SYNCHROTRON SCIENCE

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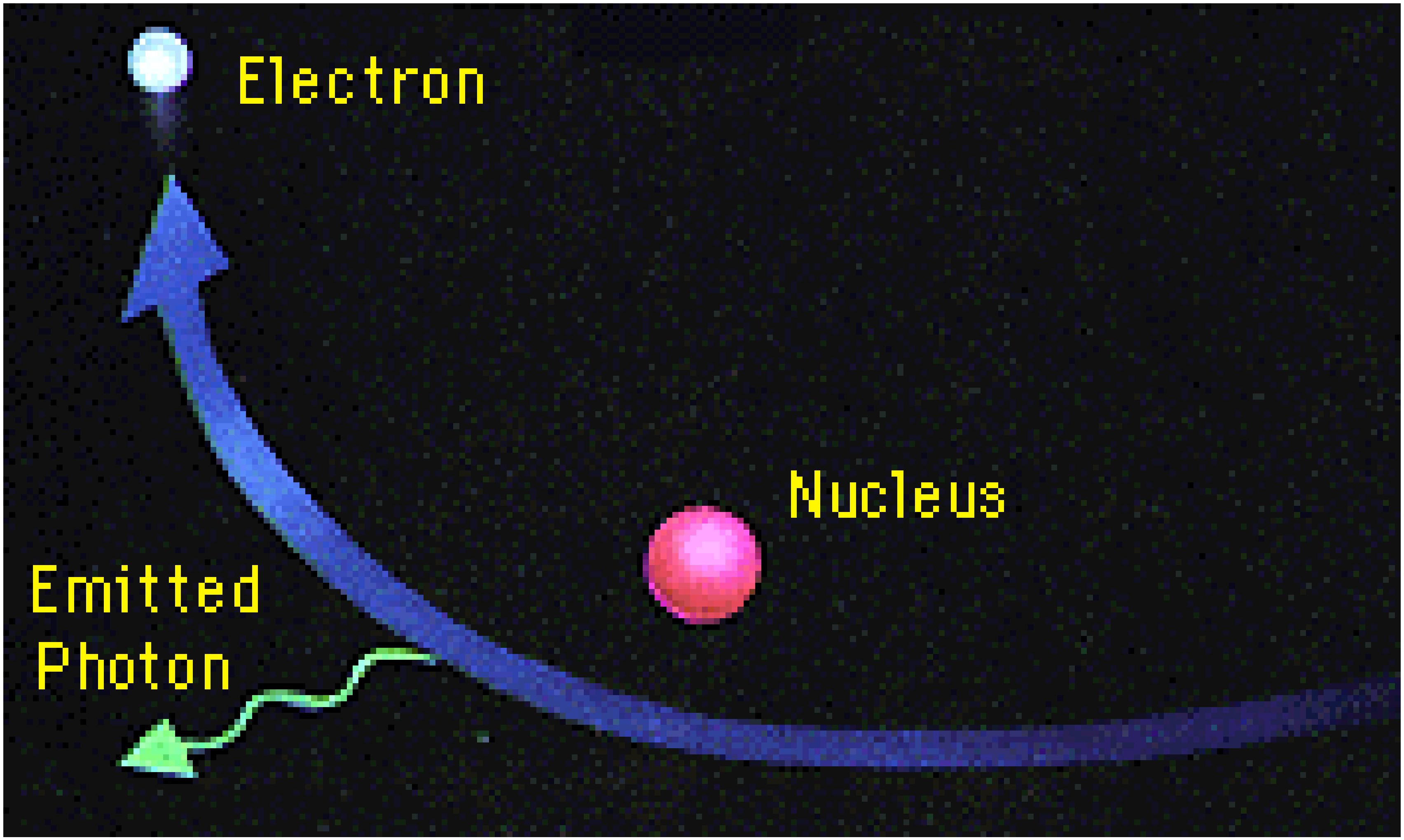
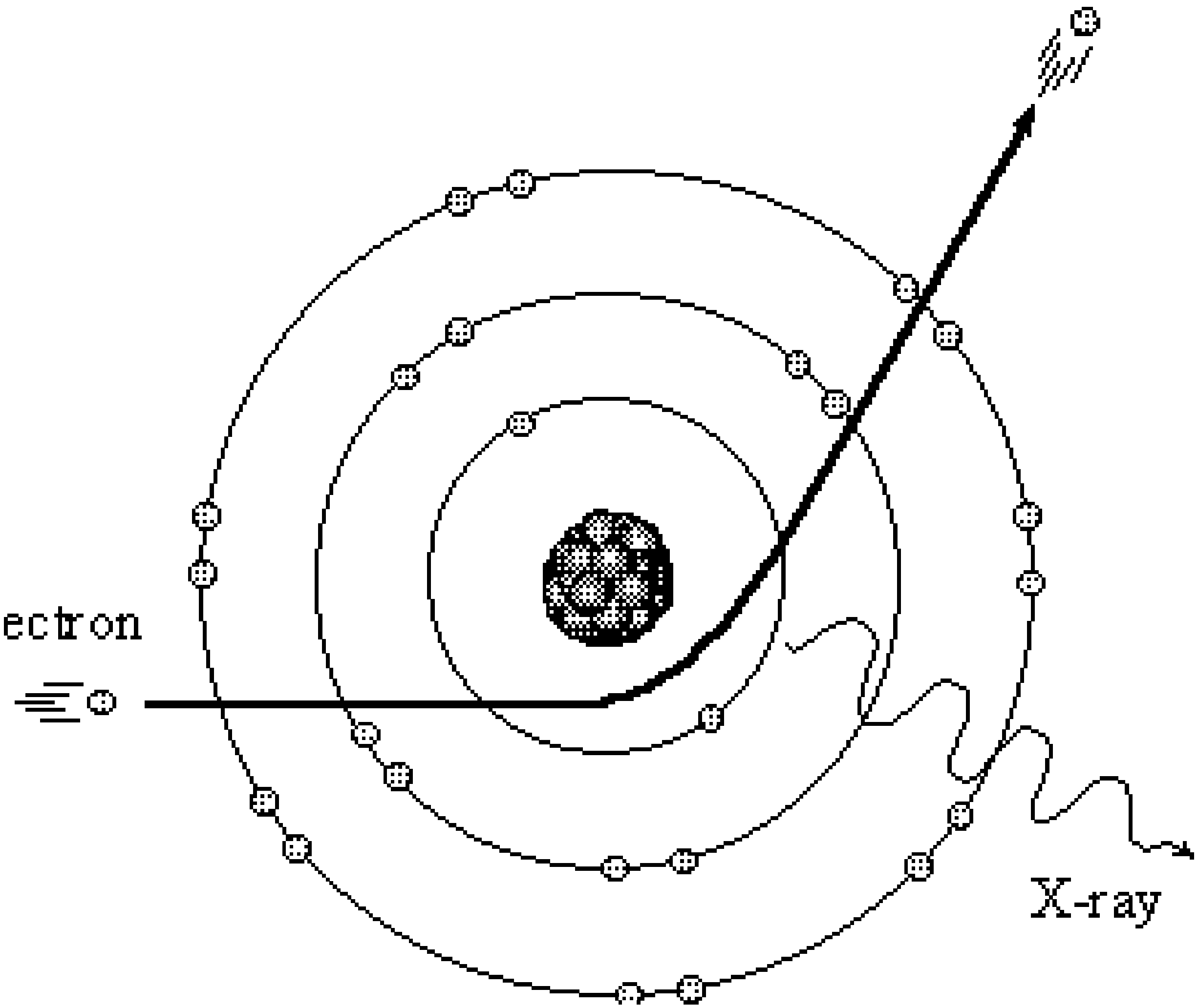
What will we cover?

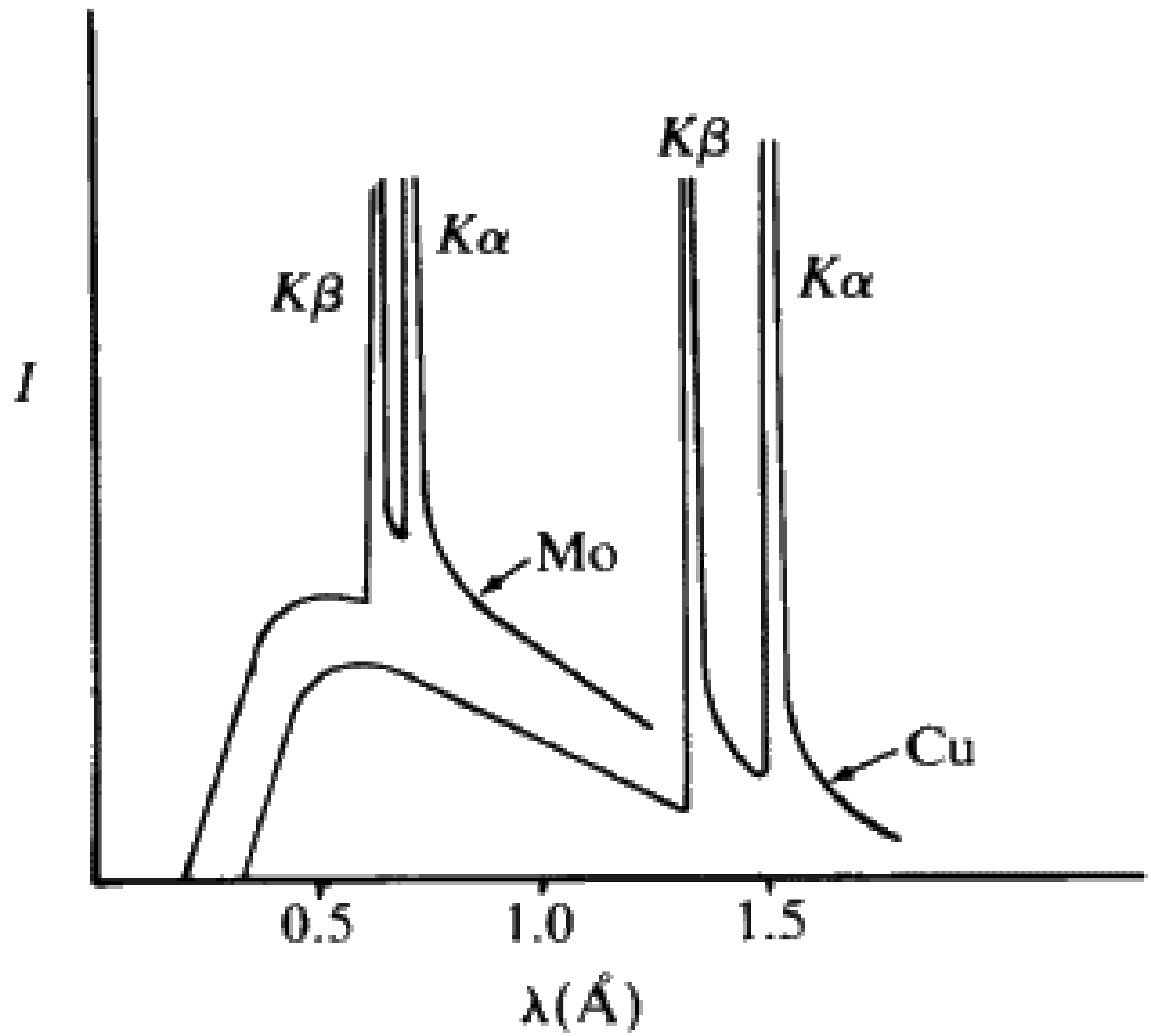
- Principles of generation
- Why is a synchrotron better?
- Interactions with matter
- X-ray diffraction - crystal & powder
- Examples
- Resources

X-rays are produced when electrons are accelerated / decelerated



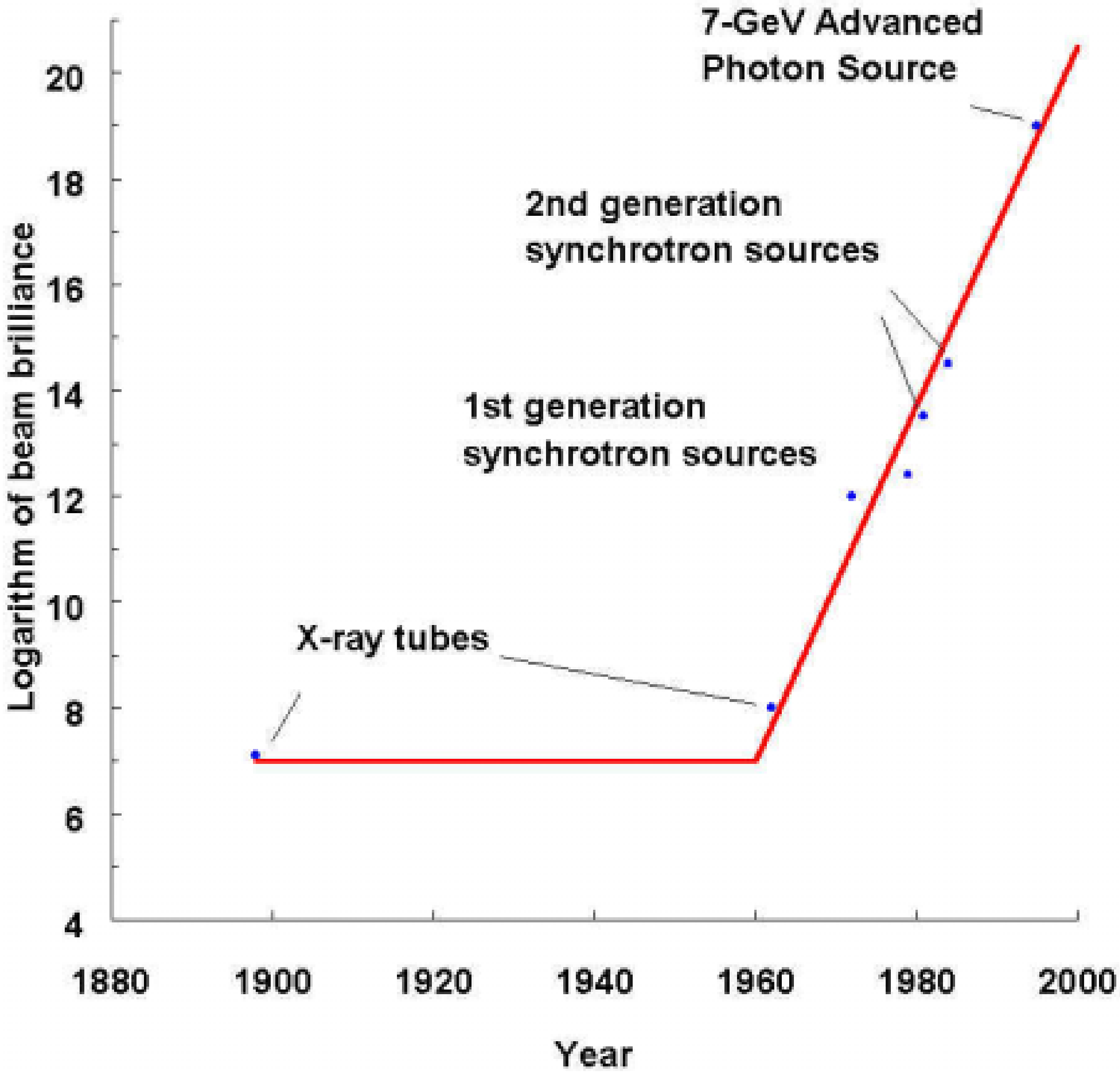
X-rays are produced when electrons are accelerated / decelerated

