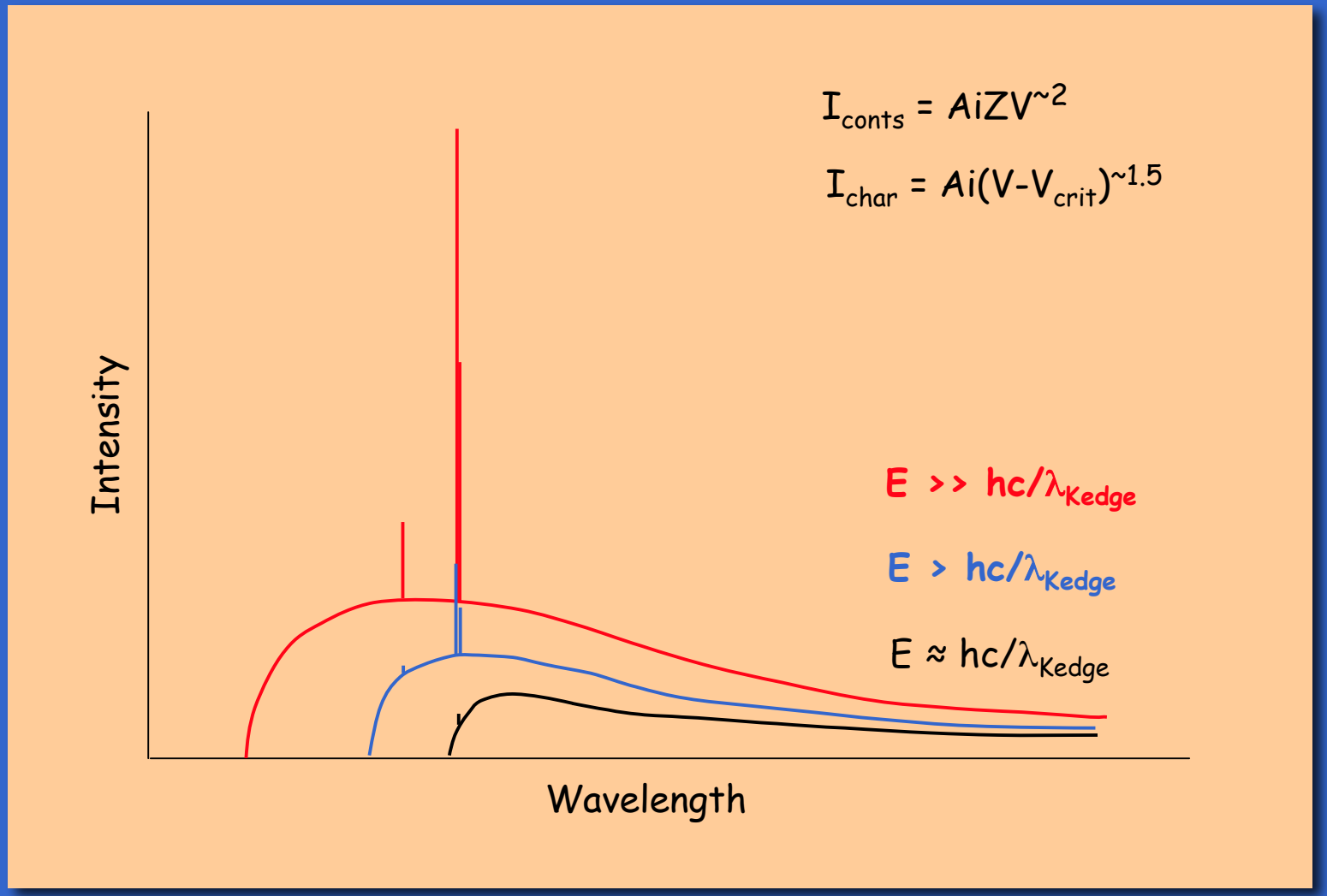
$$= \frac{hc}{\lambda_{Kedge}}$$

X-rays

Typical tube spectrum

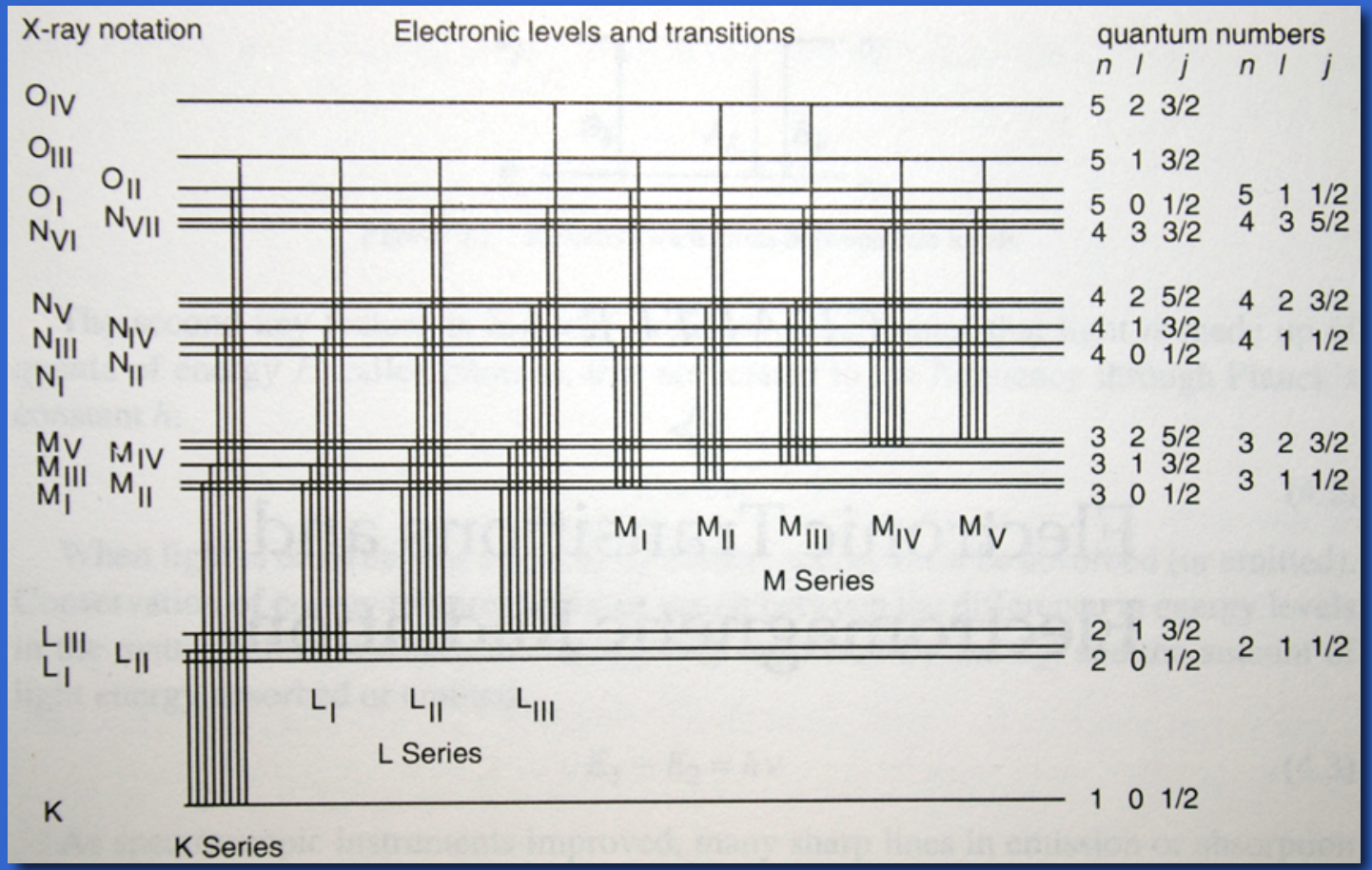


X-rays - vary tube voltage



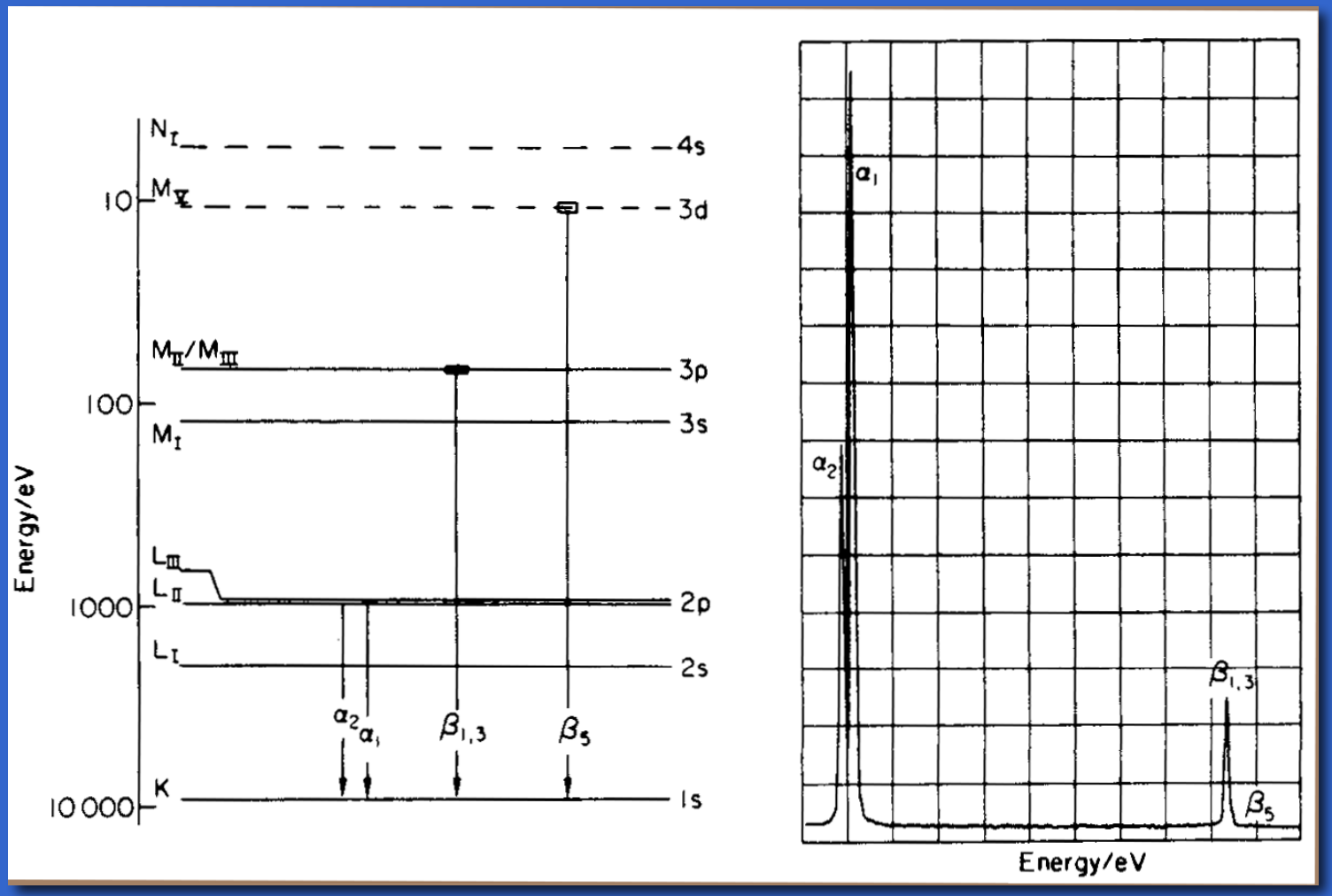
X-rays

More electron transitions



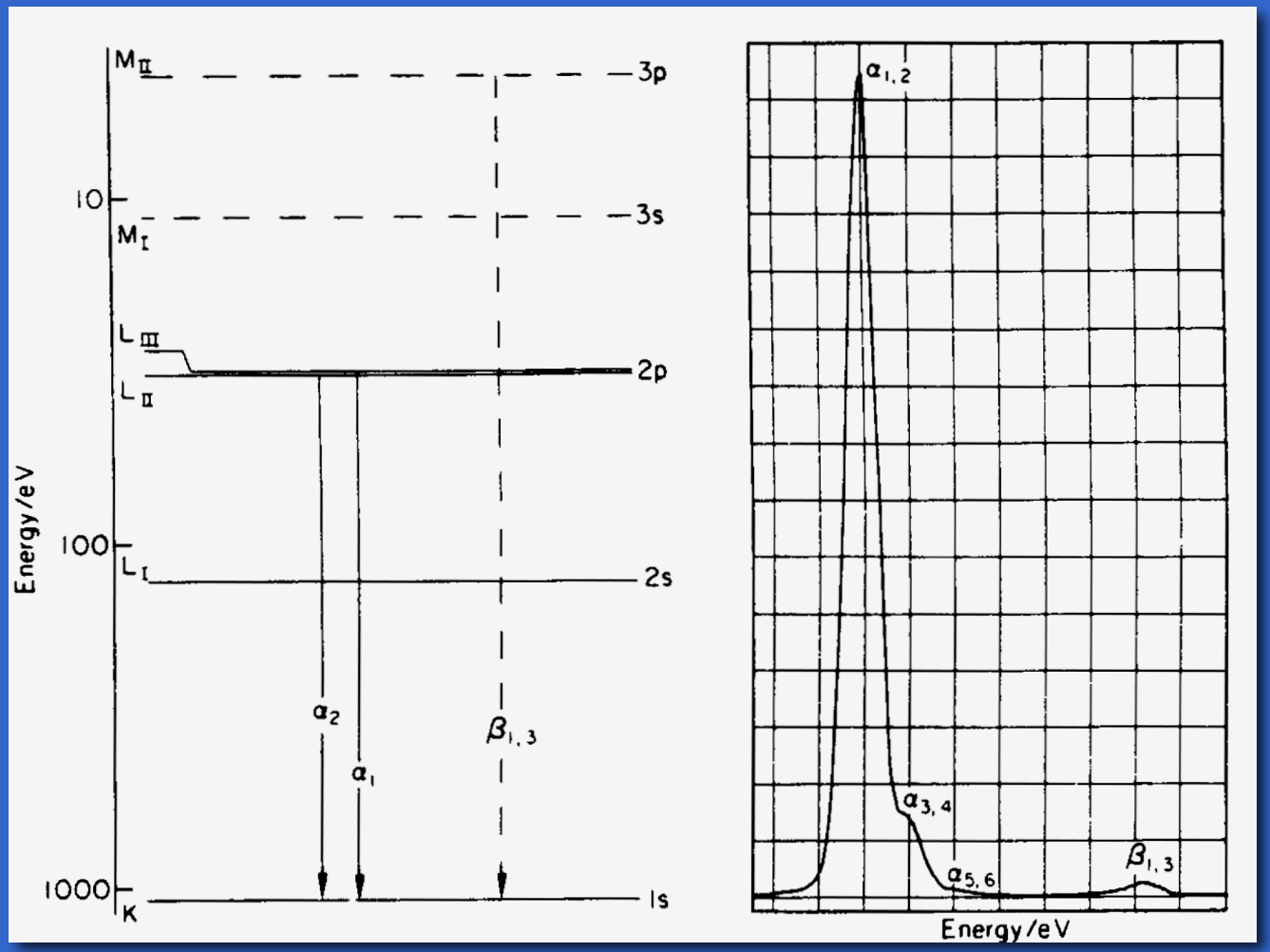
X-rays

Cu spectrum



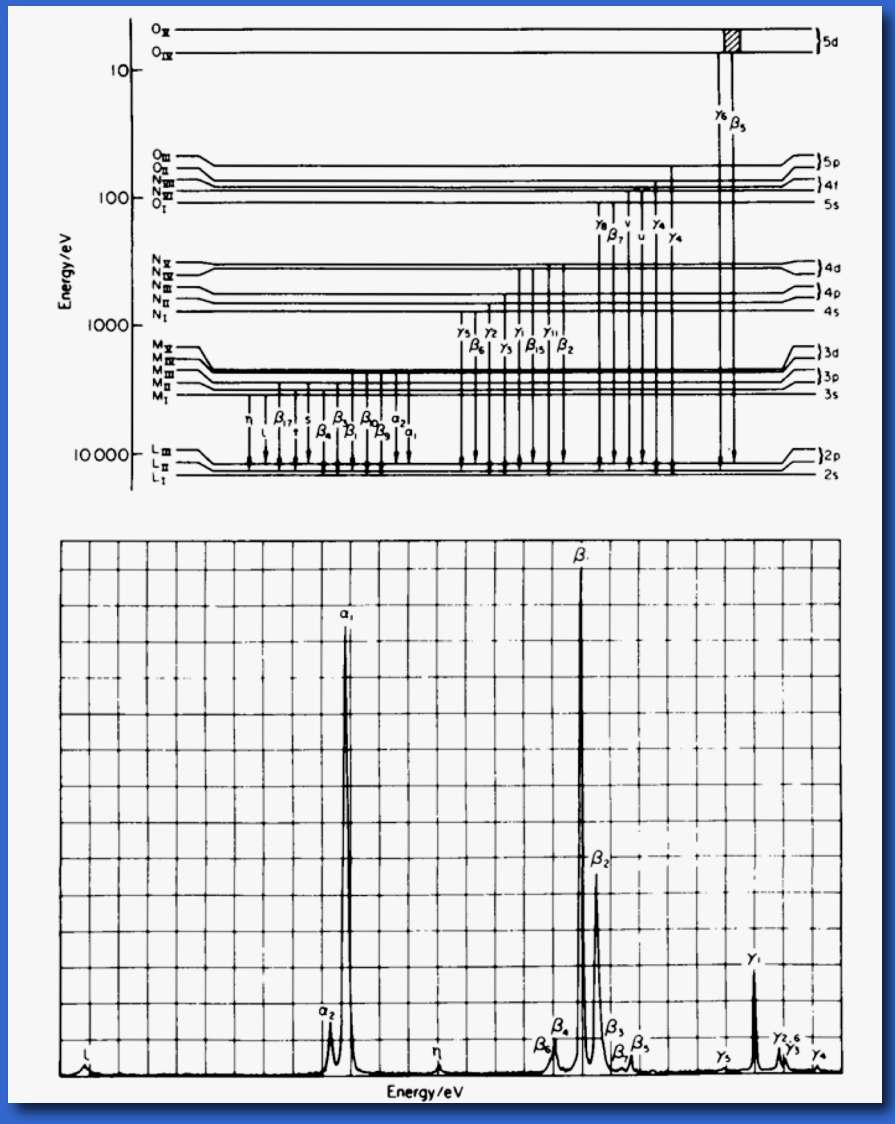
X-rays

