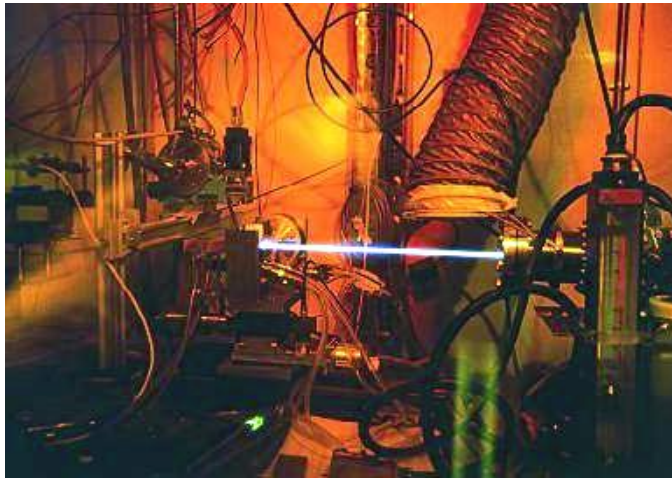# Synchrotron Radiation (ESRF)

Operating energy: 6 GeV
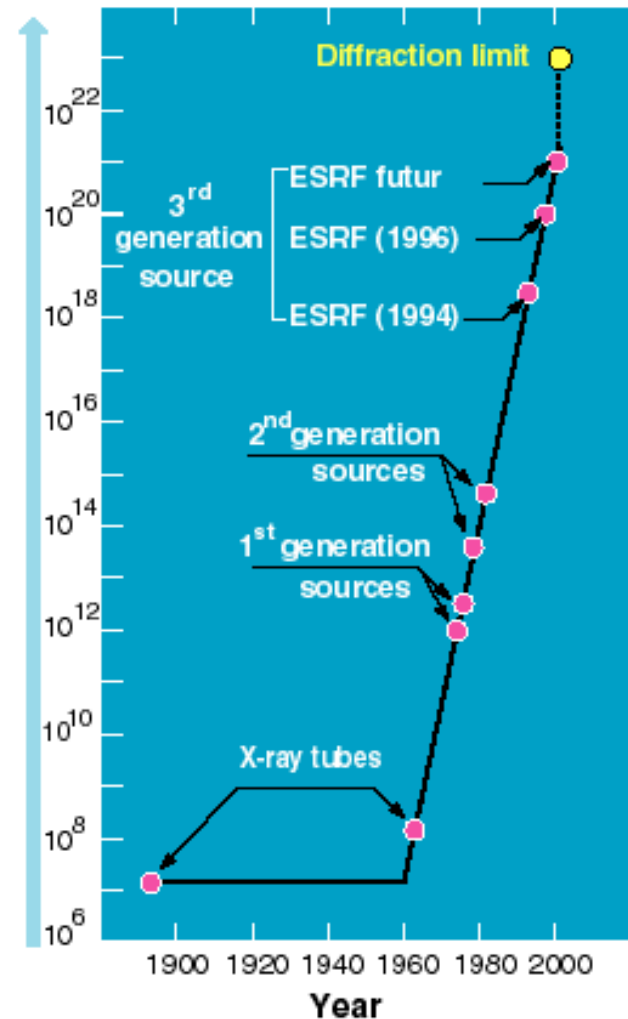
$$v_e / c \sim 0.998$$
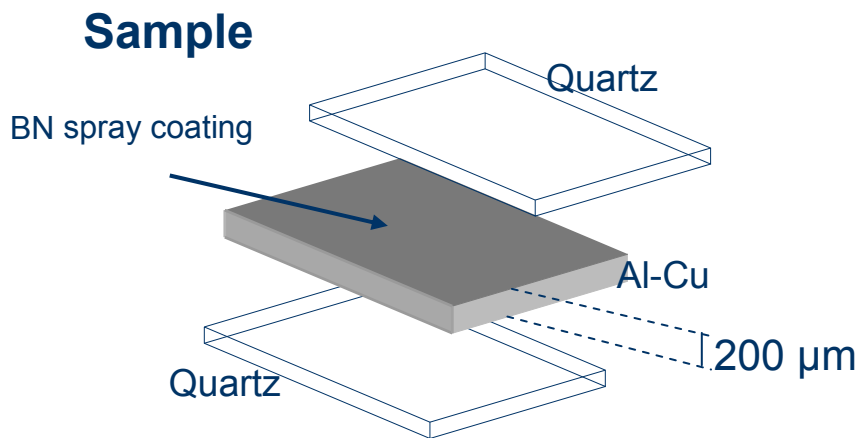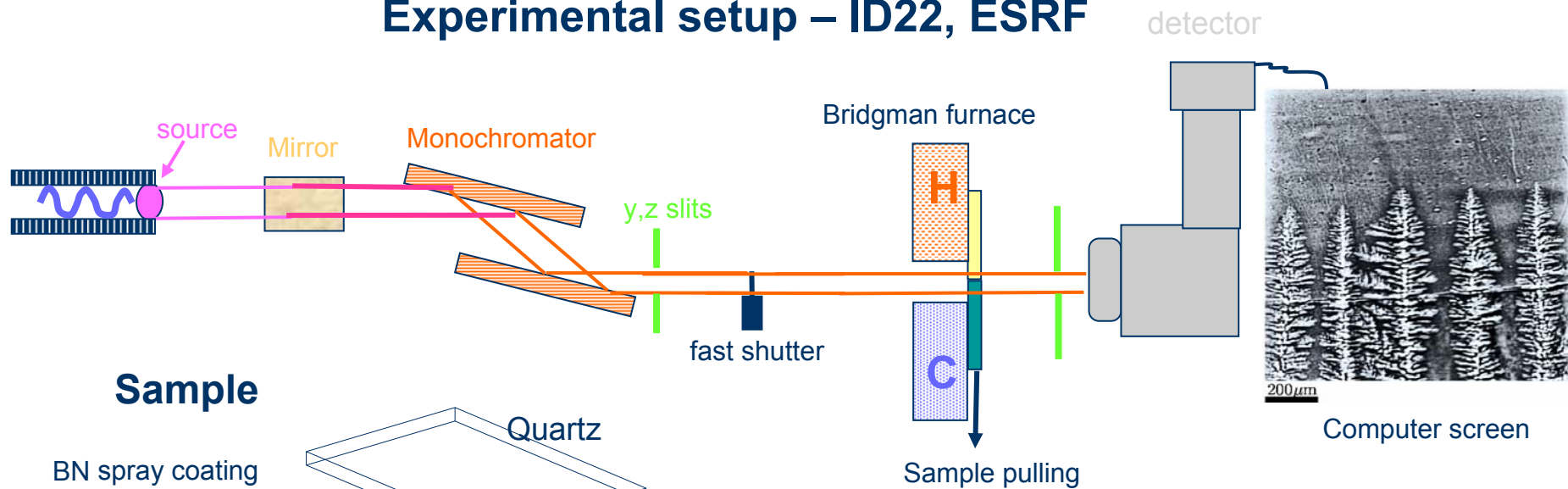