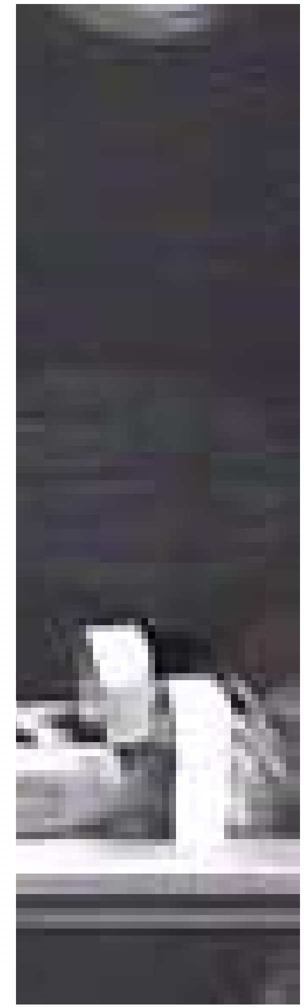




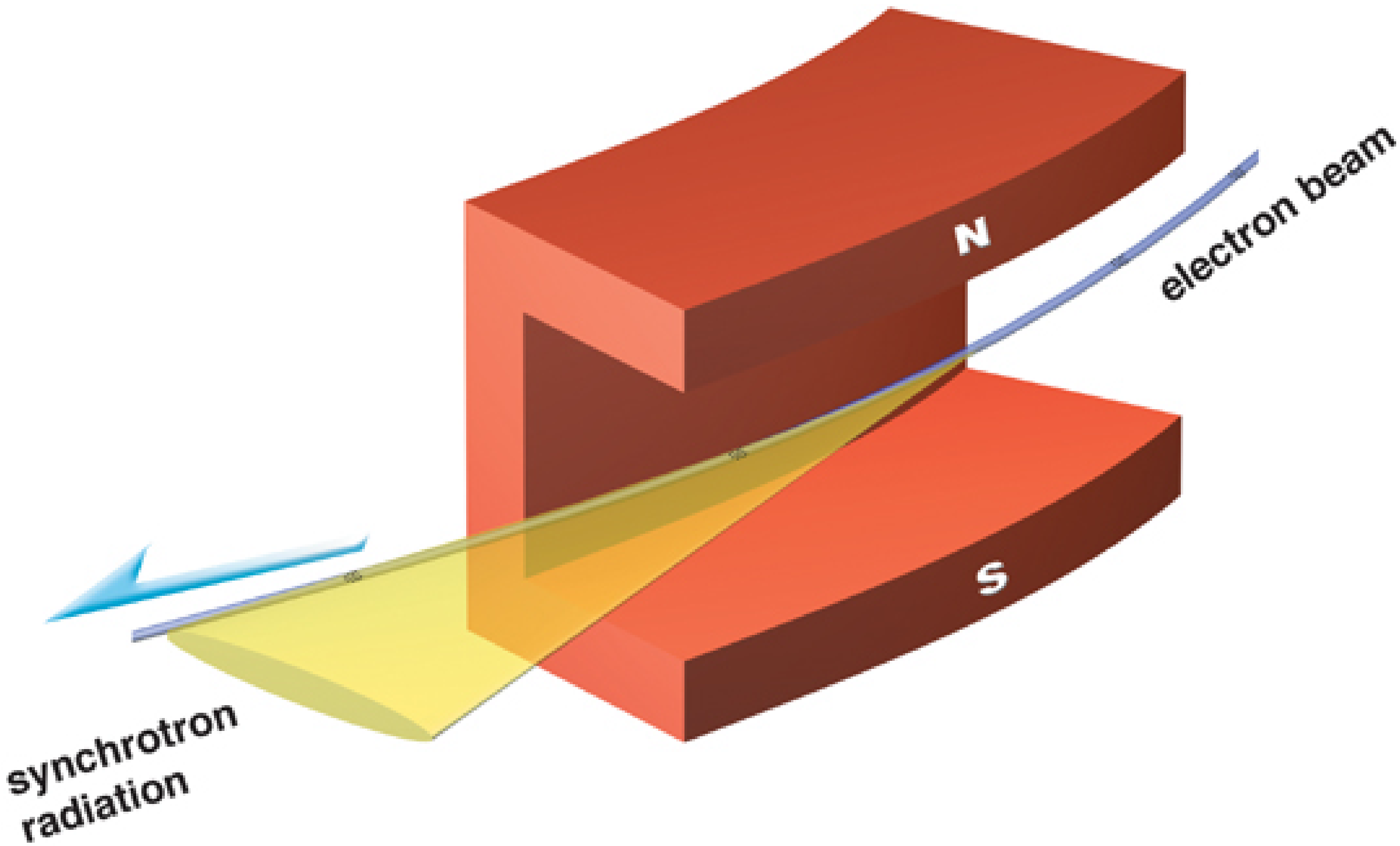
I
Kβ
Kα
Mo
Kβ
Kα
Cu
0.5
1.0
1.5
λ(Å)

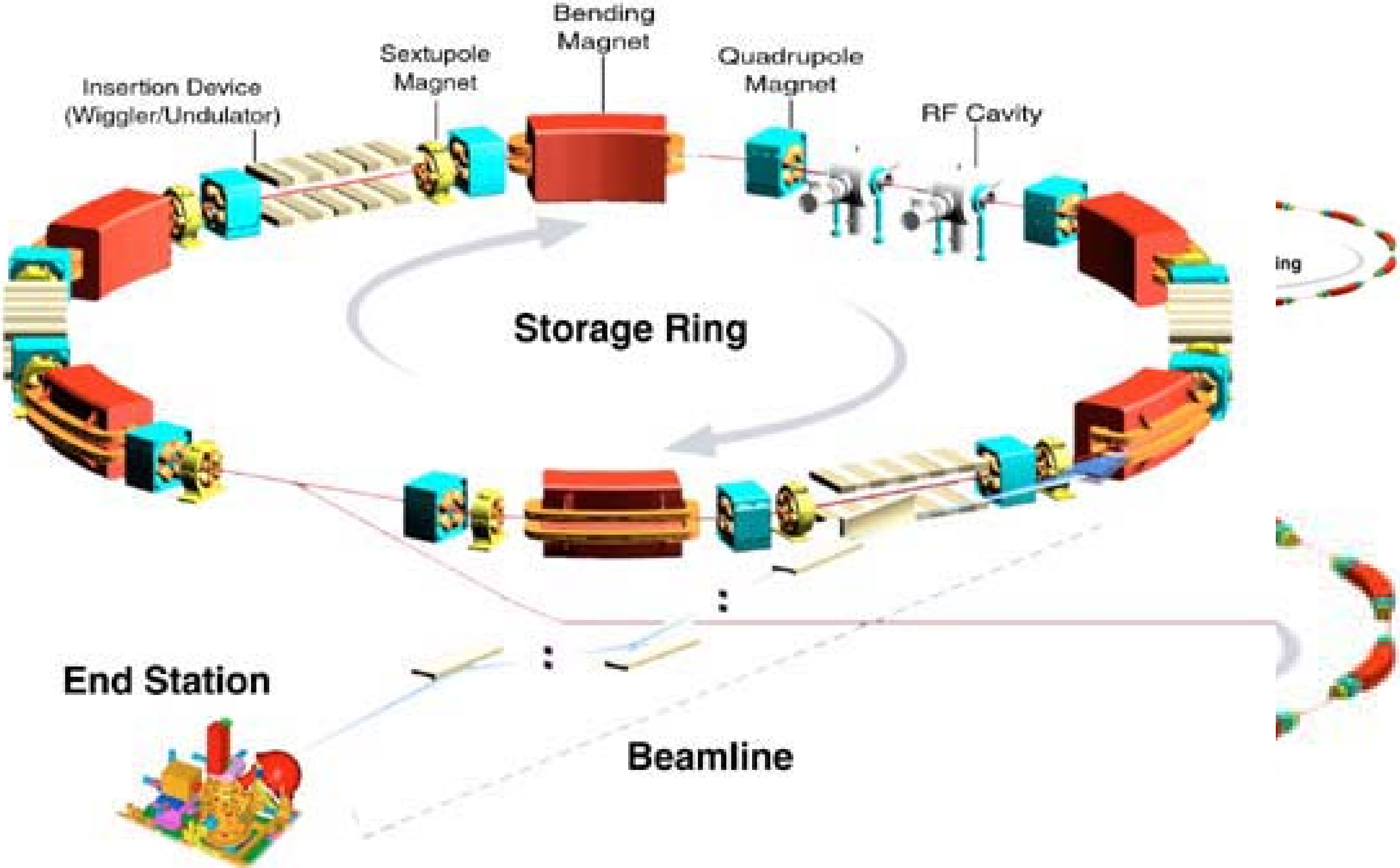
More power....


7-GeV Advanced
Photon Source
2nd generation
synchrotron sources
1st generation
synchrotron sources
X-ray tubes
Logarithm of beam brilliance
20
18
16
14
12
10
8
6
4
1880
1900
1920
1940
1960
1980
2000
Year



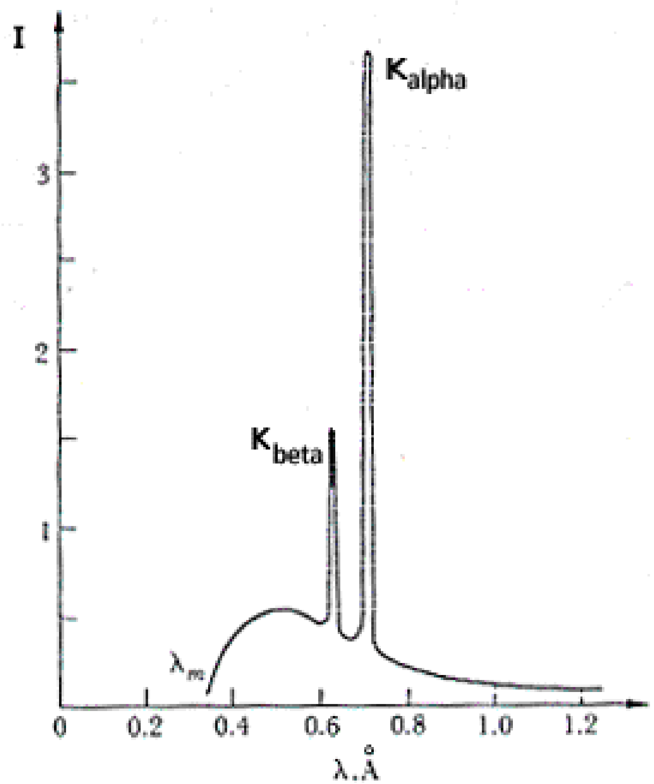
The synchrotron

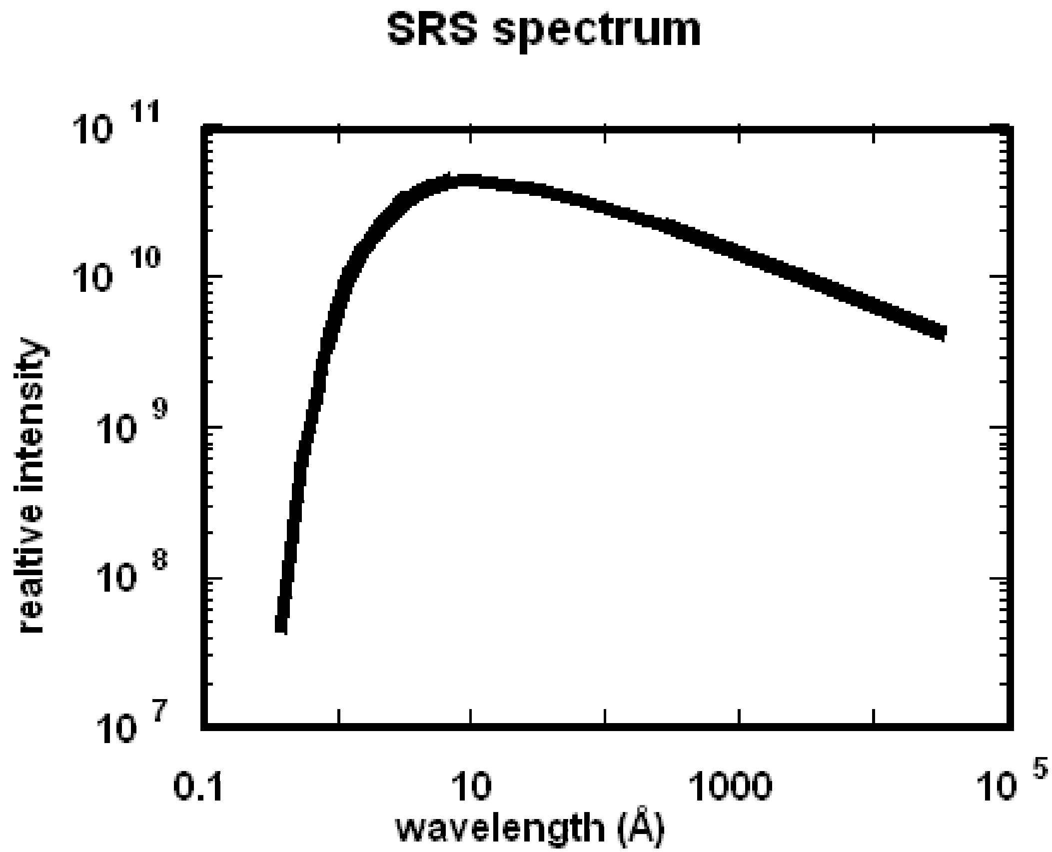



Bending
Magnet
Sextupole
Magnet
Quadrupole
Magnet
Insertion Device
(Wiggler/Undulator)
RF Cavity
Storage Ring
End Station
Beamline

