Characterisation of the
X-ray microprobe in Krakow
and properties of the beam focusing system

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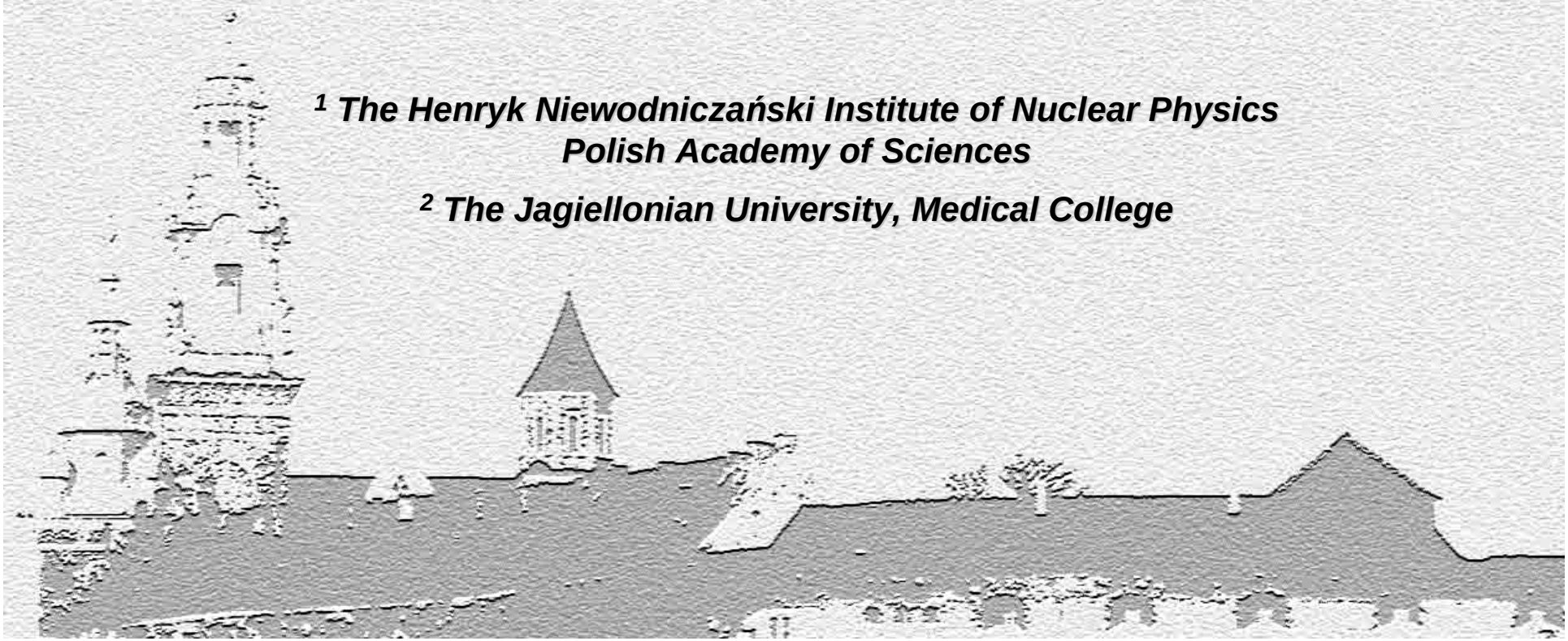


Outline

0. Idea of the experiment

1. **X ray source** - Hamamatsu L9191

- Tube parameters, spectra
- Ti-Kα line intensity optimization
- Tube spot size determination

2. **X ray focusing system** – Kirkpatrick-Baez mirrors

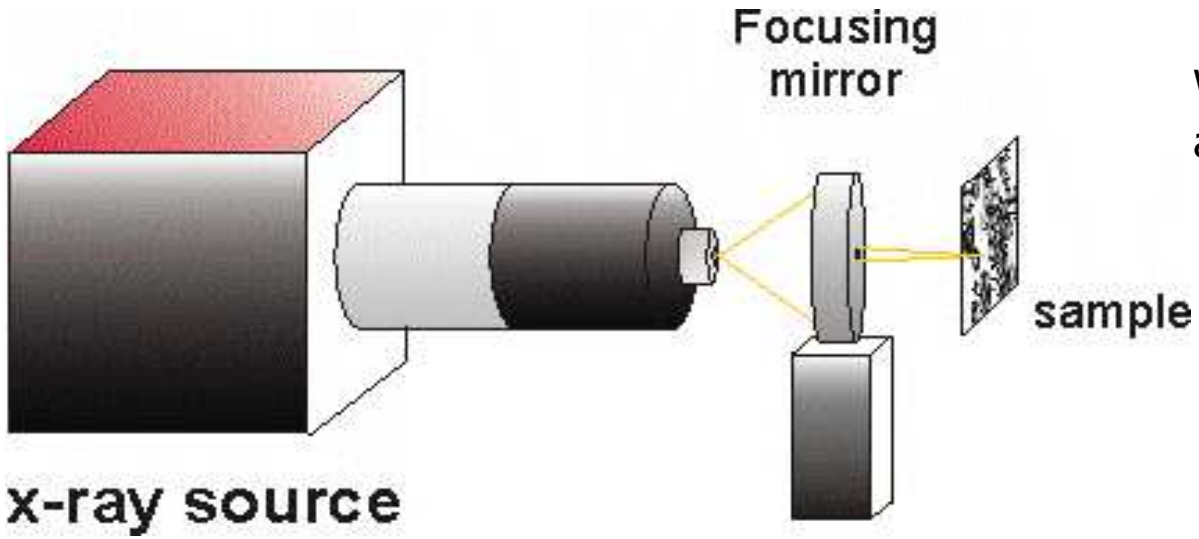
- Zone plates vs multilayer mirrors
- Focal spot size measurements