Al spectrum



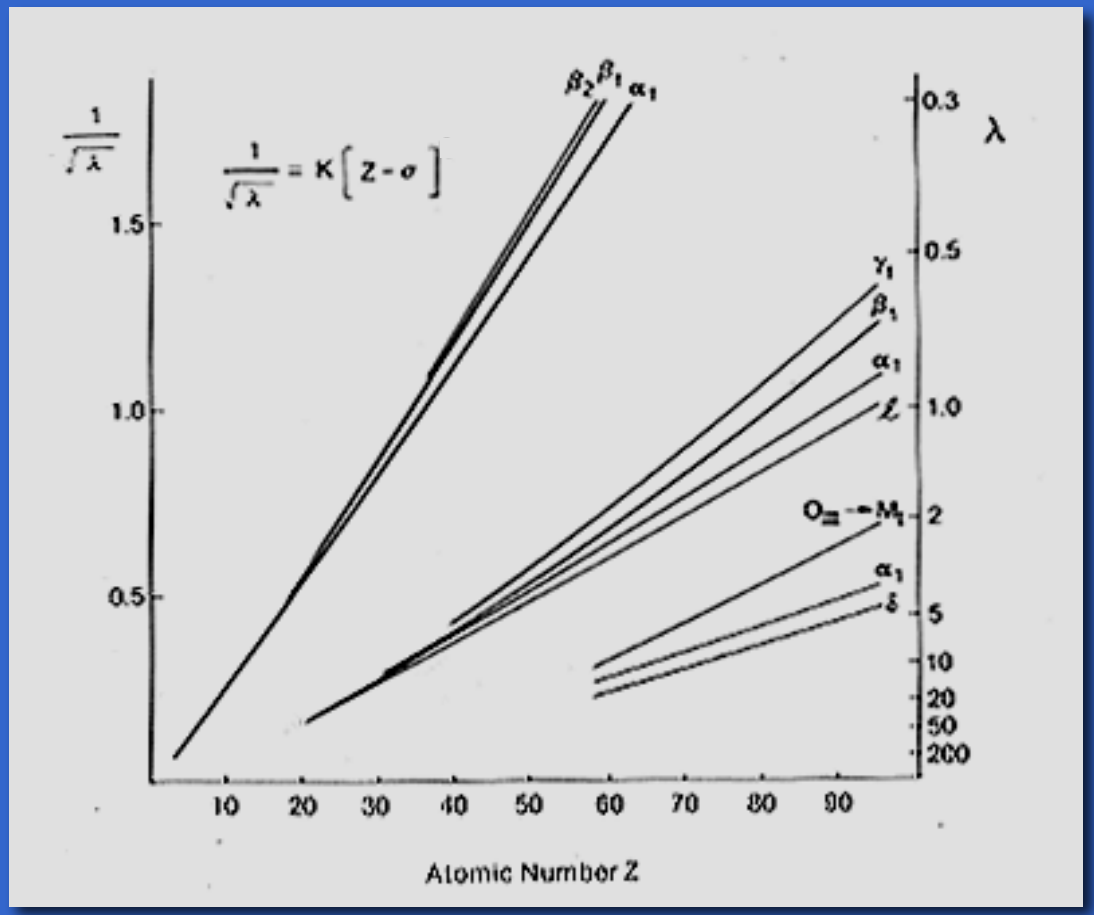
X-rays

Au L spectrum



X-rays

Moseley's law - energy vs. atomic number



X-ray sources

Sealed tubes - Coolidge type

common - Cu, Mo, Fe, Cr, W, Ag

Some commonly used K wavelengths

Element	$K\alpha$ (weighted average)*	$K\alpha_2$ strong	$K\alpha_1$ very strong	$K\beta_1$ weak
Cr	2.29100	2.293606	2.28970	2.08487