Boomerang - the Australian Synchrotron

The synchrotron

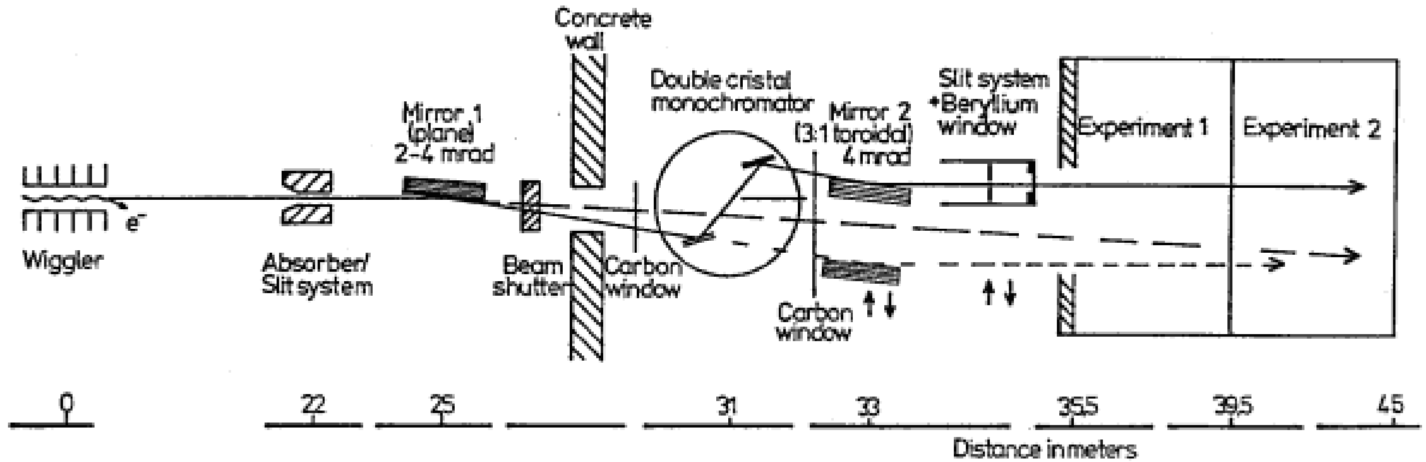


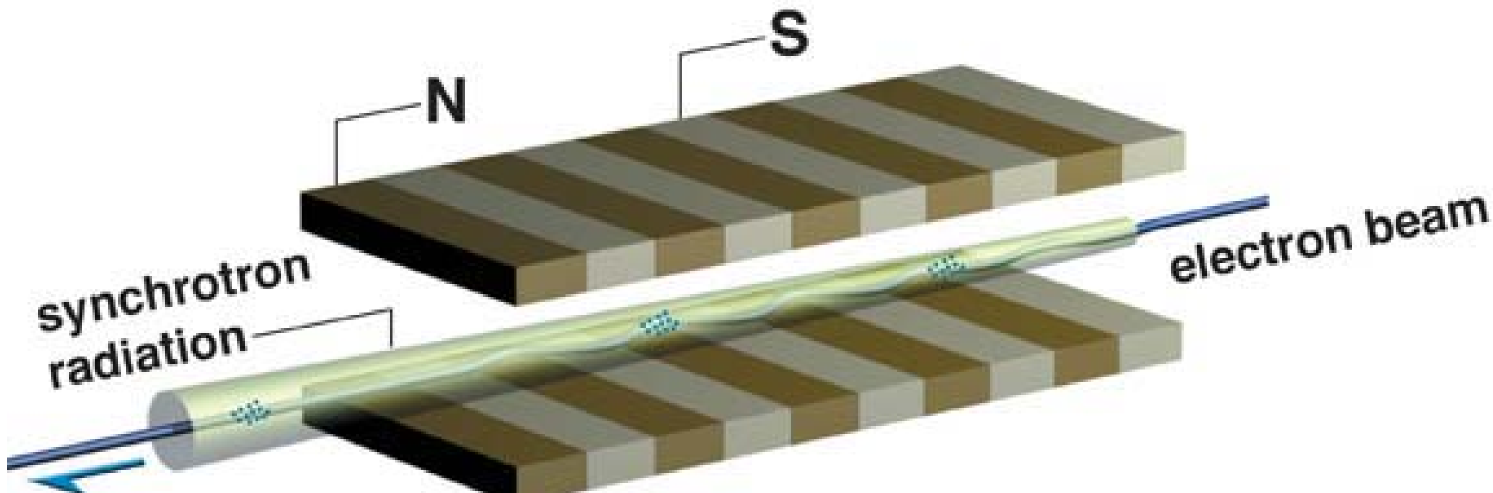


Synchrotron light has a very wide spectrum

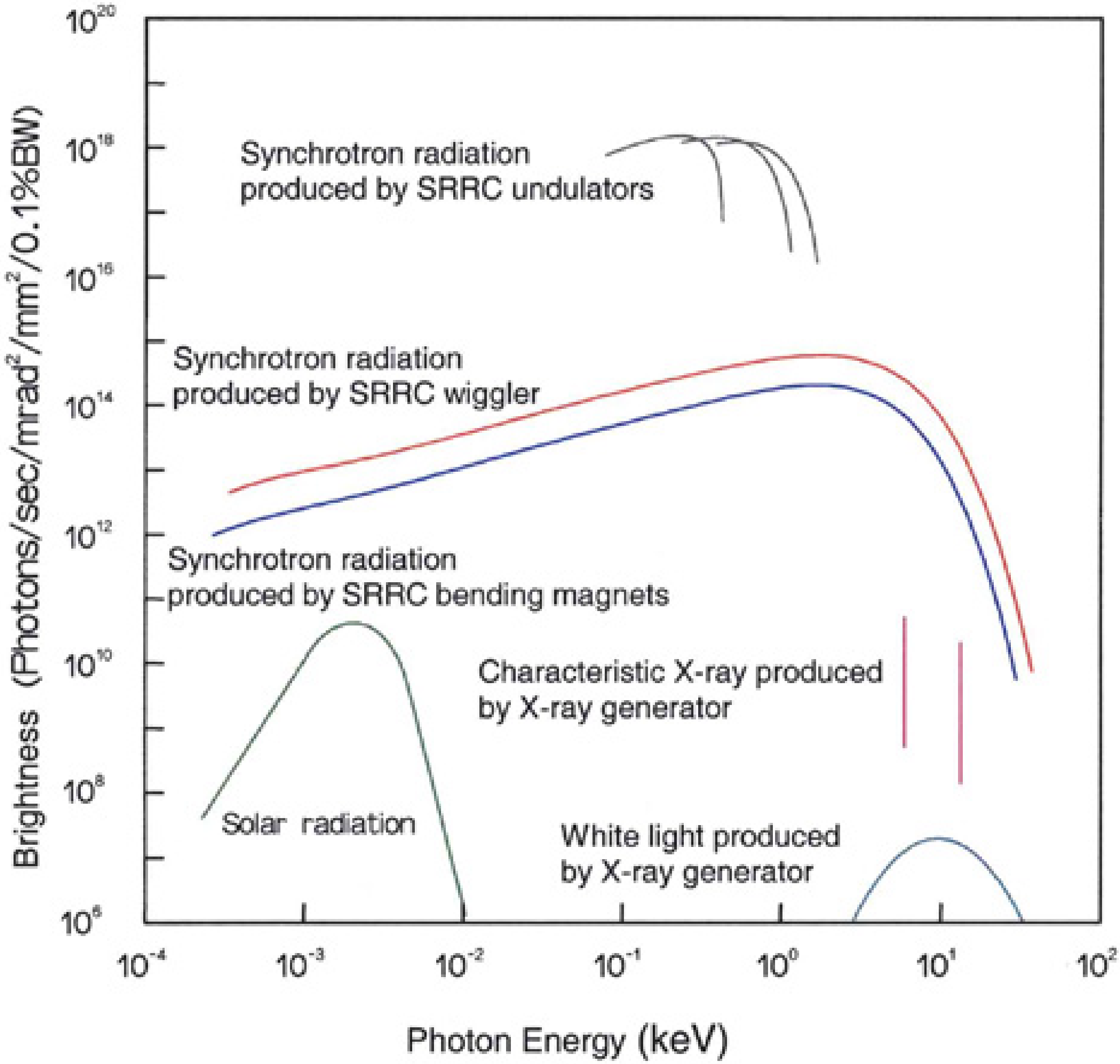
Yet more power, Igor....