3. **Sample positioning**

Idea of the experiment

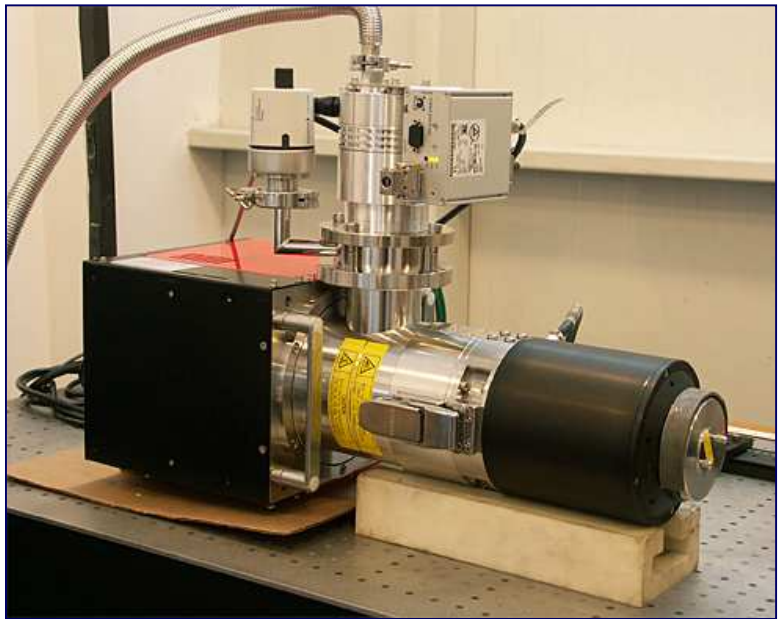
- Research on consequences of an x-ray irradiation for a single biological cell and a cells population.
- Comparison of the ionization density and determination the difference in the number of double strand breaks in cells between particles and x-ray irradiation

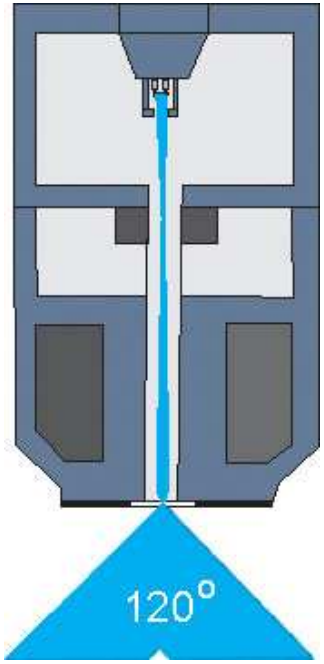
	Proton microbeam	**X-ray microbeam**
Ionisation density	high	low (photoelectrons)
Mean detph of penetration in cells	100 µm total range for 3 MeV protons	half of intensity at 100 µm for 4.5 keV x-rays



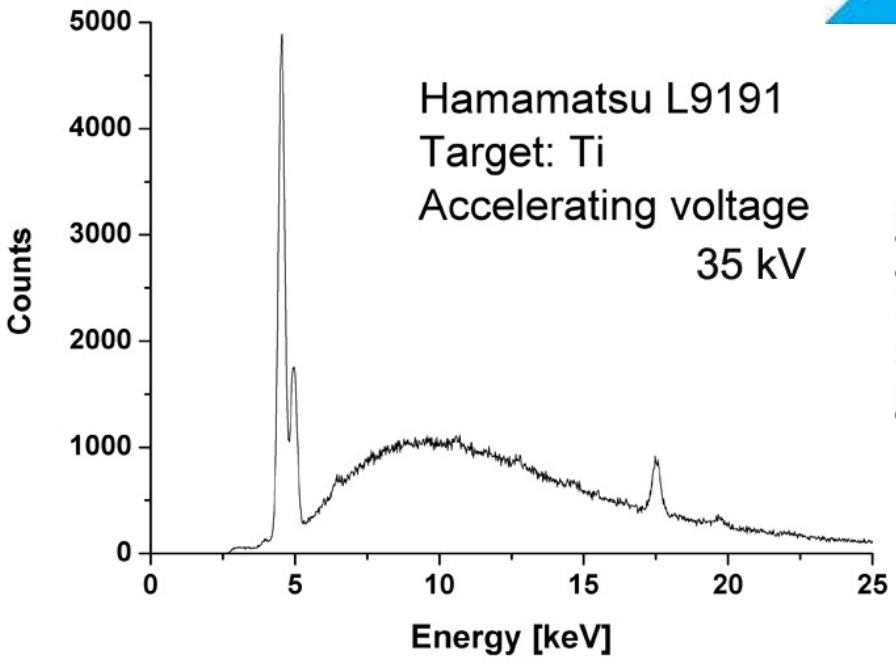
We have to focus the beam at chosen single cells.