Fe	1.937355	1.939980	1.936042	1.75661
Co	1.790260	1.792850	1.788965	1.62079
Ni	1.659122	1.661747	1.657910	1.500135
Cu	1.541838	1.544390	1.540562	1.392218
Mo	0.710730	0.713590	0.709300	0.632288

* $K\alpha_1$ is given twice the weight of $K\alpha_2$.

Characteristic L Lines of Tungsten

Line	Relative intensity	Wavelength
$L\alpha_1$	Very strong	1.47639
$L\alpha_2$	Weak	1.48743
$L\beta_1$	Strong	1.281809
$L\beta_2$	Medium	1.24460
$L\beta_3$	Weak	1.26269
$L\gamma_1$	Weak	1.09855

$$\lambda_{Ka} = (2\,\lambda_{Ka1} + \lambda_{Ka2})/3$$

X-ray sources

Sealed tubes - Coolidge type

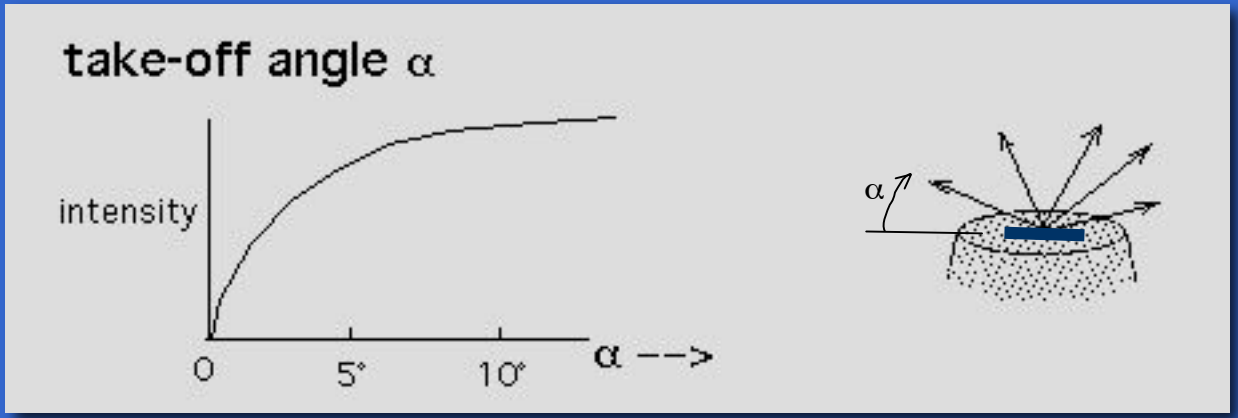
common - Cu, Mo, Fe, Cr, W, Ag

intensity limited by cooling requirements (2-2.5kW)

(~99% of energy input converted to heat)