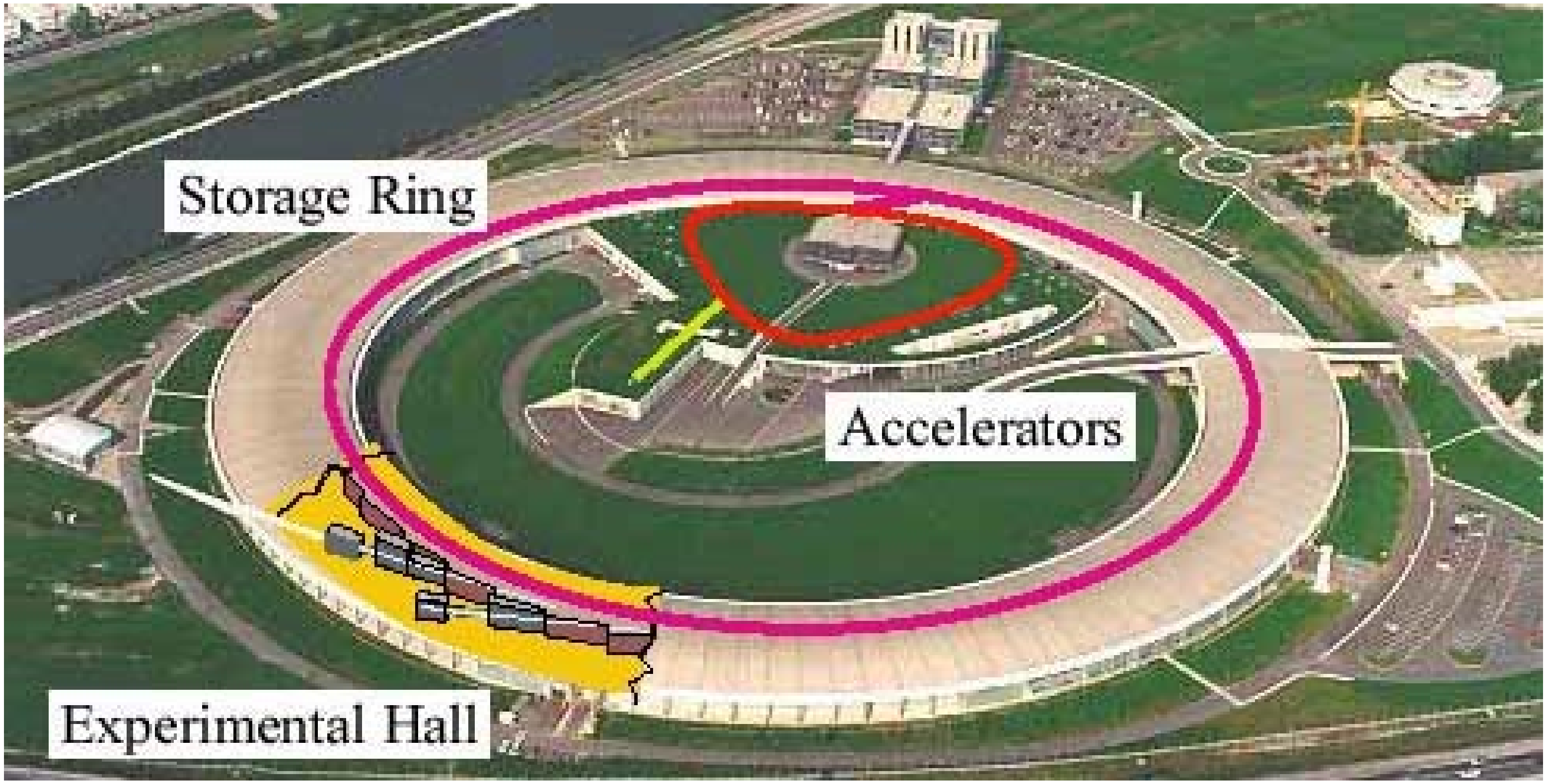
More power: wigglers and undulators

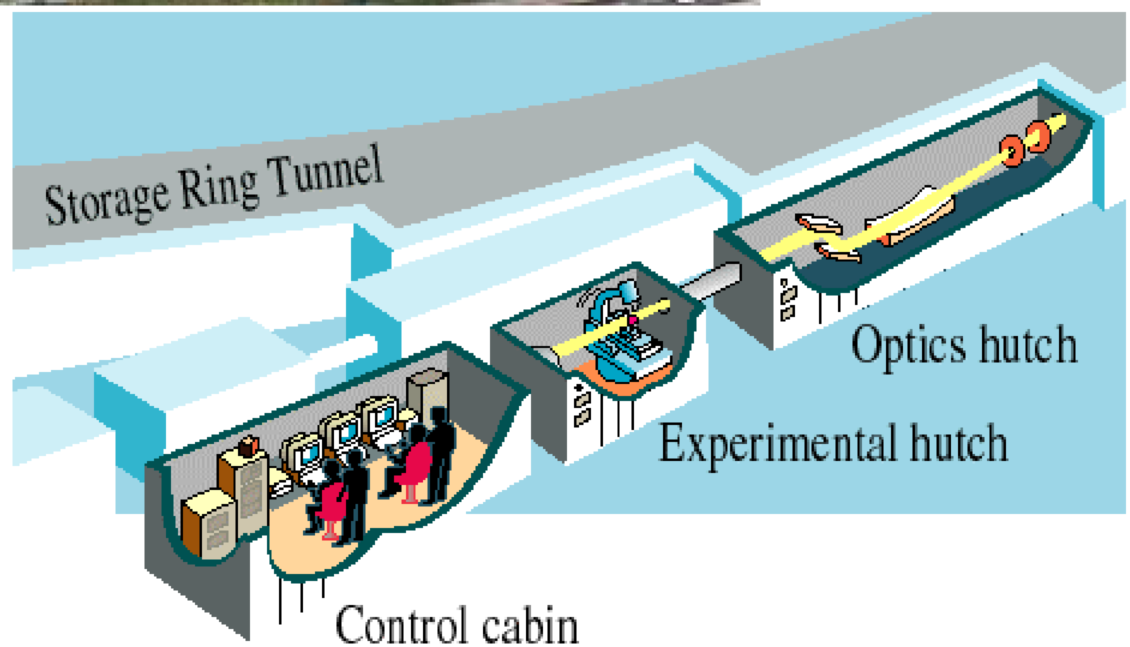


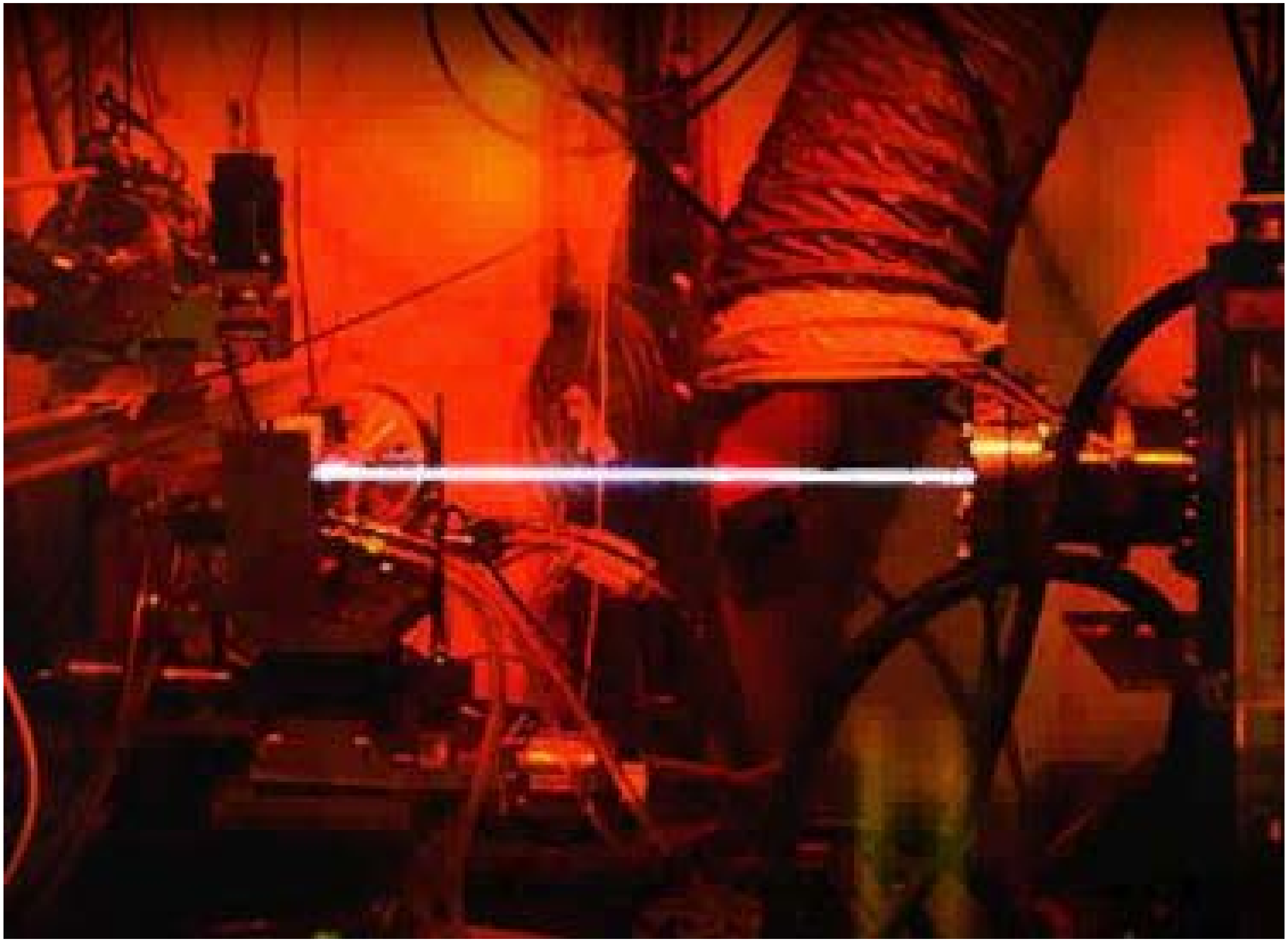


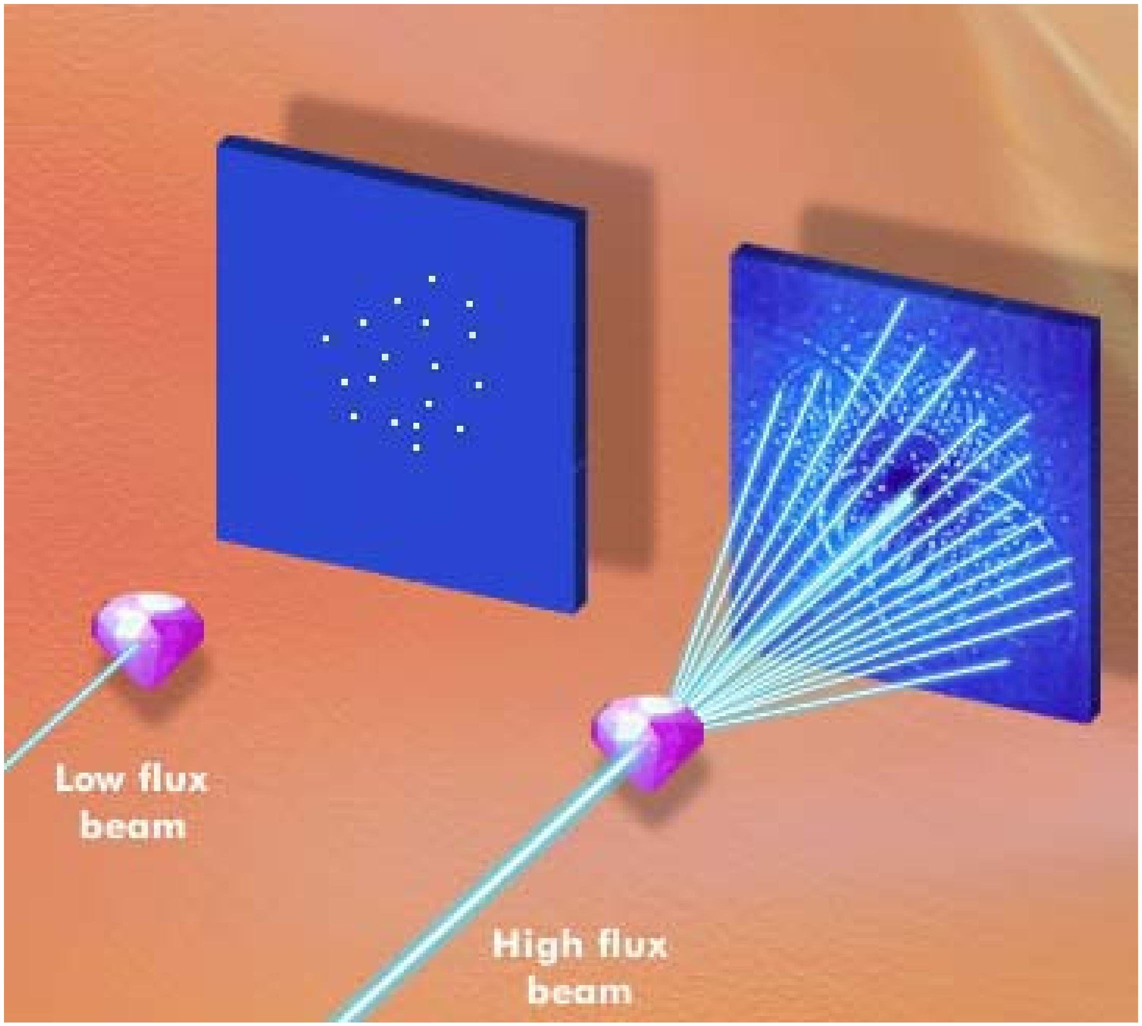
The synchrotron




Storage Ring
Accelerators
Experimental Hall


Storage Ring Tunnel
Optics hutch
Experimental hutch
Control cabin

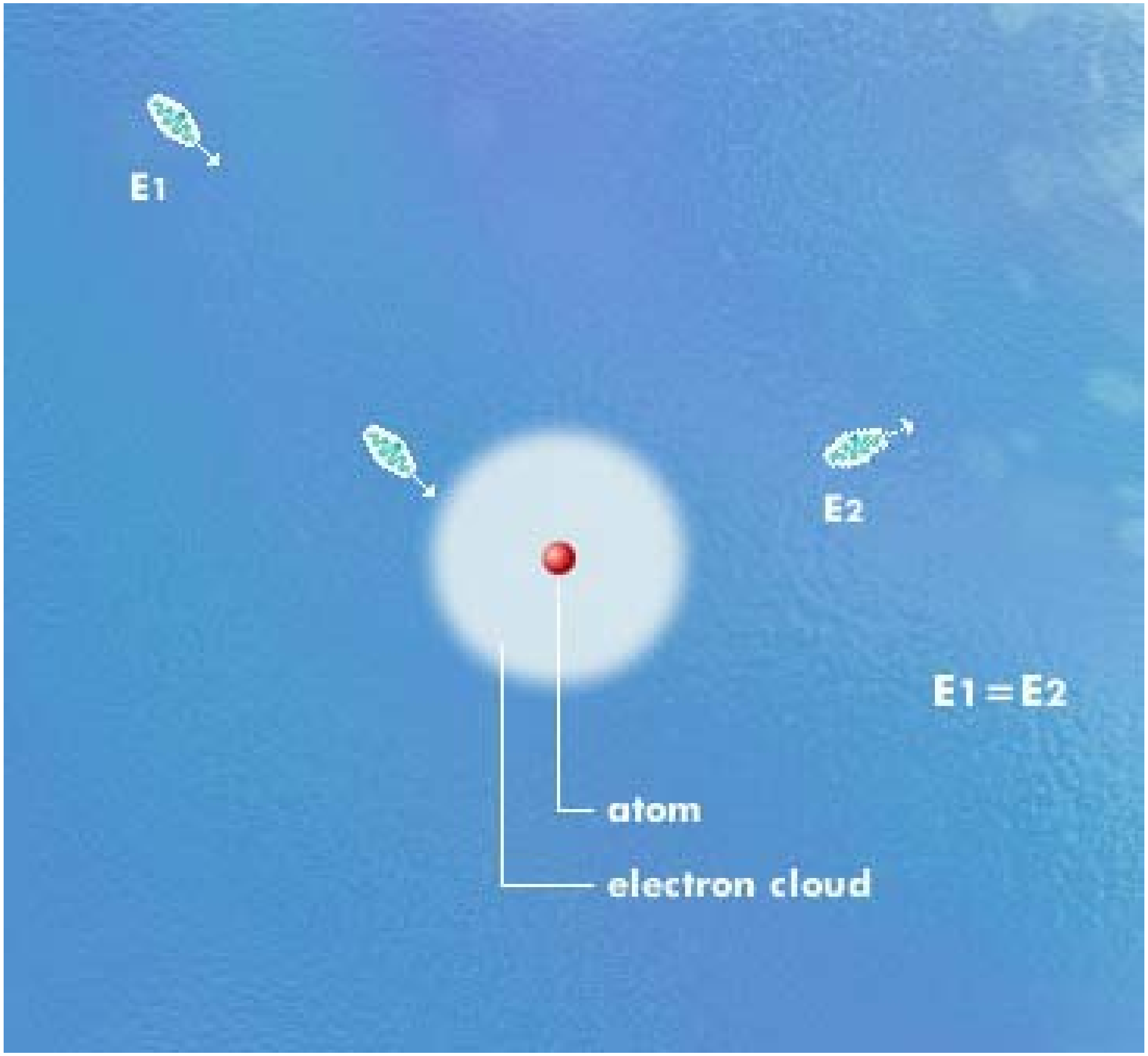



Low flux
beam
High flux
beam

Synchrotron light is:

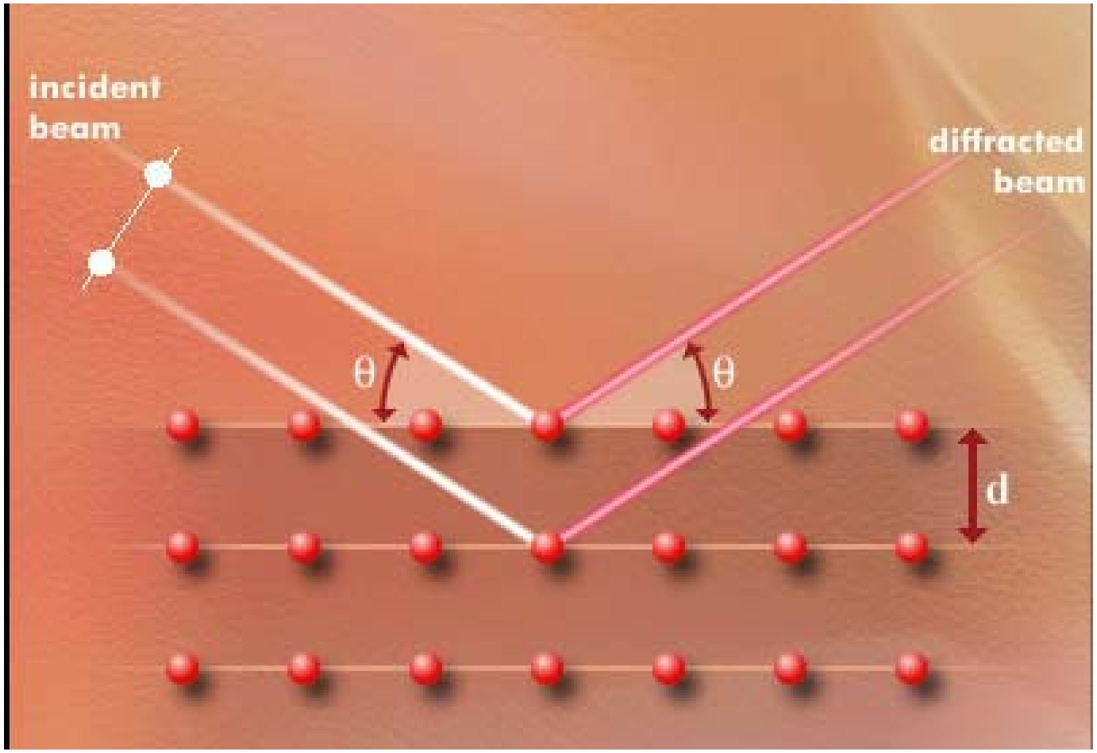
- Intense
- Broad spectrum
- Coherent (highly polarised)
- Pulsed
- High flux