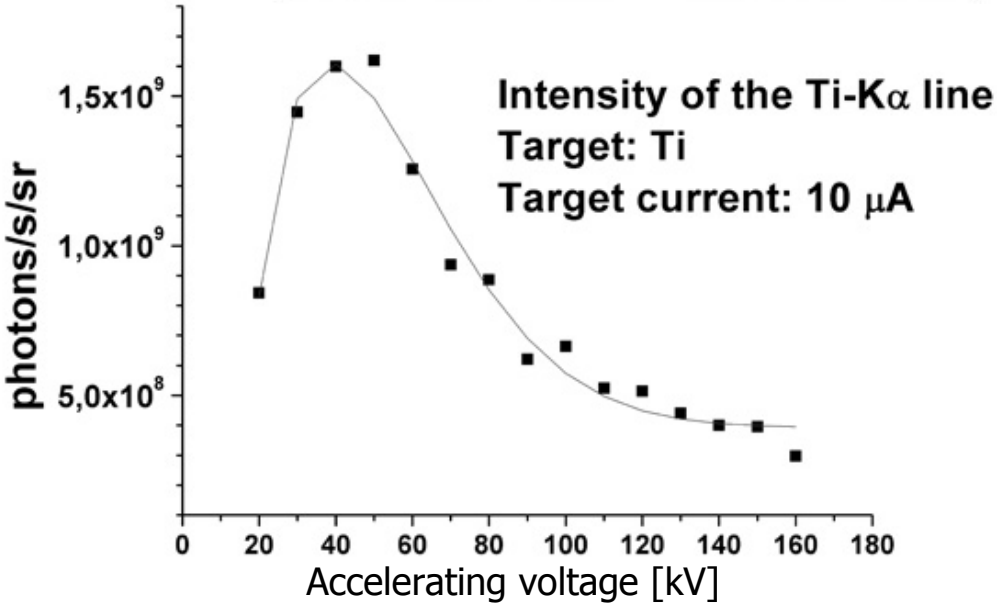
X-ray source – Hamamatsu L9191





Parameter	Value
Cathode Material	Tungsten
Targets Material	Ti (Kα 4.5keV),Mo (Kα 17.4keV),W (Lα 8.4keV, Kα 59.3keV),Ag(Kα 22.2 keV)
X-Ray Output Windows Material /Thickness	Beryllium / 0.5mm
X-Ray Tube Voltage Setting Range	20kV – 160kV
X-Ray Tube Current Setting Range	0 µA – 200 µA
Expected Resolution	1µm
X-ray Beam Angle	120 degrees



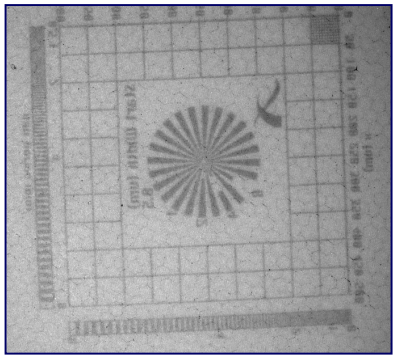


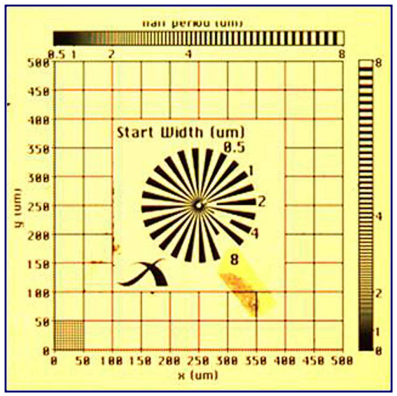
Tube resolution measurements

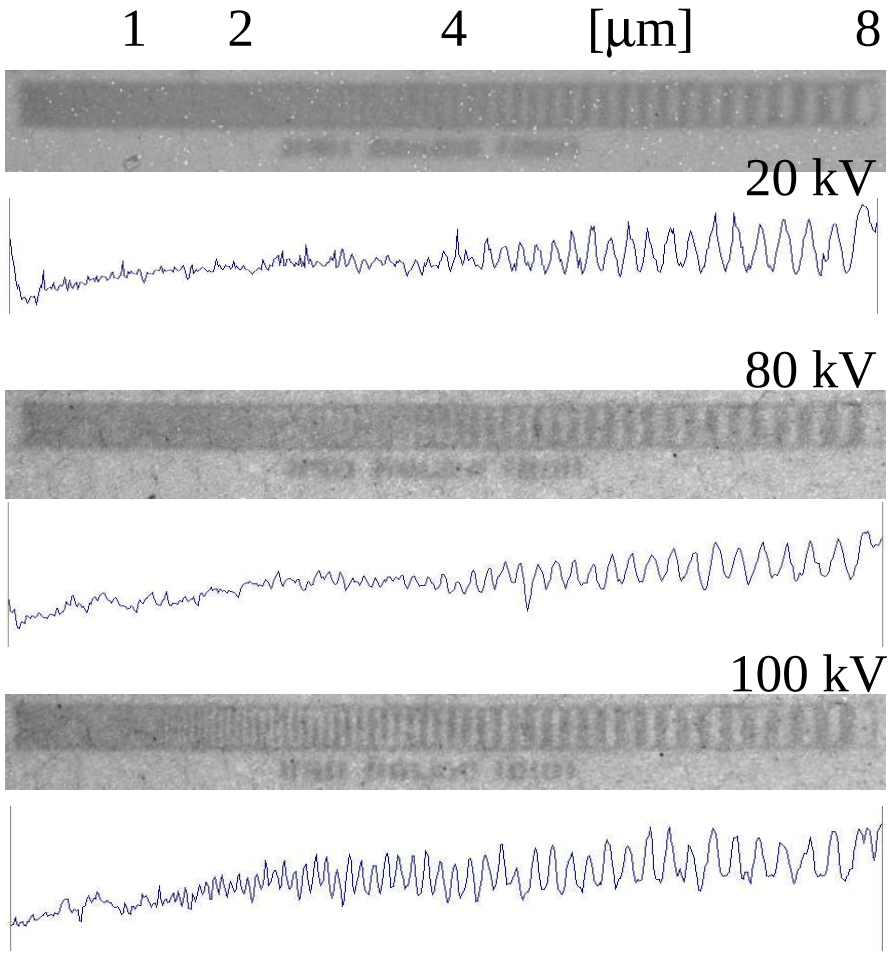
The 500x500 μm sized pattern tile situated in the front of the tube gives the information about the tube resolution.