Superrelativistic electrons $\Longrightarrow$

- Broad photon energy spectrum
- source partially coherent

Brilliance of the X-ray beams
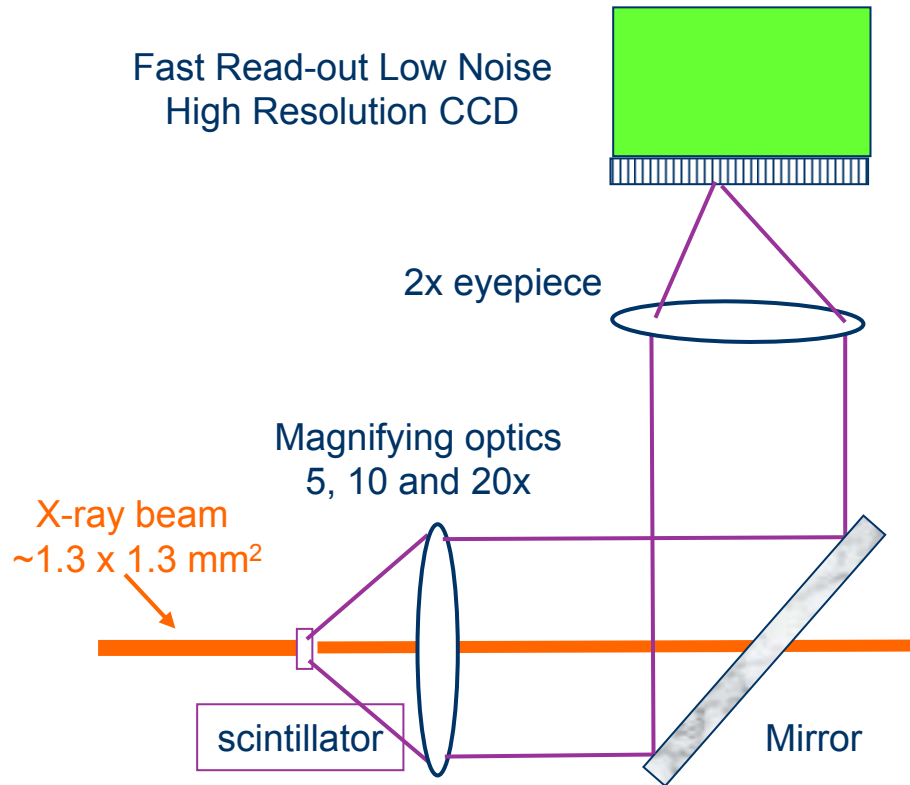(photons / s / mm^2 / mrad^2 / 0.1% BW)