Interaction of X-rays with matter



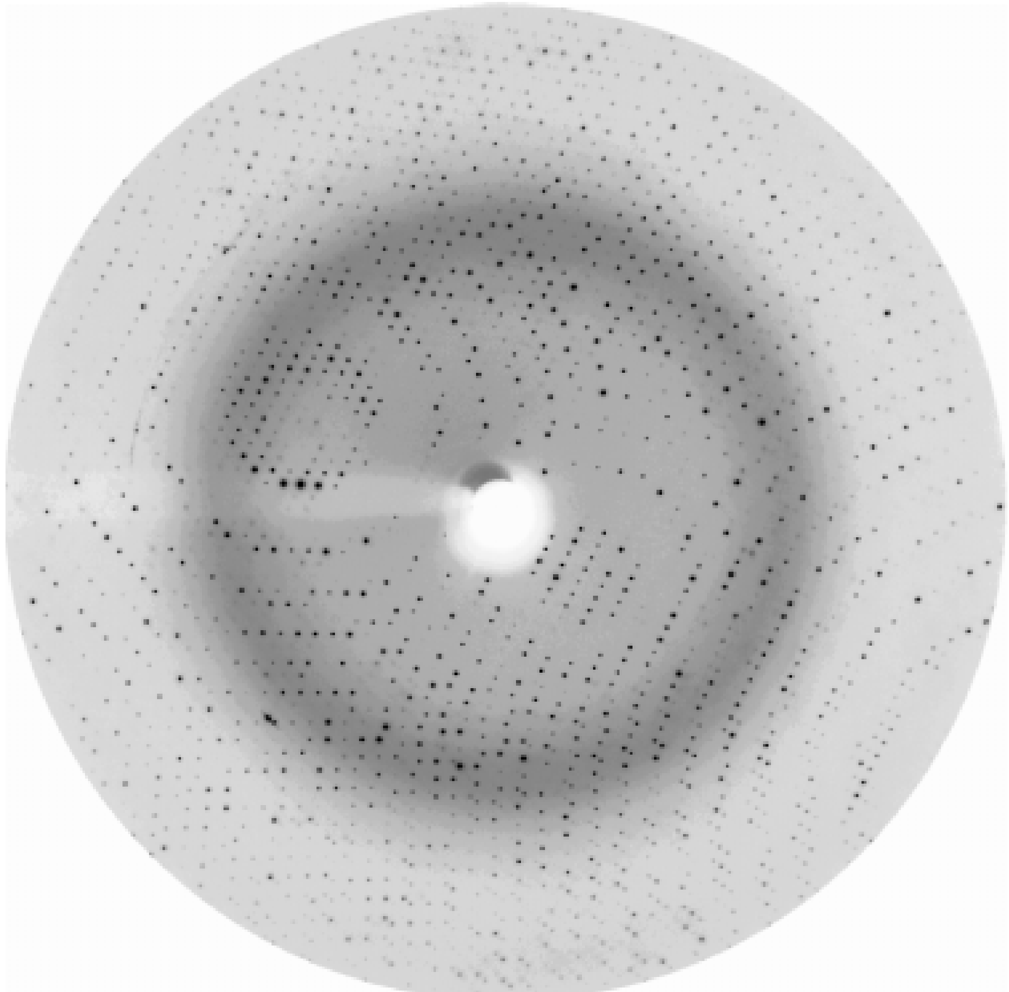
Thompson (elastic) scattering

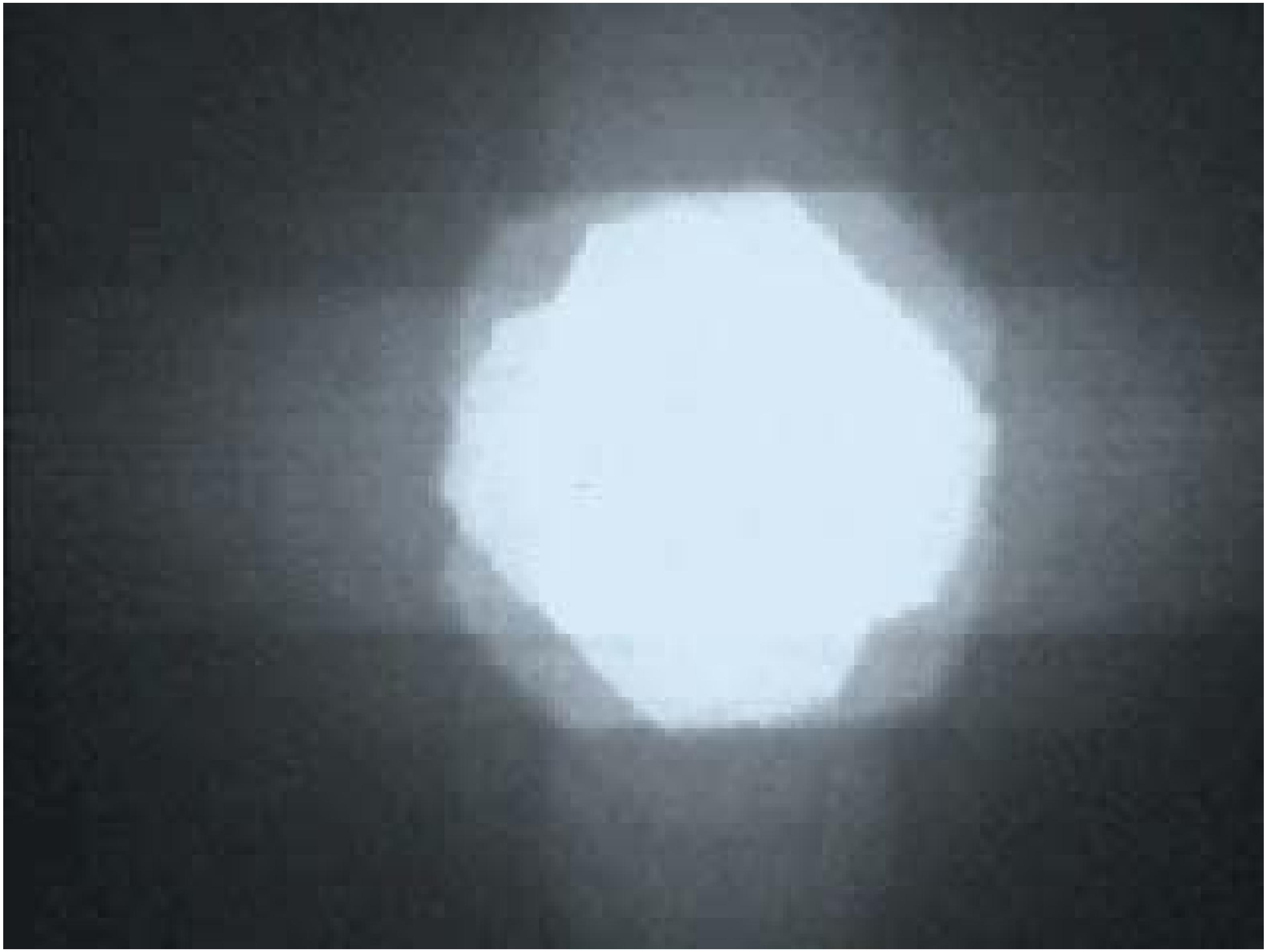
BRAGGS LAW



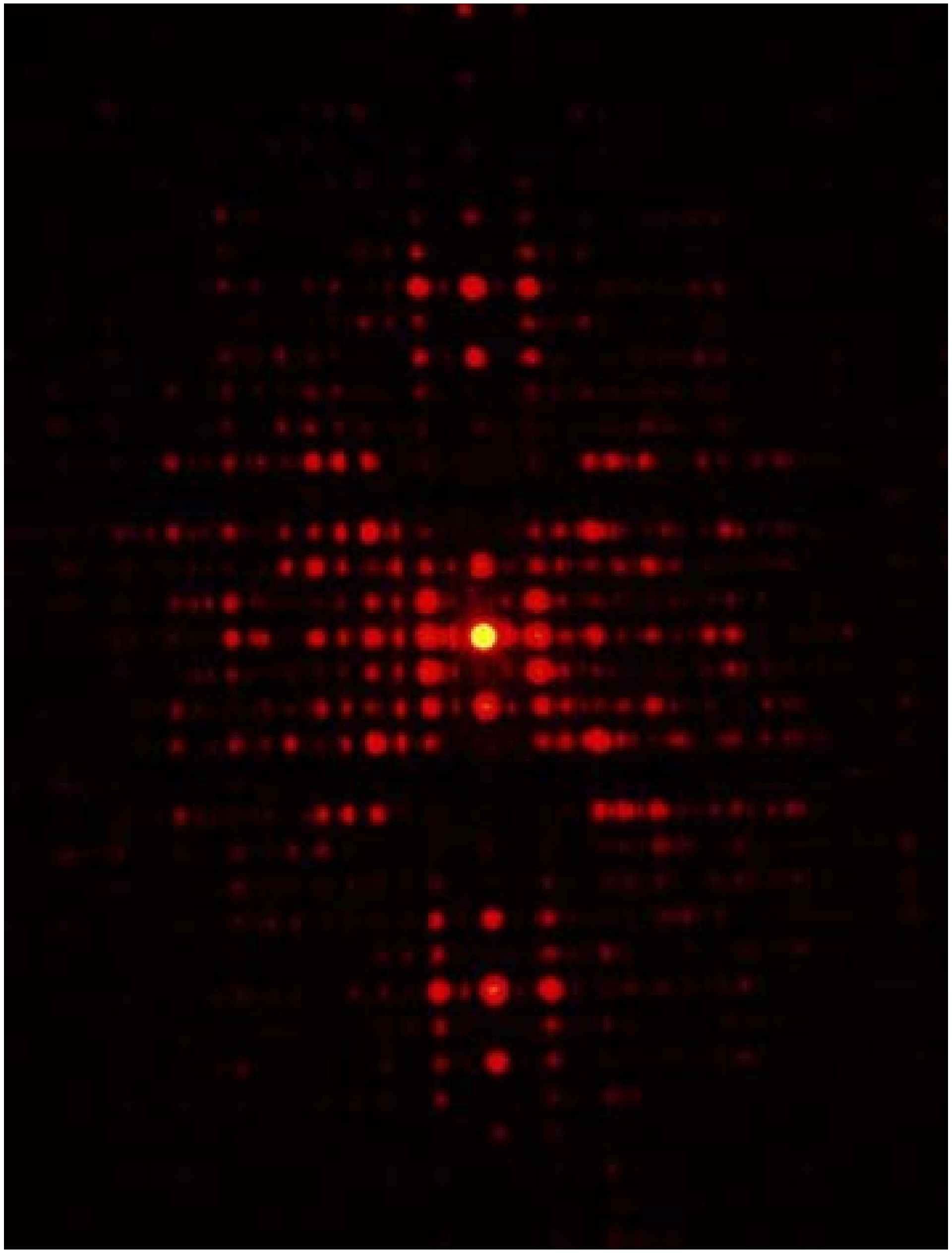
X-ray diffraction is observed when constructive interference occurs. For this to be satisfied, extra distance traveled by second wave must be an integer value of λ