Image intensity at edges of pattern profile (CCD pixels read-out) is the result of the convolution of the normal distribution and the Heaviside (step) function.

Through deconvolution operation the tube focal spot size is obtained.

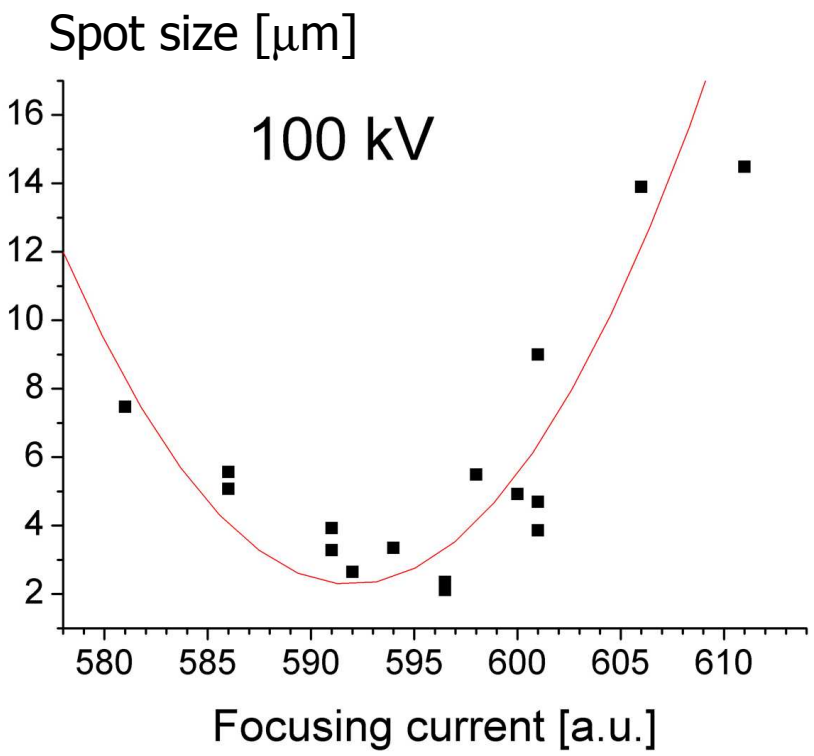


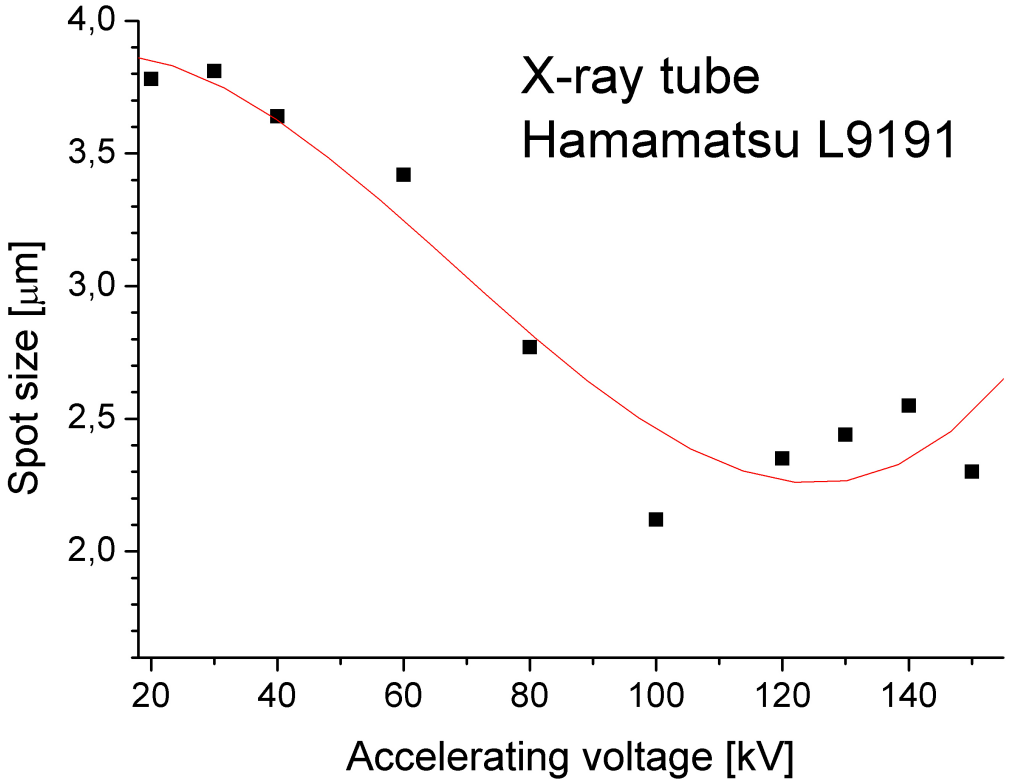




Tube spot size

The tube focal spot size depends on the accelerating voltage and the focusing current of electromagnetic lenses.
Optimal spot size (about **2 μm**) was obtained at **100 kV**.