Diffraction limit

3rd generation source
- ESRF futur
- ESRF (1996)
- ESRF (1994)

2nd generation sources

1st generation sources

X-ray tubes

Experimental setup – ID22, ESRF

Sample

Computer screen

- E= 12-25 keV, $\Delta E/E \sim 10^{-4}$

- Flux density at sample: $\sim 10^{13}$ ph/(s•mm^2)

- Nominal resolutions (2 x 2 binning):
  $\Delta r \sim 1.4$ μm
  $\Delta t \sim 0.15$ s

- Absorption and phase contrast

Alloys studied: Al-Cu: 5, 10,15, 20, 30%wtCu
                    Pb-Sn: 52, 90 %wtSn
                    Al-Bi(Zn): 5, 6, 8%wtBi, (8%wtZn)

Detector details

Fast Read-out Low Noise
High Resolution CCD

2x eyepiece

Magnifying optics
5, 10 and 20x

X-ray beam
~1.3 x 1.3 mm^2

scintillator

Mirror

4.2 Mpixels, 4 Ch. Read-Out

Nominal features:

- Unbinned

$$\Delta d \sim 0.8 \; \mu m$$
$$t_{ro} \sim 0.6 \; s$$

75 frames capacity

- Binned (2x2)

$$\Delta d \sim 1.4 \; \mu m$$
$$t_{ro} \sim 0.1 \; s$$

300 frames capacity

Synchrotron direct beam X-ray imaging

- Refractive index

$$n(r) = 1 - \delta(r) - i\beta(r)$$

- where

$$\delta \propto \rho_a Z \sim 10^{-5}$$
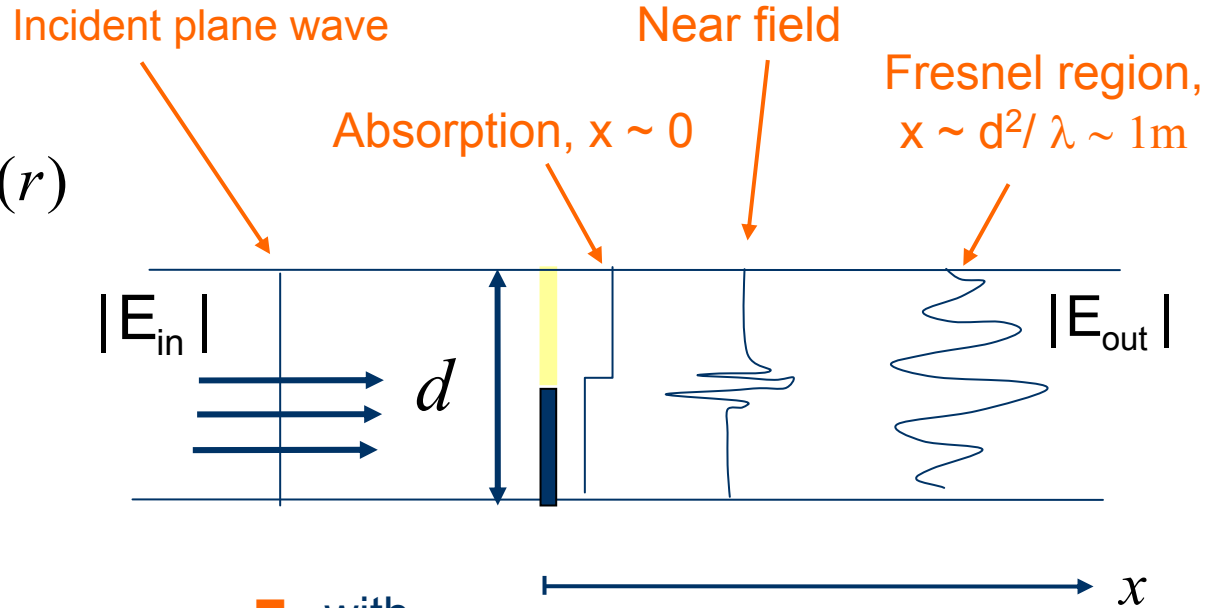
$$\beta \propto \rho_a Z^4$$