X-ray sources

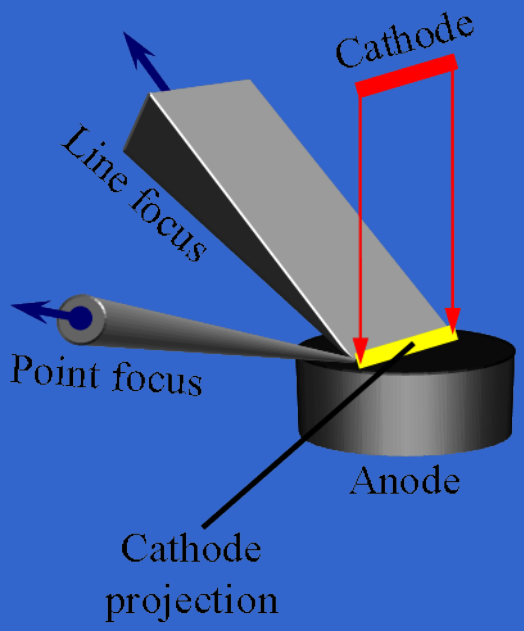
Intensity changes with take-off angle

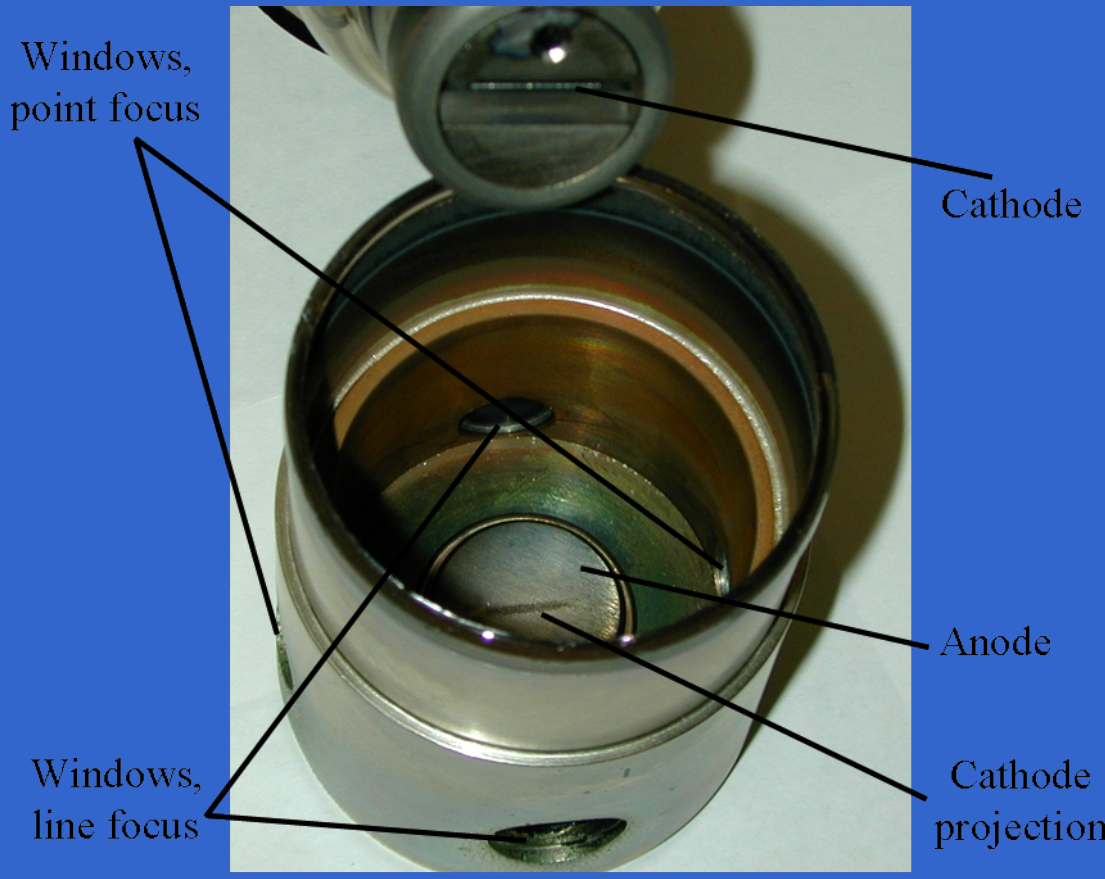


But resolution decreases with take-off angle

focal spot - normal focus 1x10 mm	--> 0.1x1mm (line)	α = 6°
	1x1mm (spot)	
fine focus 0.4 x 0.8 mm	--> 0.04 x 0.8 mm (line)	
	0.4 x 0.8 mm (spot)	