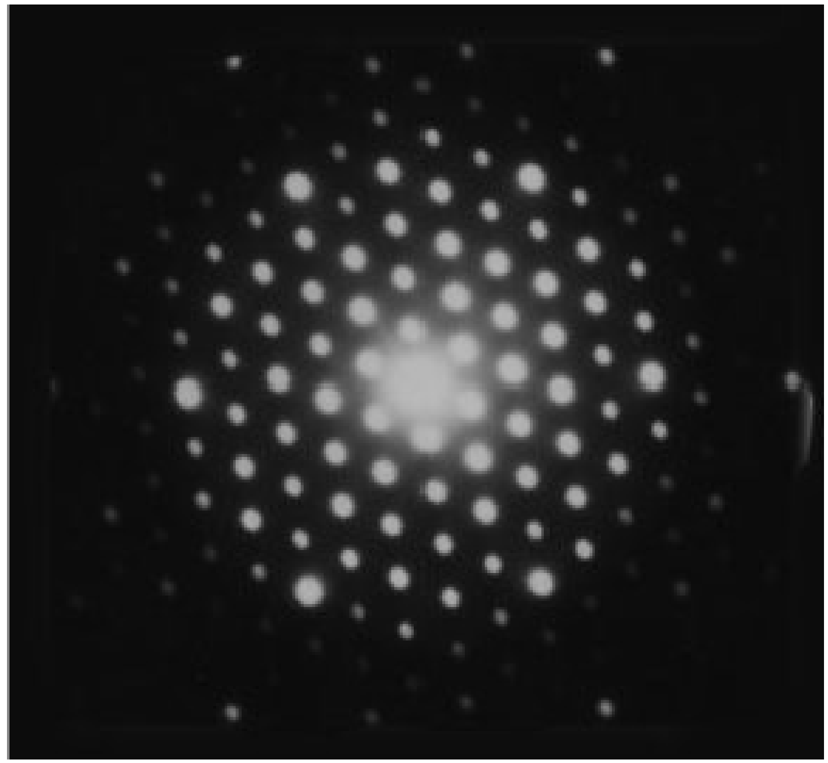
$$n\lambda = 2d\sin\theta$$

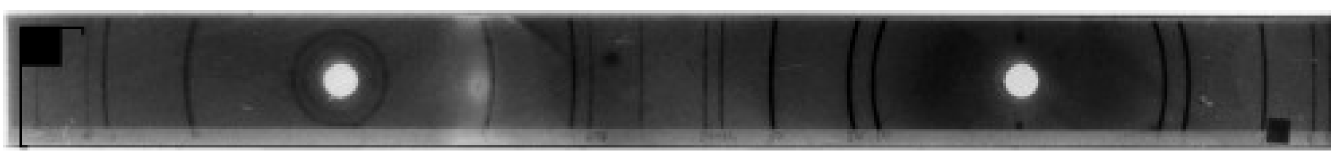


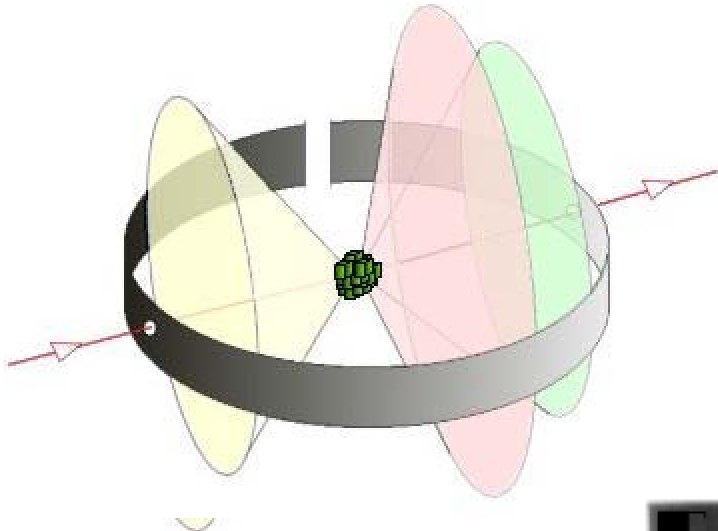


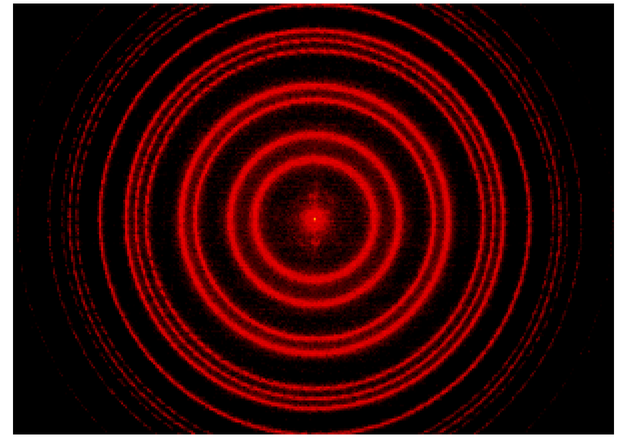
DIFFRACTION PATTERN OF DNA

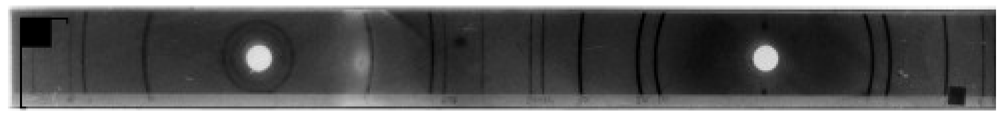


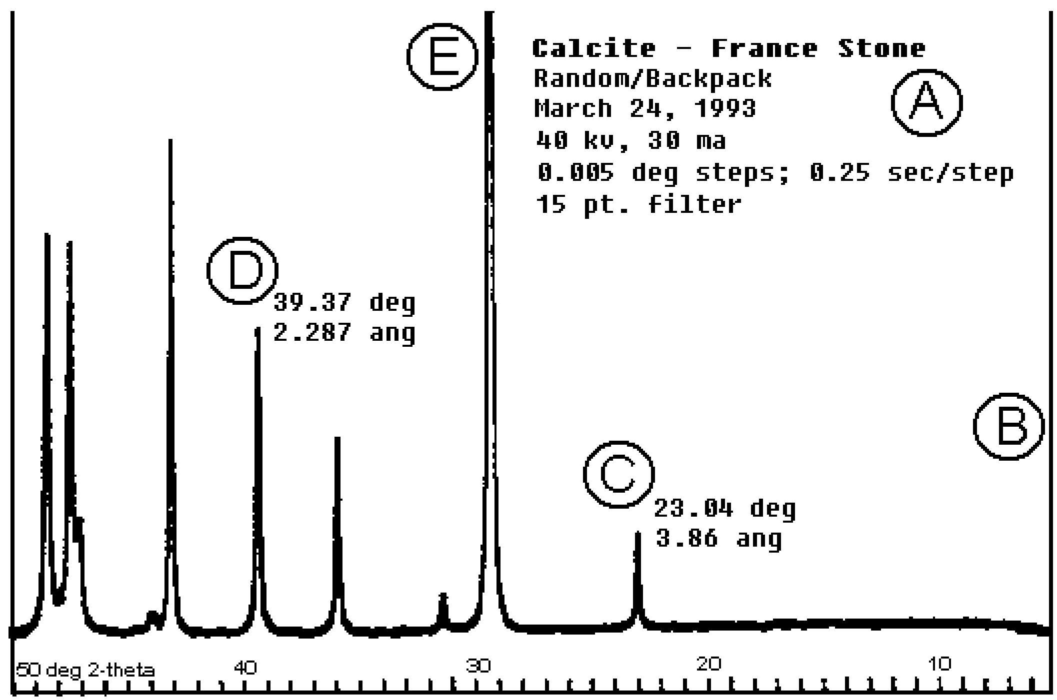


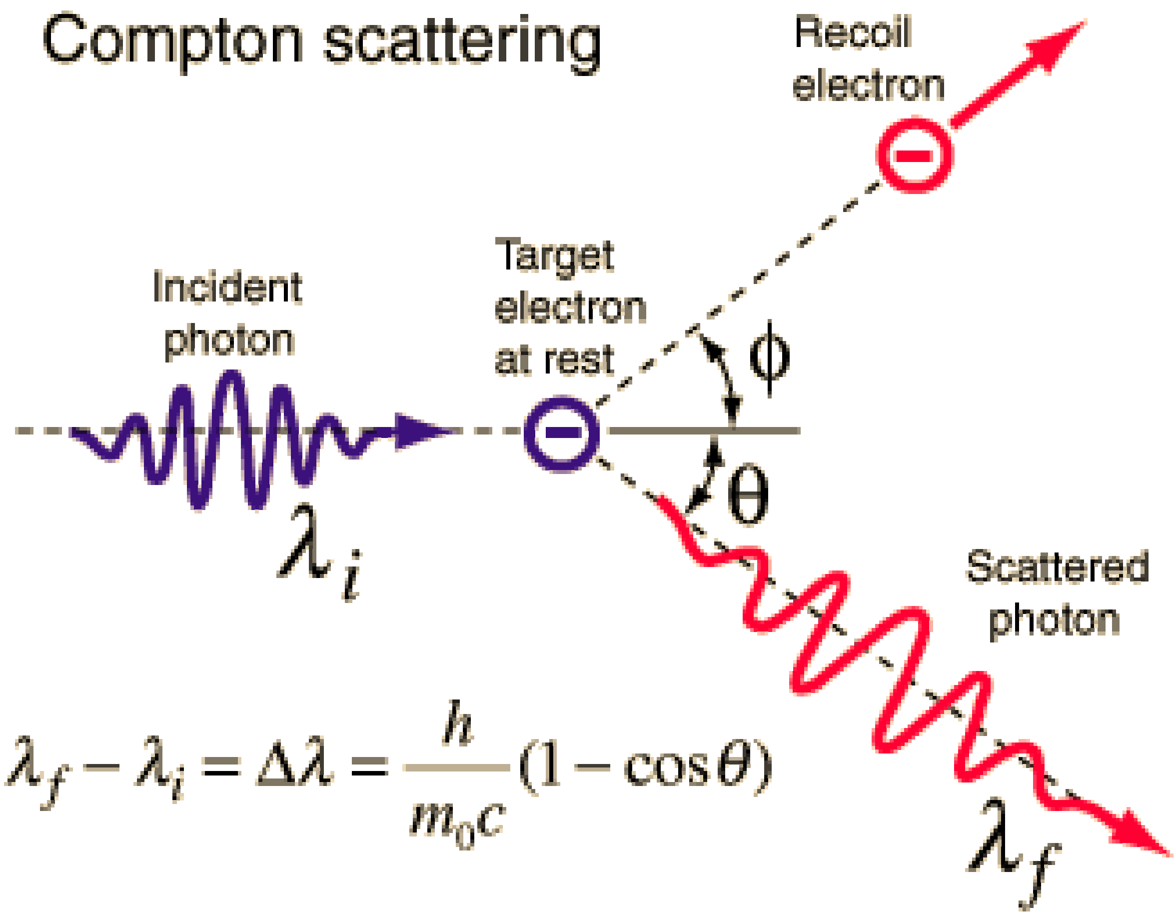






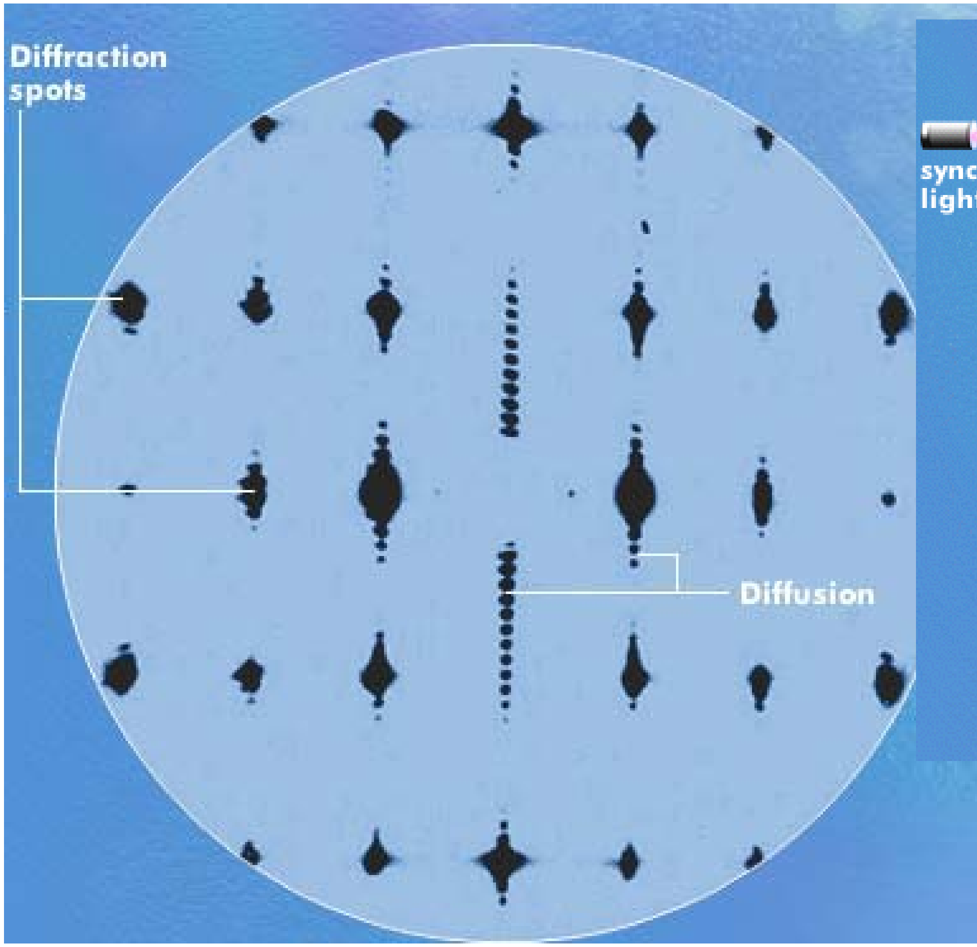


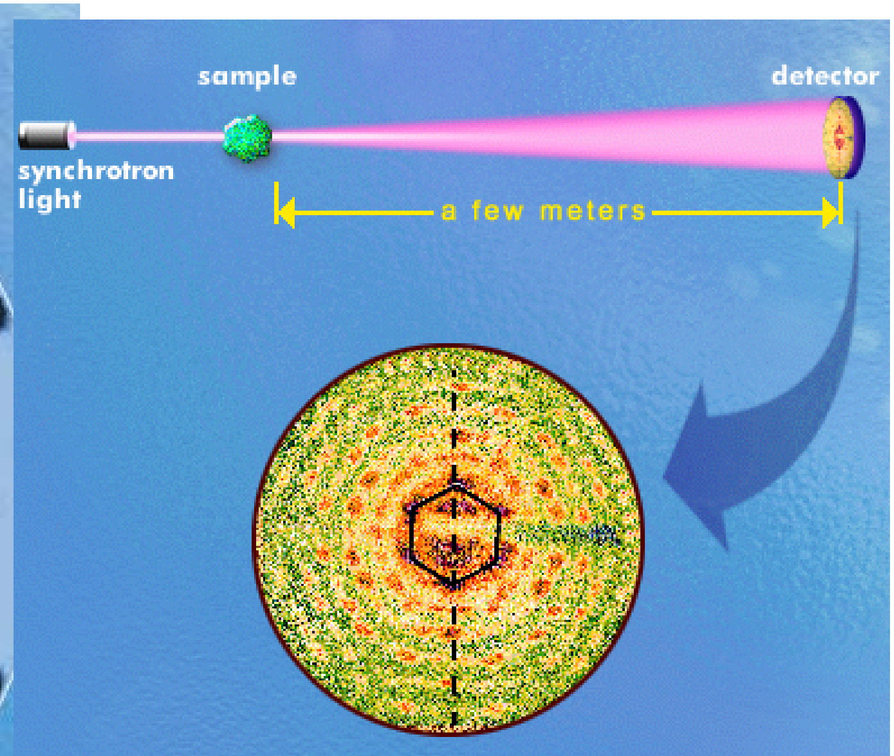

Calcite - France Stone
Random/Backpack
March 24, 1993
40 kv, 30 ma
0.005 deg steps; 0.25 sec/step
15 pt. filter
A
B
C
23.04 deg
3.86 ang
D
39.37 deg
2.287 ang
E
50 deg 2-theta
40
30
20
10