Incident plane wave

Near field

Absorption, x ~ 0

Fresnel region, x ~ d^2/λ ~ 1m

$|E_{in}|$ d $|E_{out}|$

x

- Object transmission

$$E_{out}(y,z) = F(y,z)E_{in}(y,z)$$

$$= A(y,z)e^{i\varphi(y,z)}E_{in}(y,z)$$
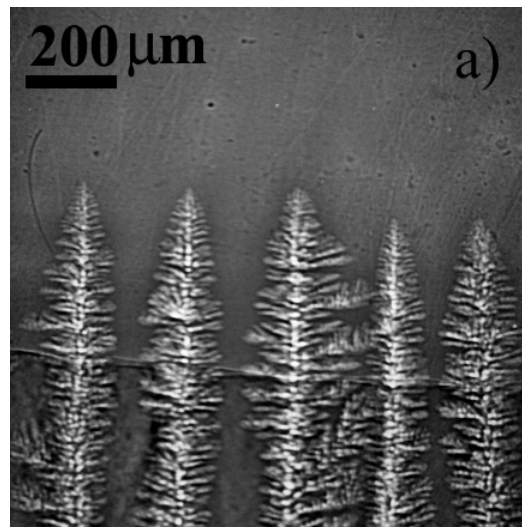
- with

$$A(y,z) = e^{(-2\pi/\lambda \int \beta(r)dx)}$$
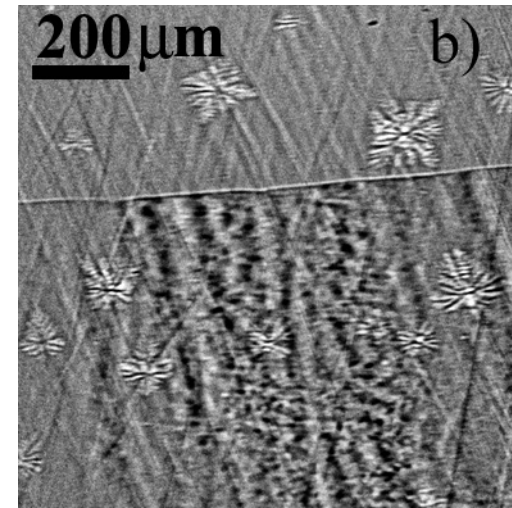
$$\varphi(y,z) = -\frac{2\pi}{\lambda}\int \delta(r)dx$$

Phase Contrast Requirement:

$$l_\perp > \Delta d \ (\sim 10^{-5}\lambda)$$

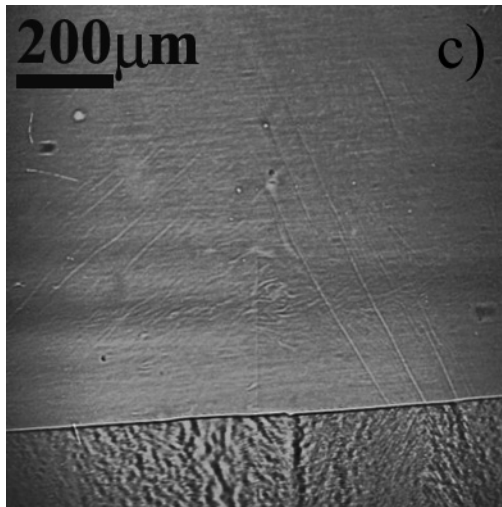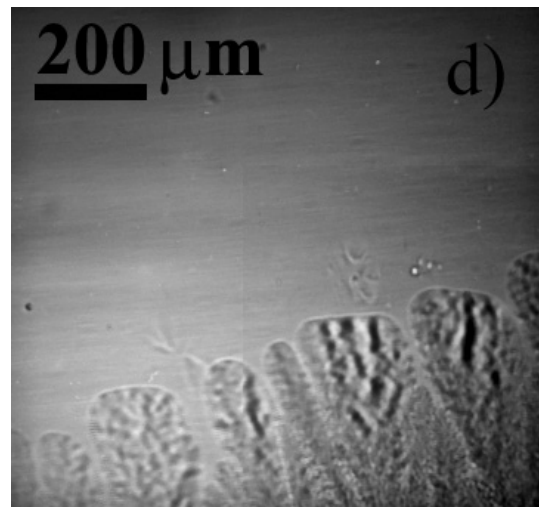# Results

Directional α dendrites
+ planar eutectic

Equiaxed α dendrites
+ planar eutectic

Planar eutectic

Eutectic cells

Eutectic dendrites

Examples of observed solidification modes in Al-30wt%Cu