X-ray sources

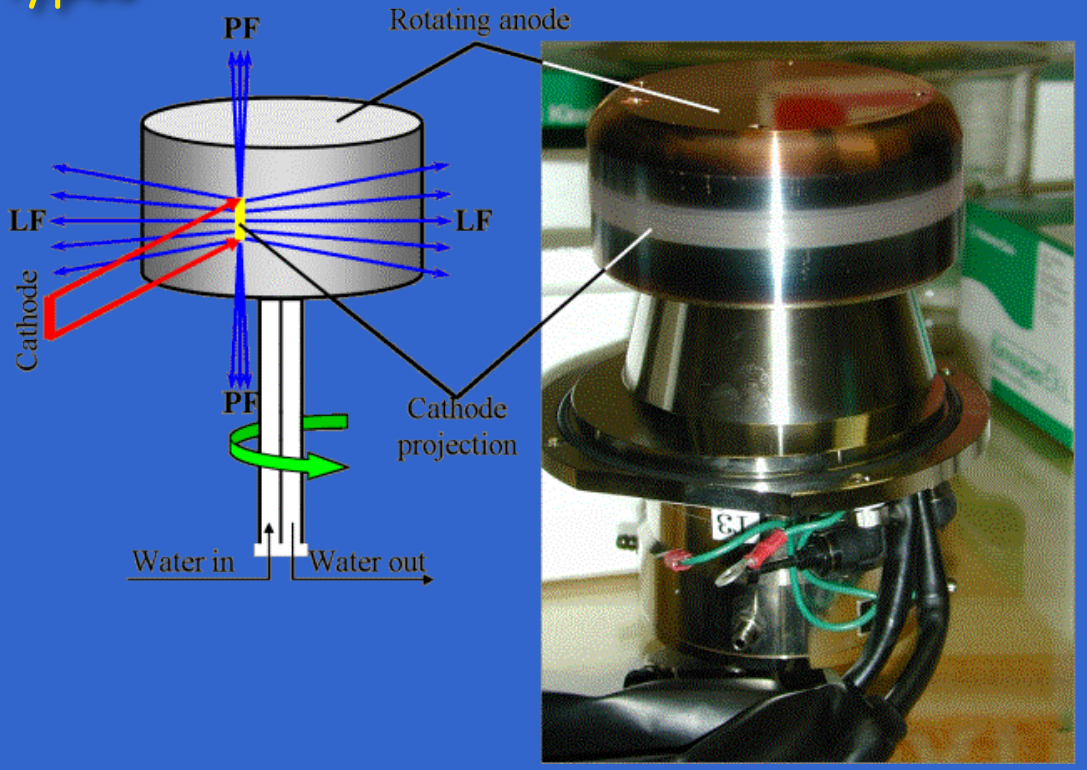




Other X-ray sources

Rotating anode

high power - 40 kW
demountable
various anode types

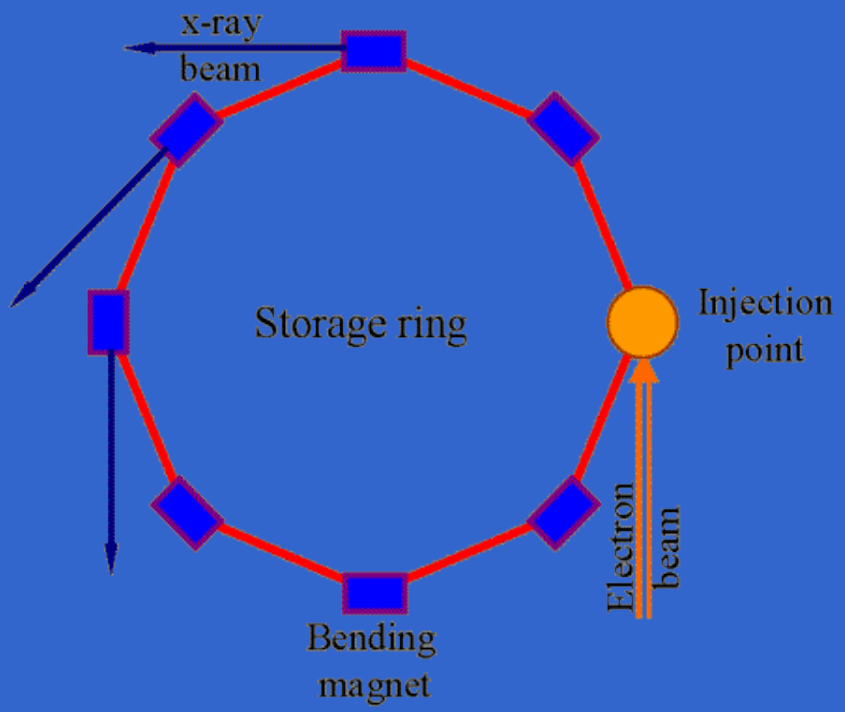


Other X-ray sources

Synchrotron

need electron or positron beam orbiting in a ring
beam is bent by magnetic field

x-ray emission at bend



Advantages

10^{-4} - 10^{-5} radians
divergence
(3-5 mm @ 4 m)

high brilliance
wavelength tunable

Other X-ray sources

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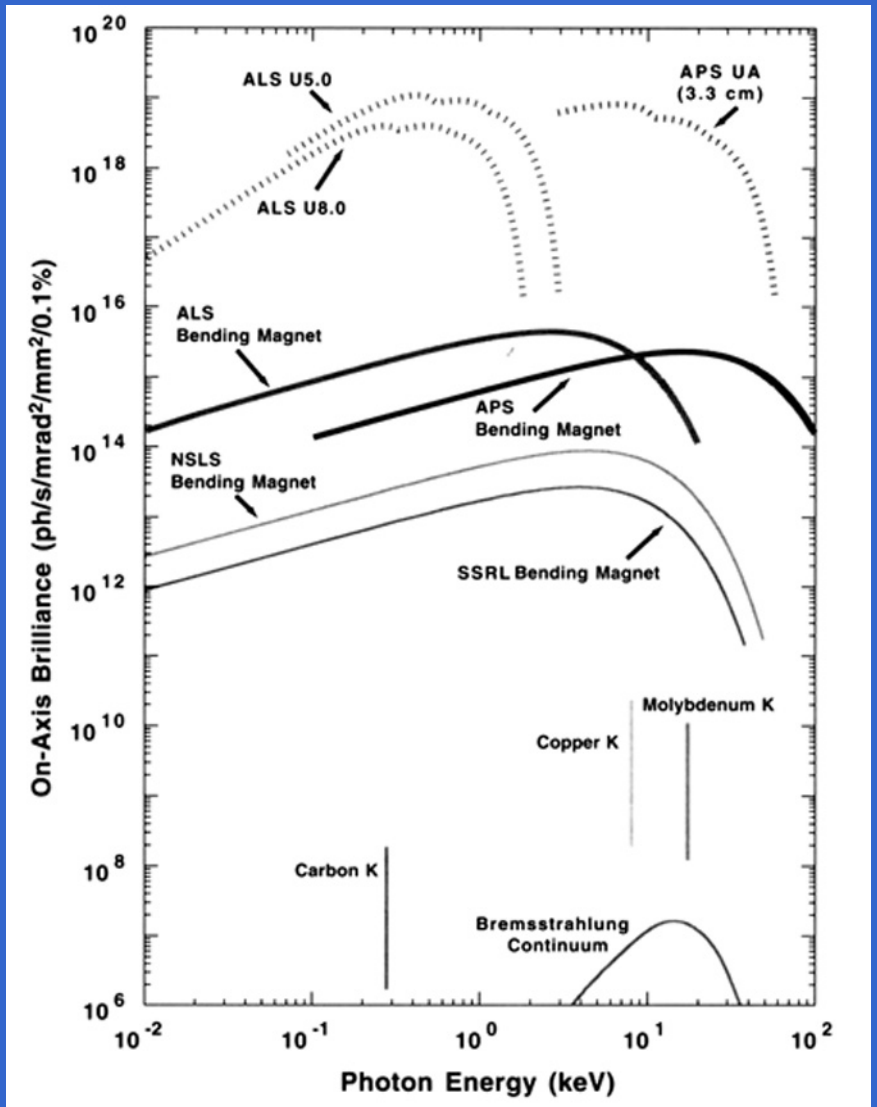


Comparisons of spectra from various synchrotron facilities as well as laboratory $K\alpha$ Cu and Mo radiation, and the white or brehmsstrahlung radiation from X-ray tubes: ALS is the Advanced Light Source at Lawrence Berkeley Laboratory, Berkeley, CA; NSLS is the National Synchrotron Light Source at Brookhaven National Laboratory, Upton, NY; SSRL is the Stanford Synchrotron Research Laboratory, Stanford, CA; and, APS is the Advanced Photon Source at Argonne National Laboratory, Argonne, IL.