Inelastic scattering

Diffuse Scattering





Small angle (as little as 0.005º means light must be very coherent

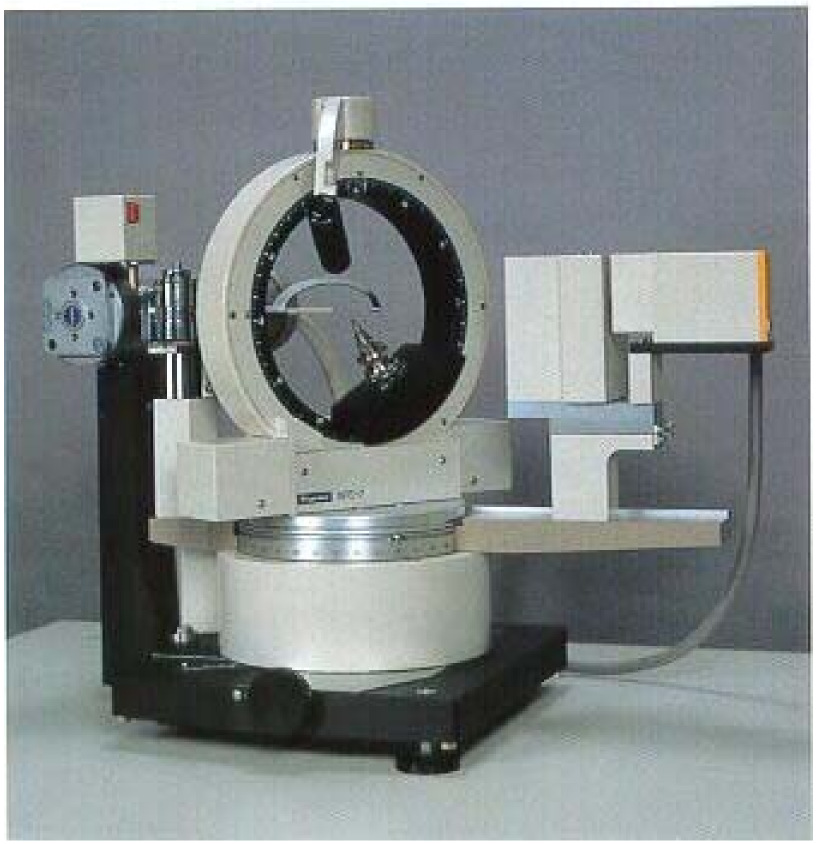
Diffuse scattering gives info on 10-2000 nm scale - biological samples, non-crystalline solids, macromolecules, polymers, catalysts etc