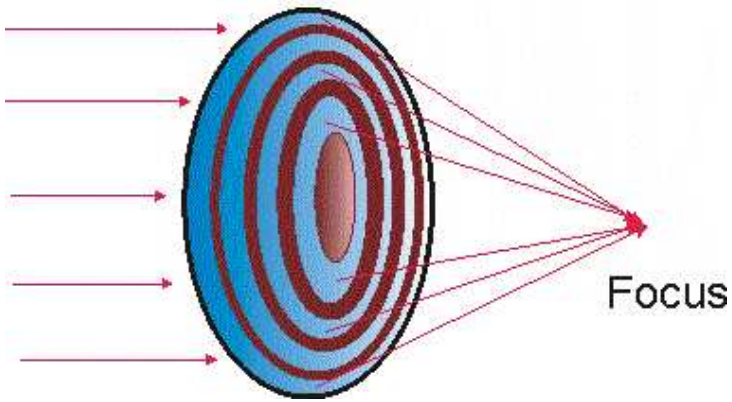


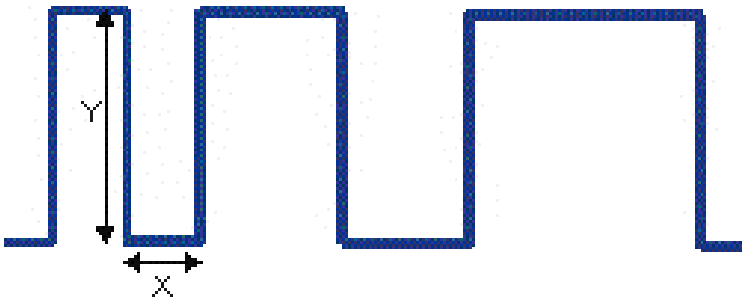
Focusing x-rays – considered methods

Fresnel zone plates

Zone plates are better for low energy radiation.
At high energies the plate should have:

- very small diameter
- high aspect ratio y/x for the smallest structures at the edge of the plate (~10 for 4.5 keV)

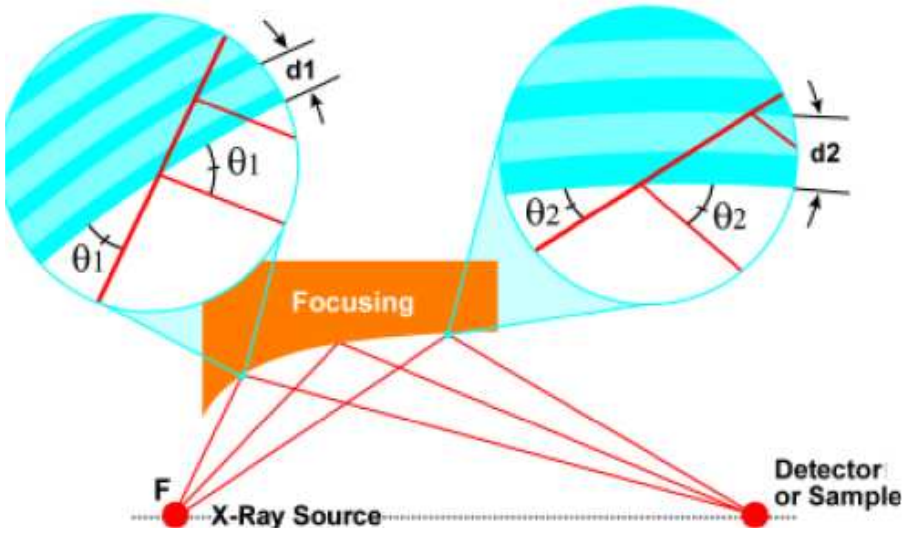




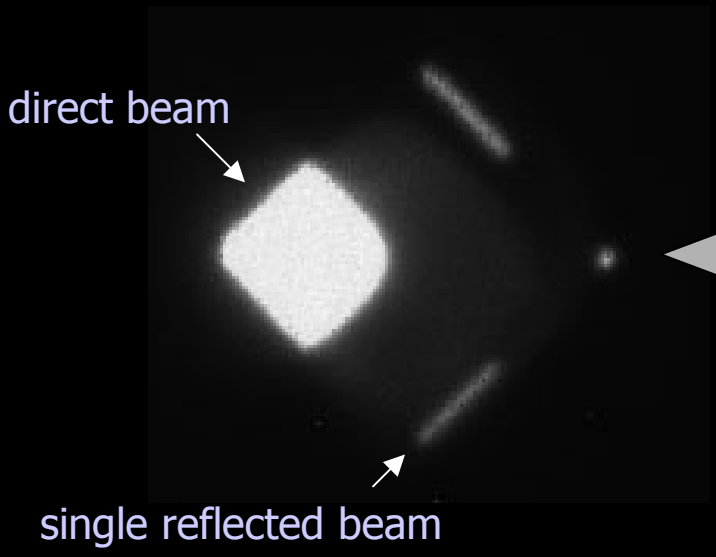
Multilayer focusing mirrors

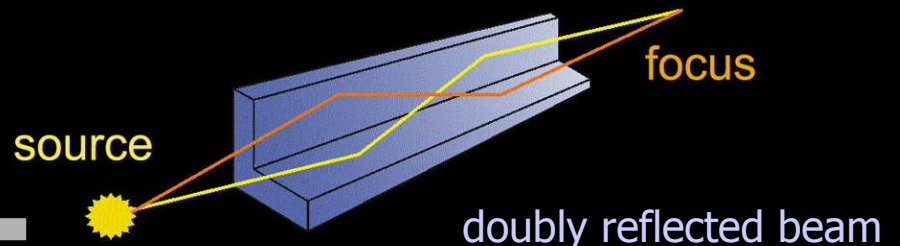
Multilayer mirrors provide Bragg reflection constructive interference along the whole mirror elliptical surface.
Due to the Bragg reflection condition the system works also as a monochromator.