Other X-ray sources

Synchrotron

need electron or positron beam orbiting in a ring
beam is bent by magnetic field

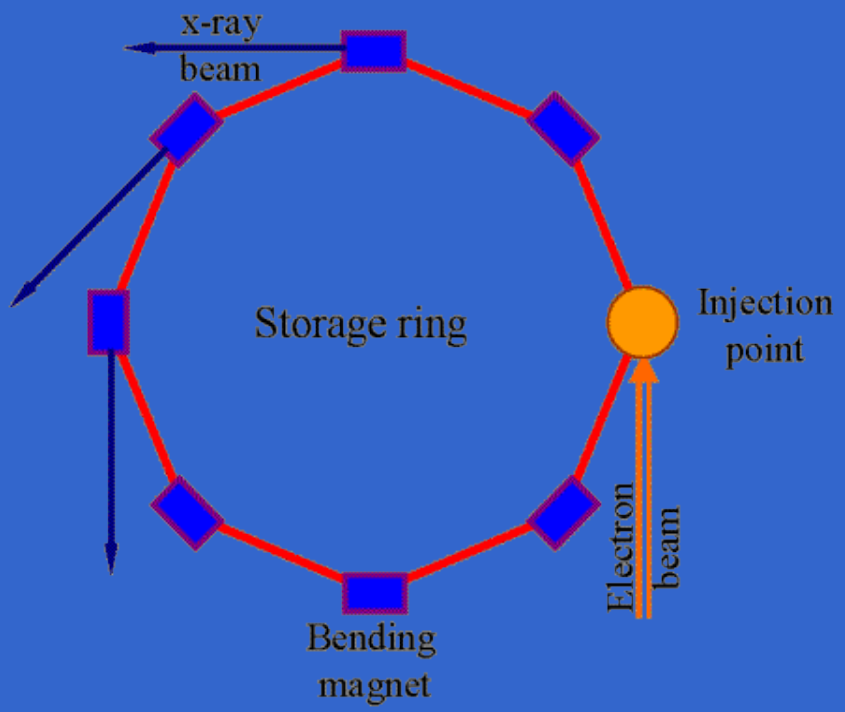
x-ray emission at bend

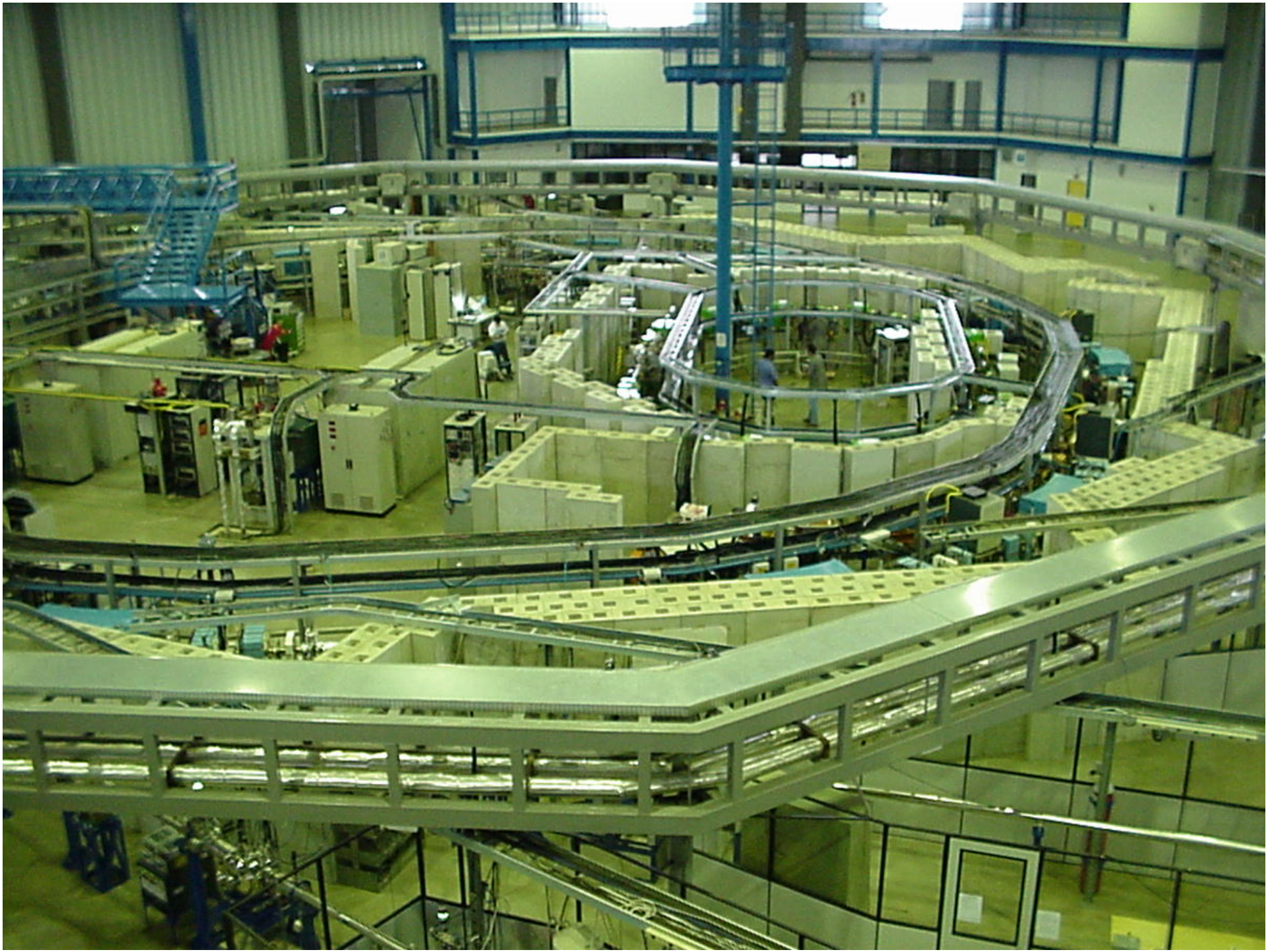
Advantages

10^{-4} - 10^{-5} rad
divergence
(3-5 mm @ 4 m)