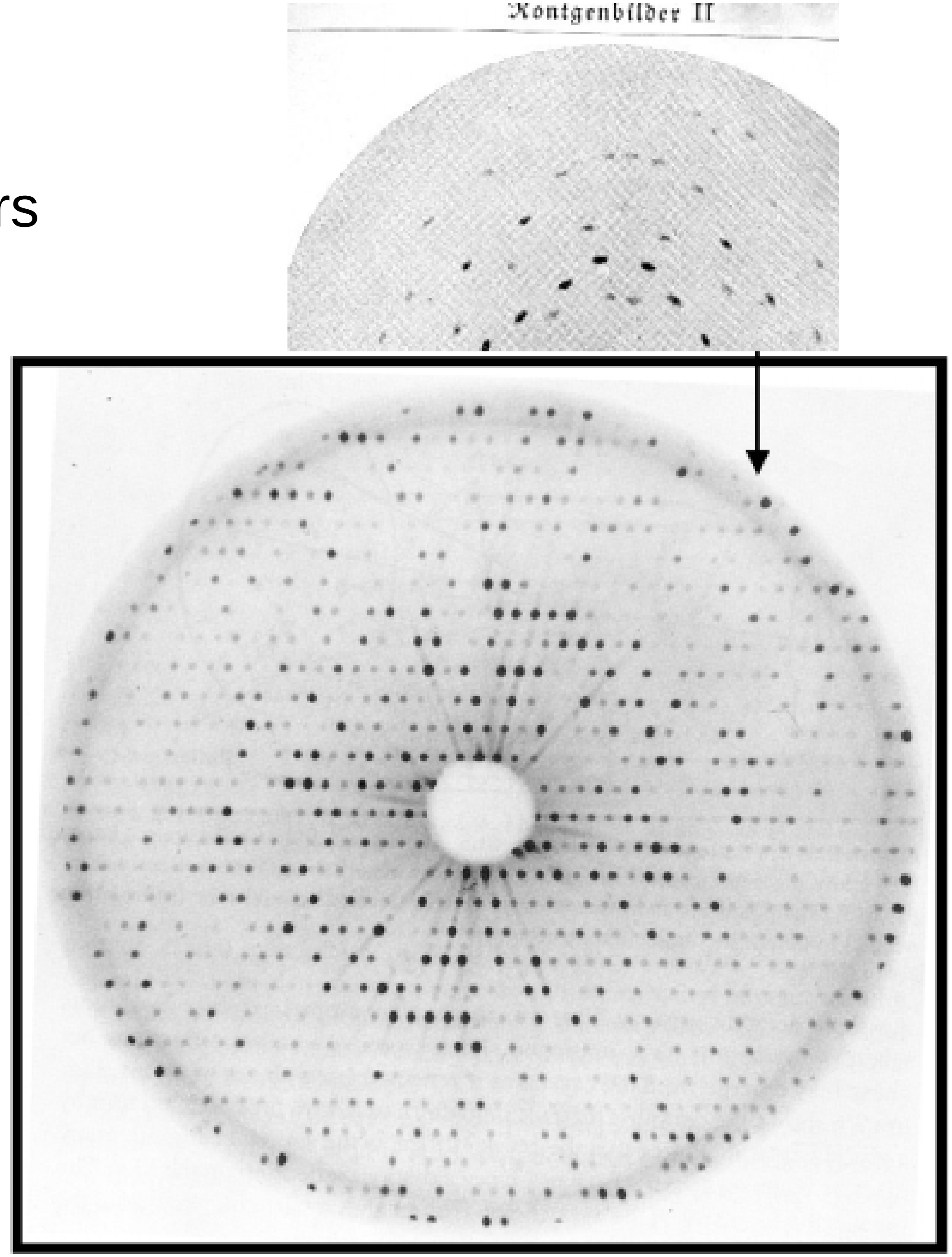
Detectors

Traditionally X-ray film

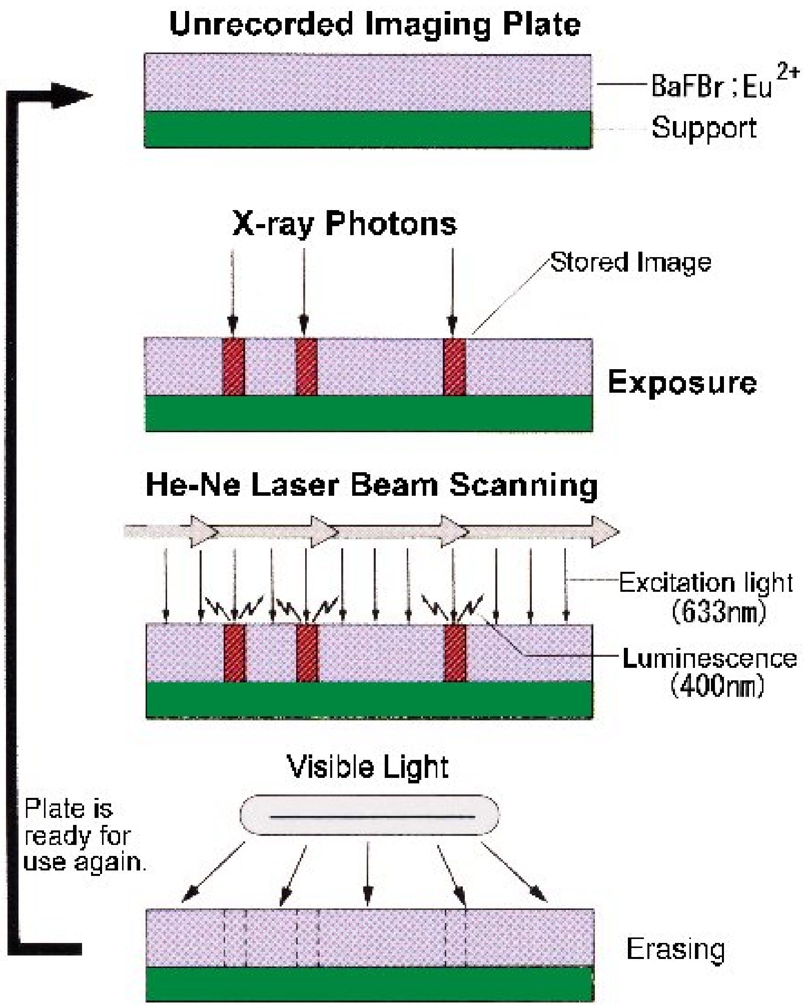
Then followed diffractometers

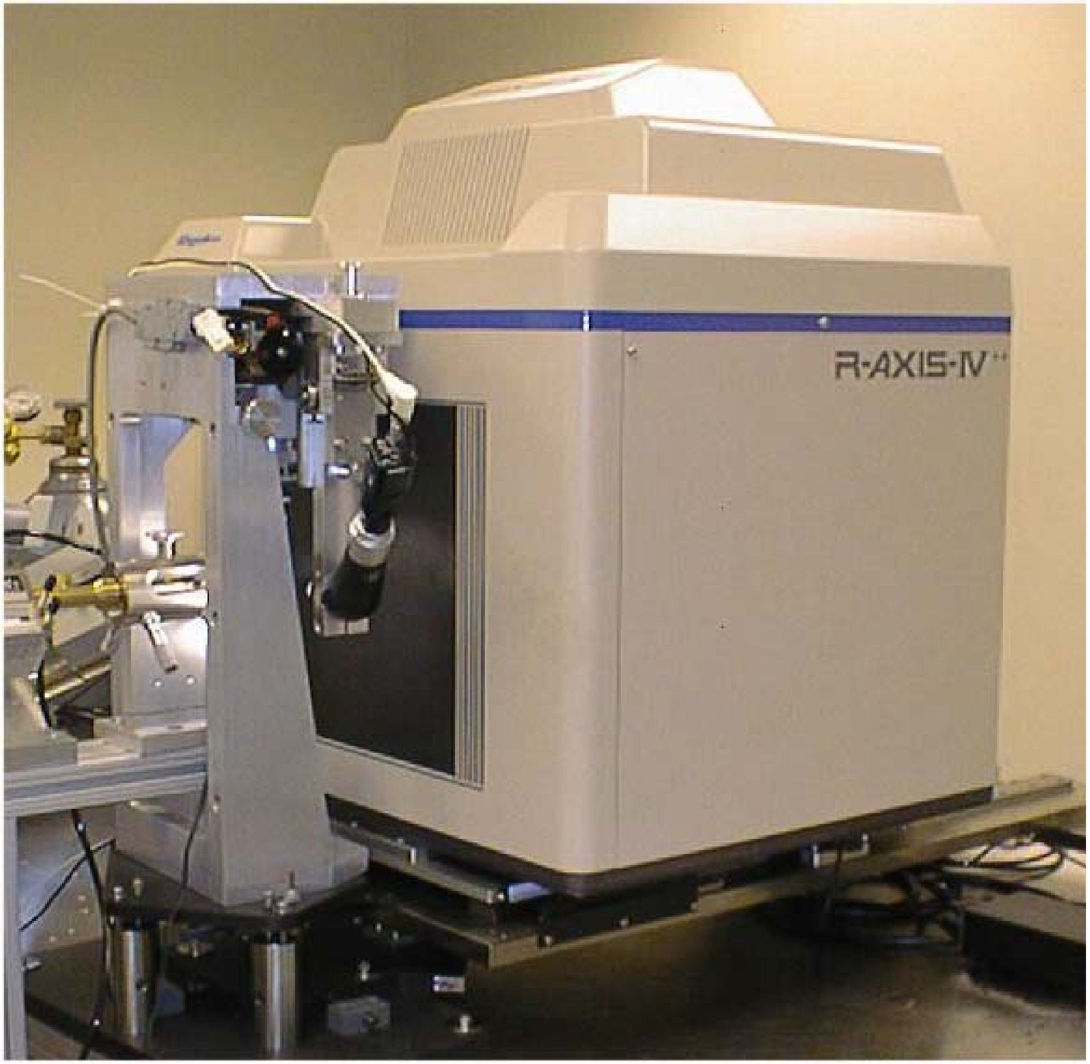
Then film again



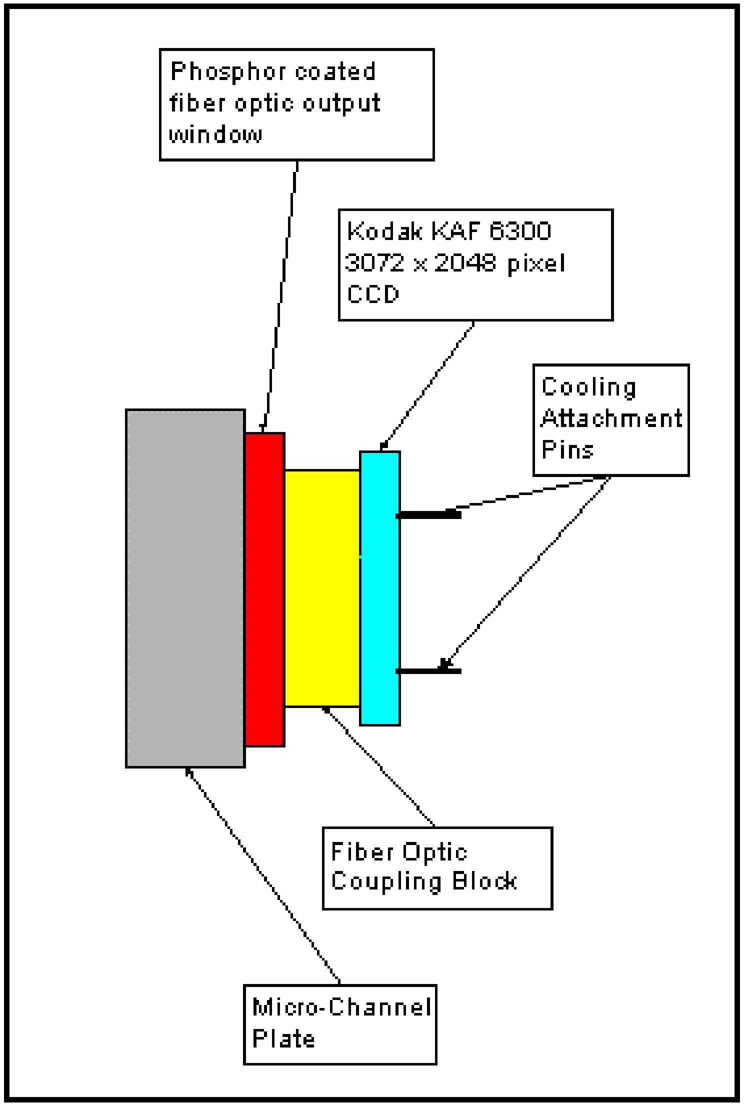


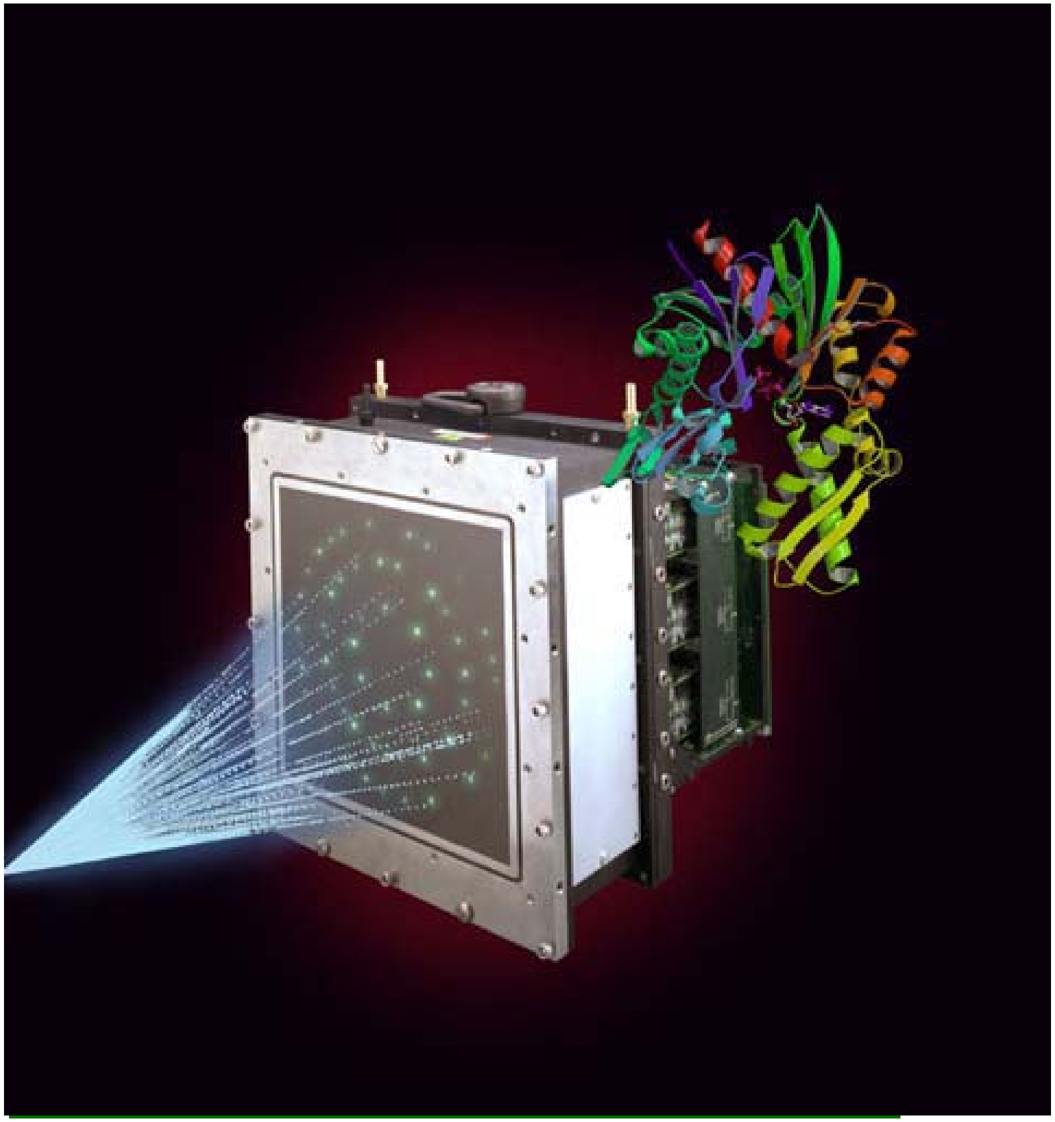
New technology: the imaging plate





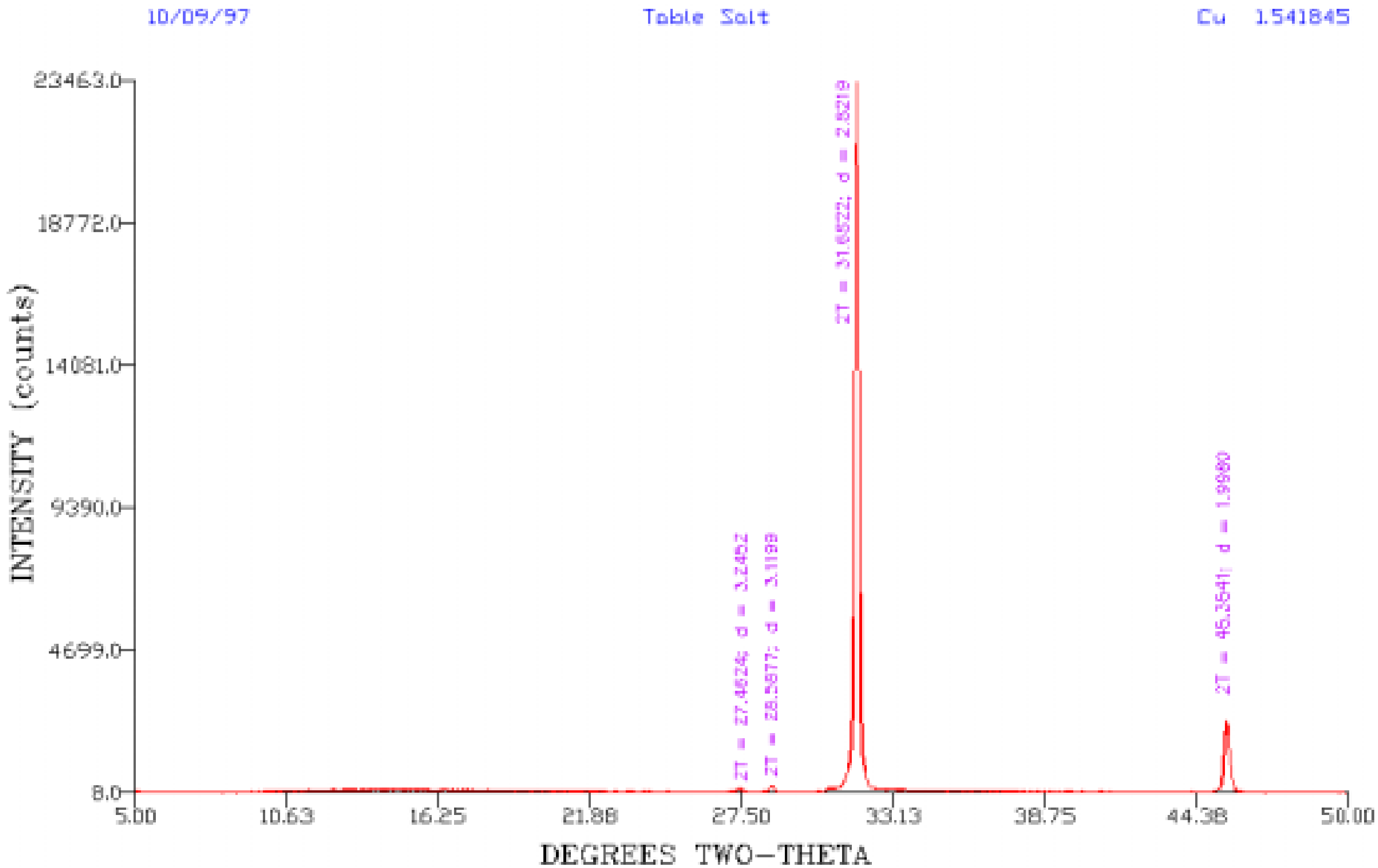
New technology: the CCD





Teaching Activities

Unit Cell Size from Diffraction Data



$n\lambda = 2d\sin\theta$

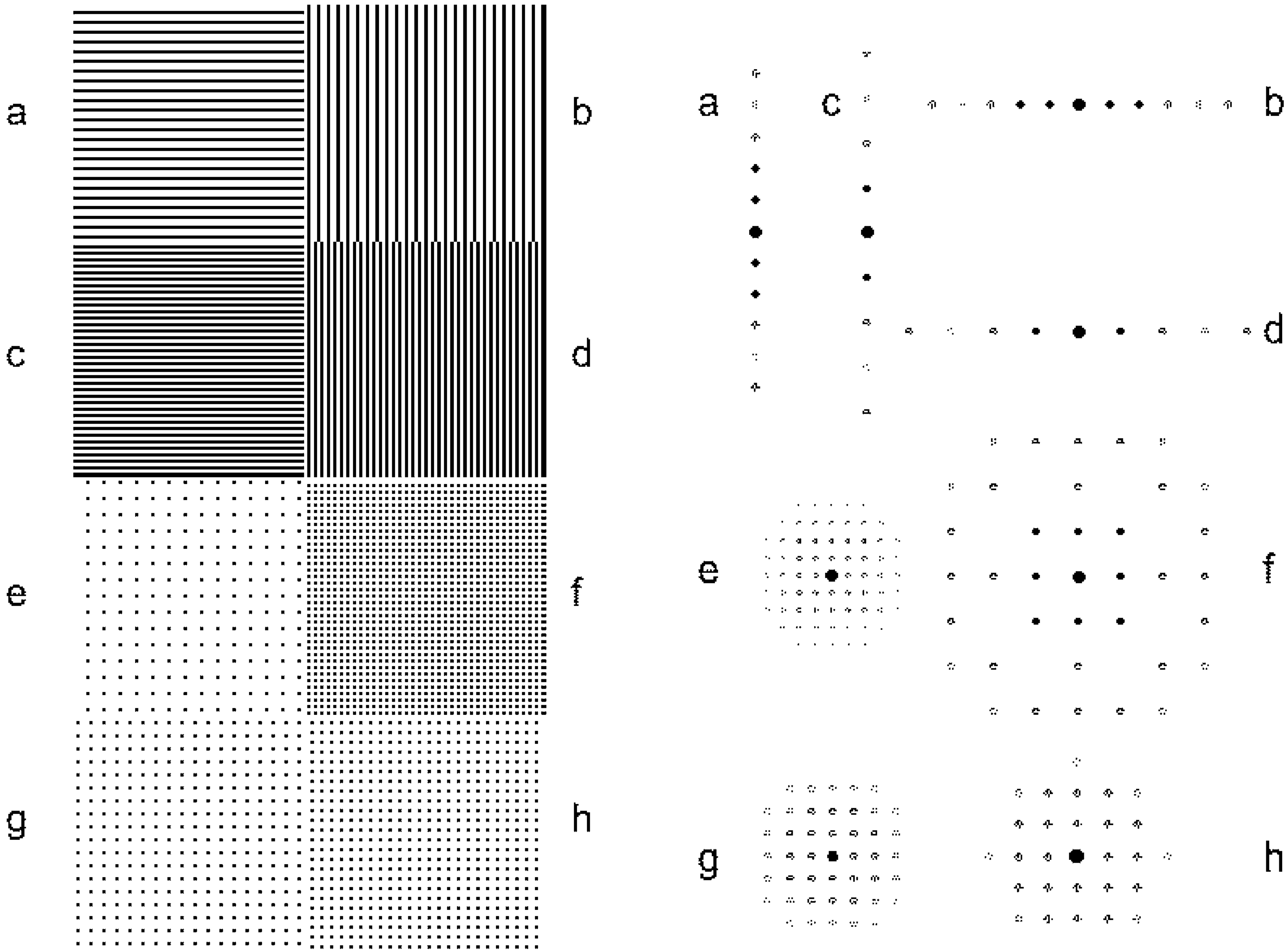
or $d = n\lambda / 2\sin\theta = 1 \times 1.542/2\sin(31.65/2) = 2.825$ Å

Other X-ray Calculations

- Given the size of the unit cell (distance between layers), predict the angle of diffraction. http://www.eserc.stonybrook.edu/ProjectJava/Bragg/index.html
- From d spacing, determine the composition of a sample.

Suggested Activities

- Moving dot on CRO with magnets
- Using lasers as model of coherent light
- Diffraction of a light globe filament with lasers
- Optical Transform Kit (From ICE – Wisconsin)
- Excursion to X-ray diffraction facility


a
b
c
d
e
f
g
h
a
c
b
d
e
f
g
h

Investigation

- Online publishing of powder x-ray diffraction of a novel substance for analysis by students

Resources

- Exploring matter with synchrotron light CD-ROM

- VEA is currently producing a Video for release later this year
- DIIRD is developing a curriculum resource

- MicroWorlds www.lbl.gov/MicroWorlds/

  Canadian Light Source for students www.lightsource.ca/students/

  Nova:Science in the News

  http://www.eserc.stonybrook.edu/ProjectJava/Bragg/index.html

- http://www.mrsec.wisc.edu/edetc/modules/HighSchool/xray/index.html

Trial Schools

- DIIRD in conjunction with VCAA is developing curriculum materials for online delivery and pilot in 2003.
- If interested see JW or Neil Champion