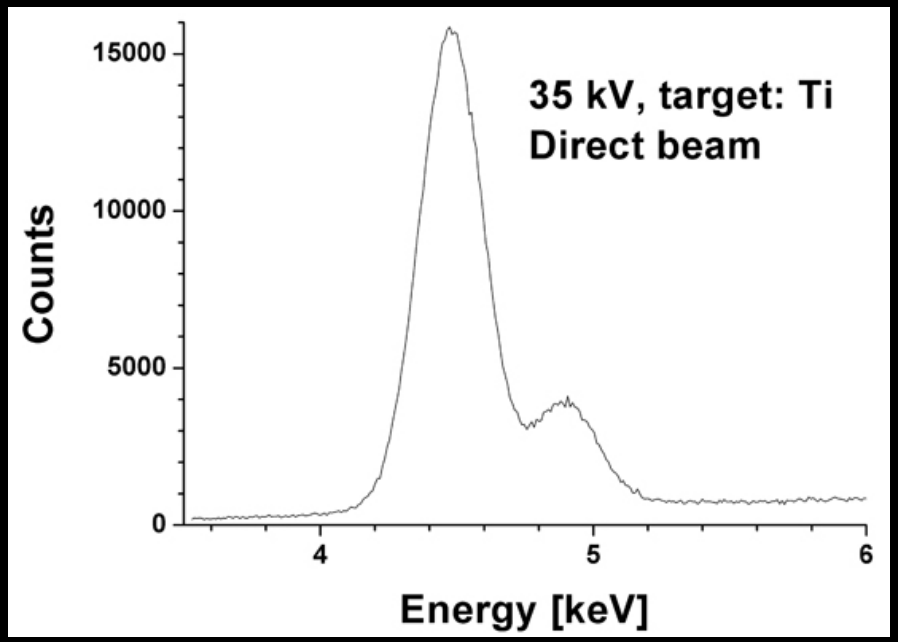
$$2d\sin\theta = n\lambda$$

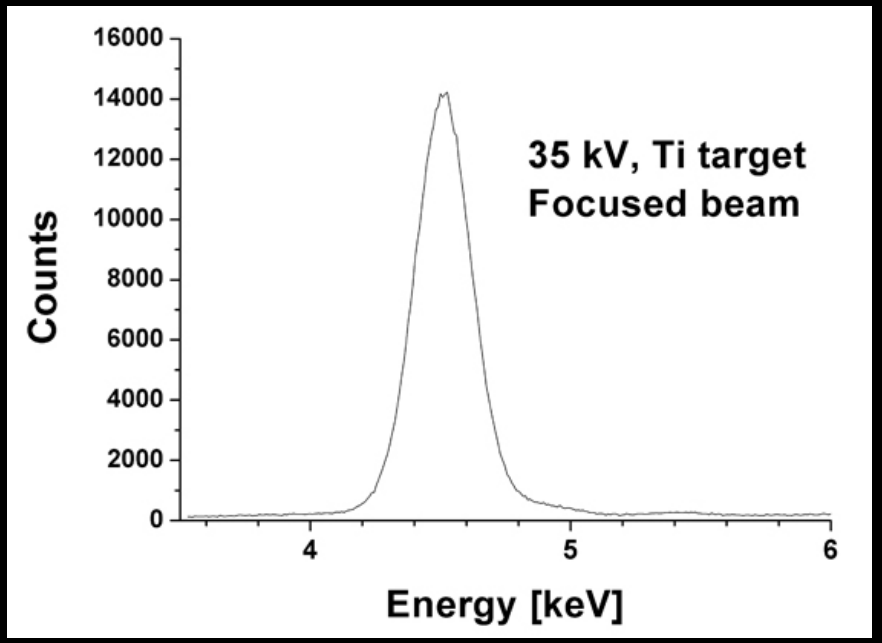


Focusing x-rays by multilayer mirrors







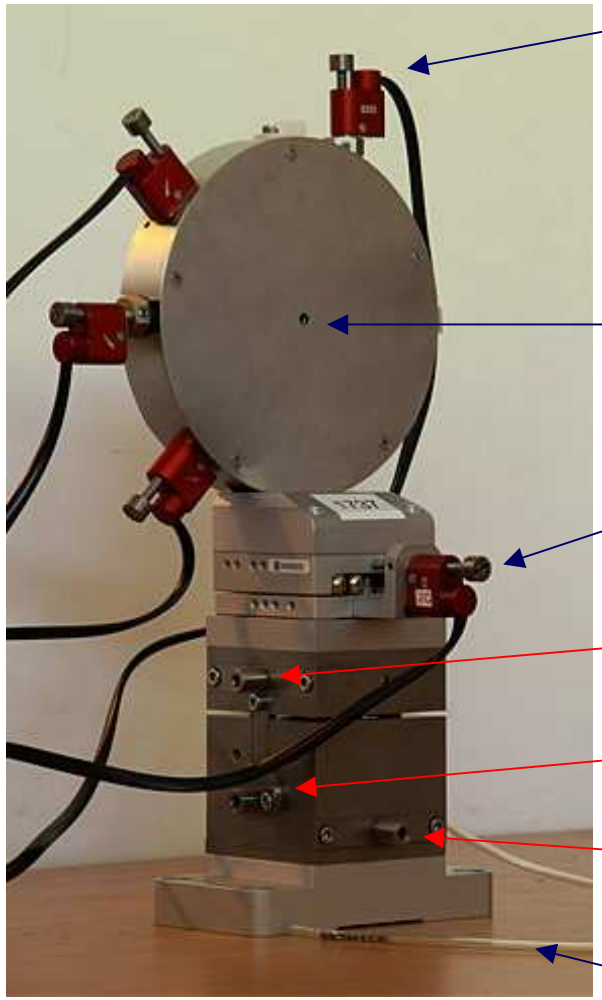


Deposited energy and dose in focus
@ acc.volt. 30 kV and target current 10 μA

4200 photons/sec * 4.5 keV = 19 MeV/sec
gives **0.7** Gy/sec for cell nucleus

Kirkpatrick-Baez multilayer mirrors