high brilliance
wavelength tunable

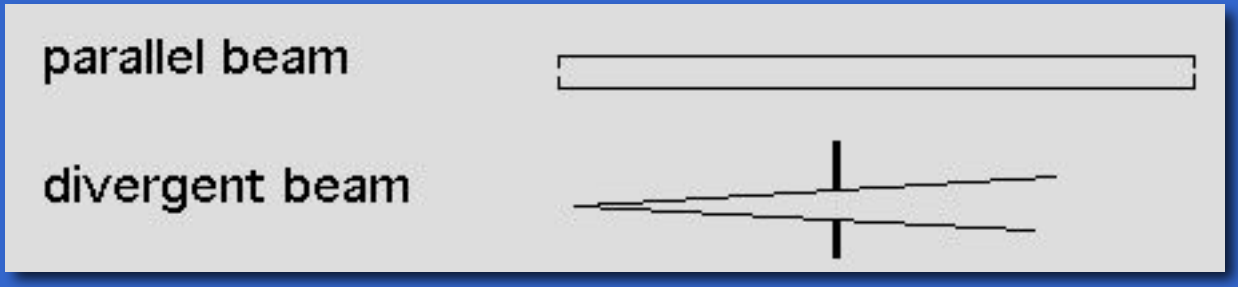
high signal/noise ratio





Beam conditioning

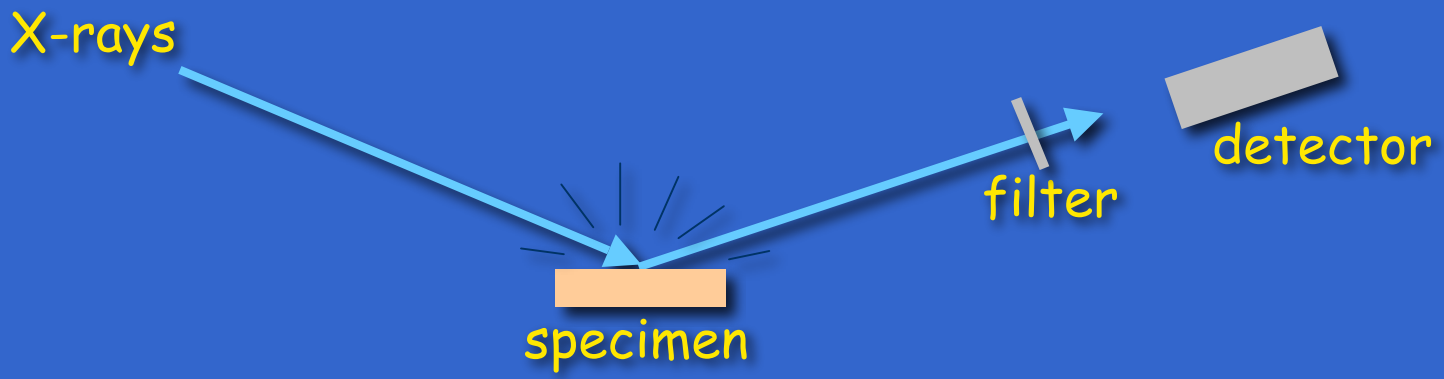
Collimation



Beam conditioning

Monochromatization

β-filters – materials have atomic nos. 1 or 2 less than anode
50-60% beam attenuation
placing after specimen/before detector
filters most of specimen fluorescence
allows passage of high intensity & long
wavelength white radiation



Beam conditioning

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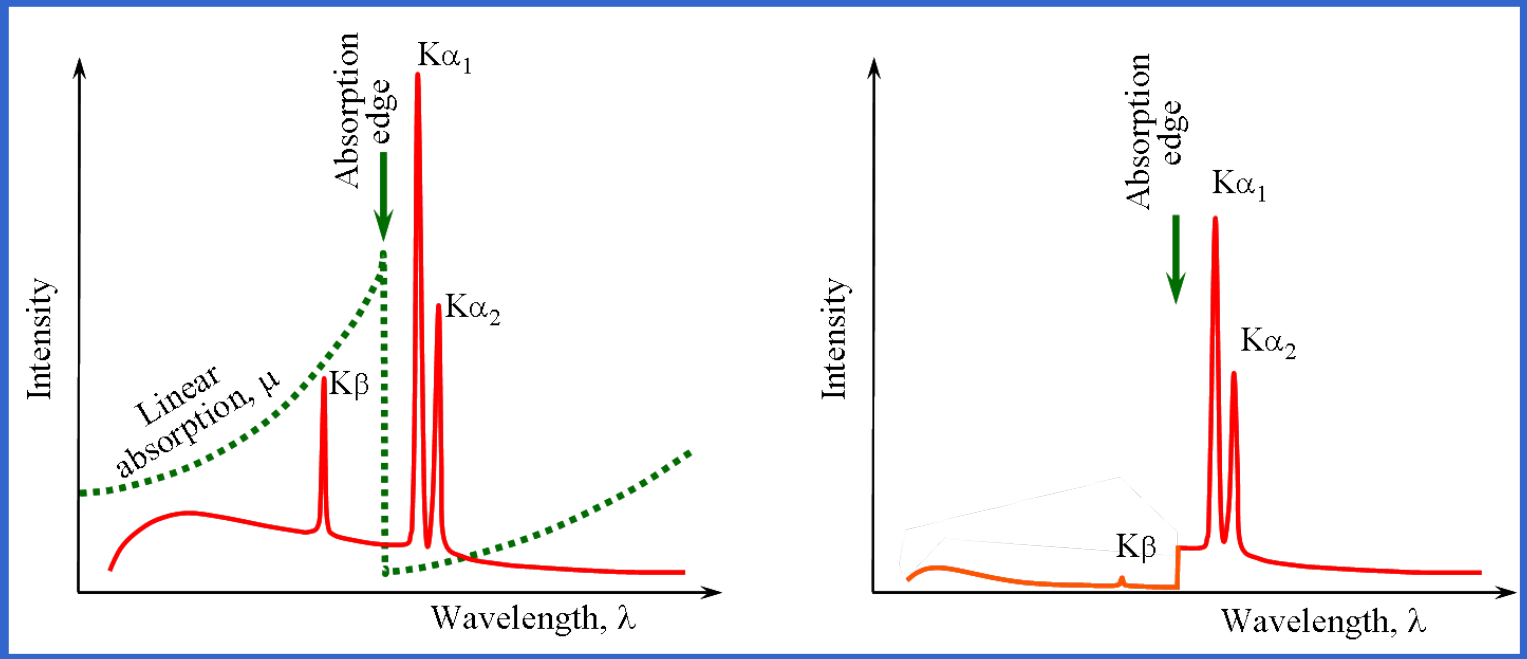

Beam conditioning

Monochromatization

Crystal monochromators – LiF, SiO_2, pyrolytic graphite

critical – reflectivity ex: for MoKα, LiF 9.4%

graphite 54 %

Beam conditioning

Monochromatization

Crystal monochromators – LiF, SiO_2, pyrolytic graphite

critical – reflectivity ex: for MoKα, LiF 9.4%

graphite 54 %

resolution – determines peak/bkgrd ratio &

spectral purity best - Si – 10"

graphite – 0.52°

Beam conditioning

Monochromatization

Monochromator shape

usually flat – problems with divergent beams

concentrating type – increases I by factor of 1.5-2