Multilayer mirrors manufactured by the Rigaku Innovative Technologies Inc. (USA) with motorized stages are used in the cells irradiation facility. The focusing distance is **15 mm**.



perpendicularity

reflection angle 1

aperture

focused beam

reflection angle 2

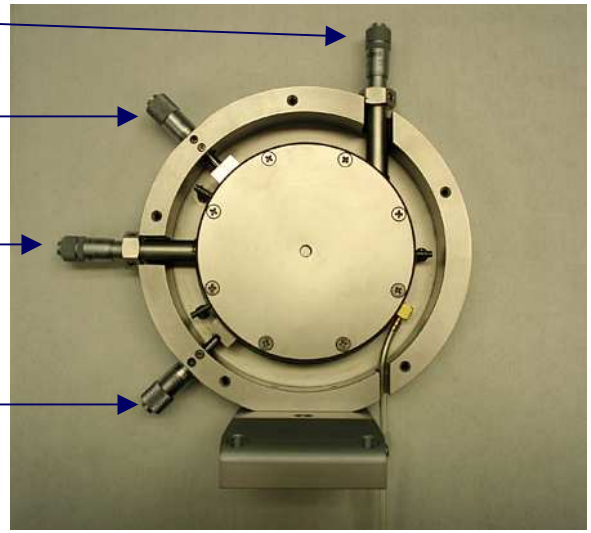
z-axis movement
(distance)

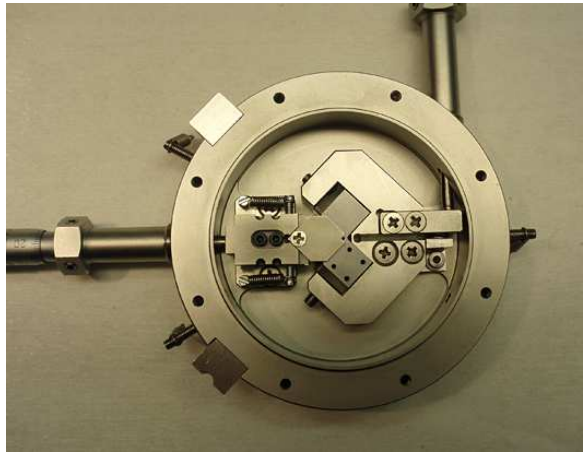
x-axis movement
not motorized

y-axis movement
(height), not motorized

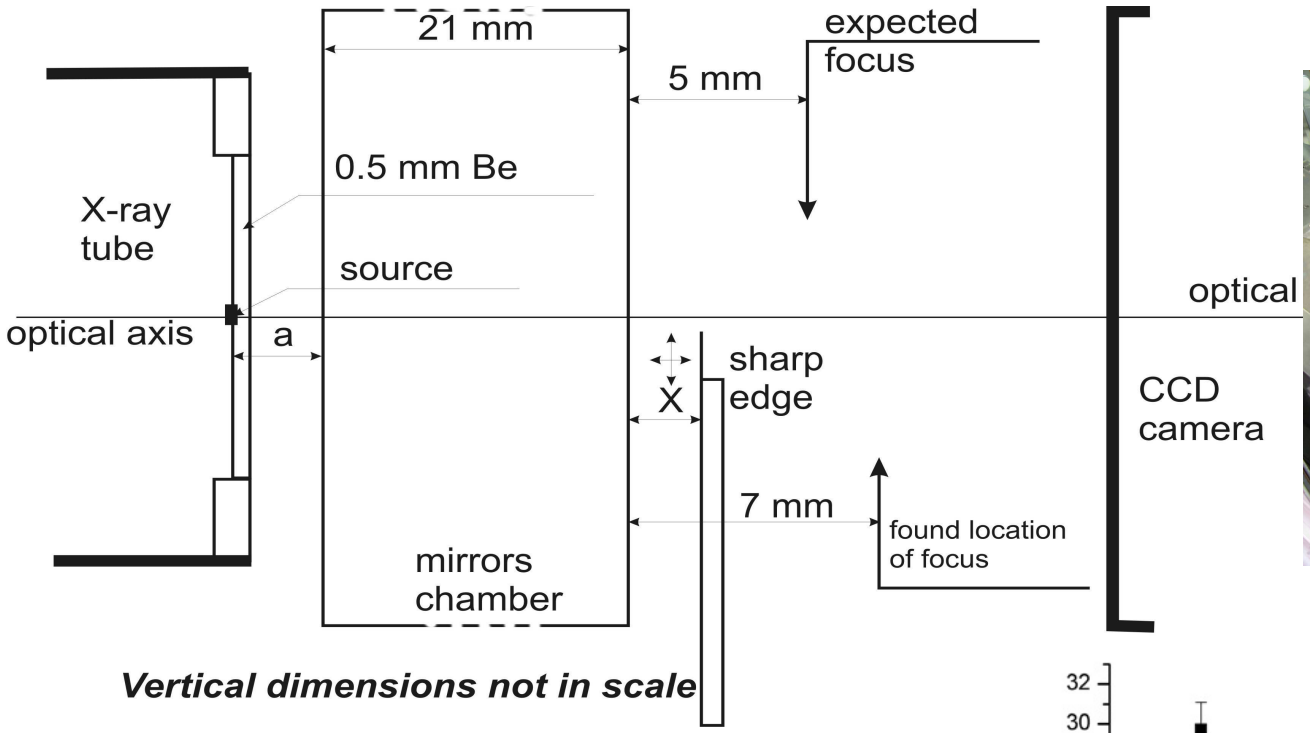
z-axis movement
(distance), not motorized

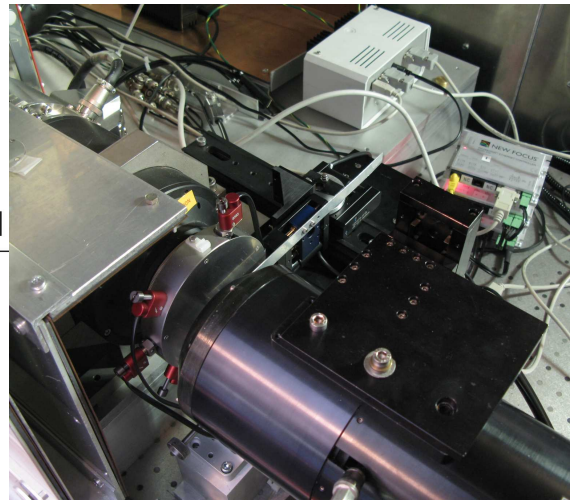
Helium filling pipe

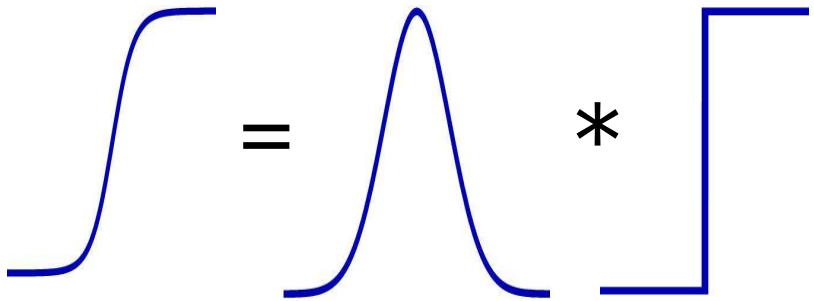


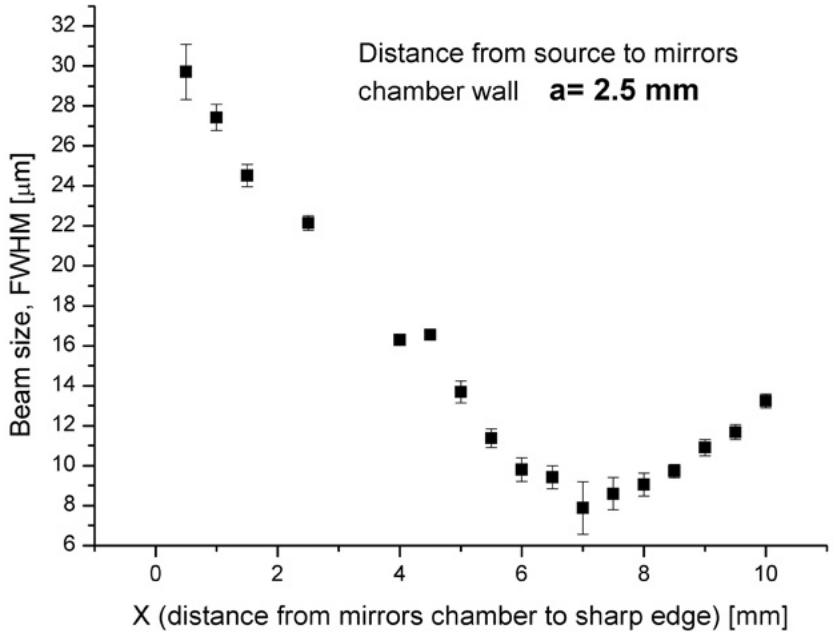


Focal spot size measurements









Sample positioning

PI motorized translation stages

- motion range: **25 mm**
- minimum incremental motion: **50 nm**
- controlling: PI software or LabVIEW

Two elements combined together enable movement in a plain

Qioptiq Zoom 160 Optical System Microscope

- motorized zoom and focus
- SHOTT's coaxial light source
- field-of-view (zoom): **16:1**
- maximum resolution: **900 lp/mm**
- camera connection

Watec WAT-231S color camera

- weight: **160 g**
- resolution: **450x480 px**
- video and Y/C signals output
- gamma correction and iris level control