Geometrical effect of target crystal on PXR generation as a coherent X-ray source

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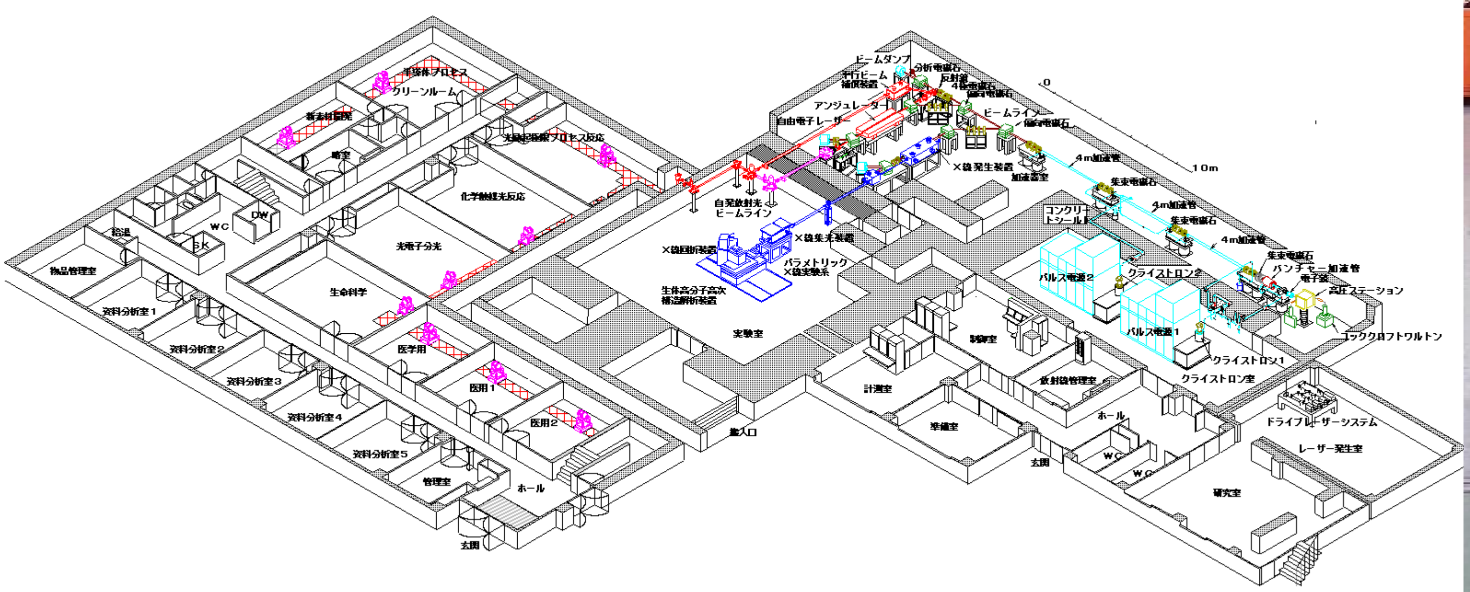
LEBRA facility at Nihon University

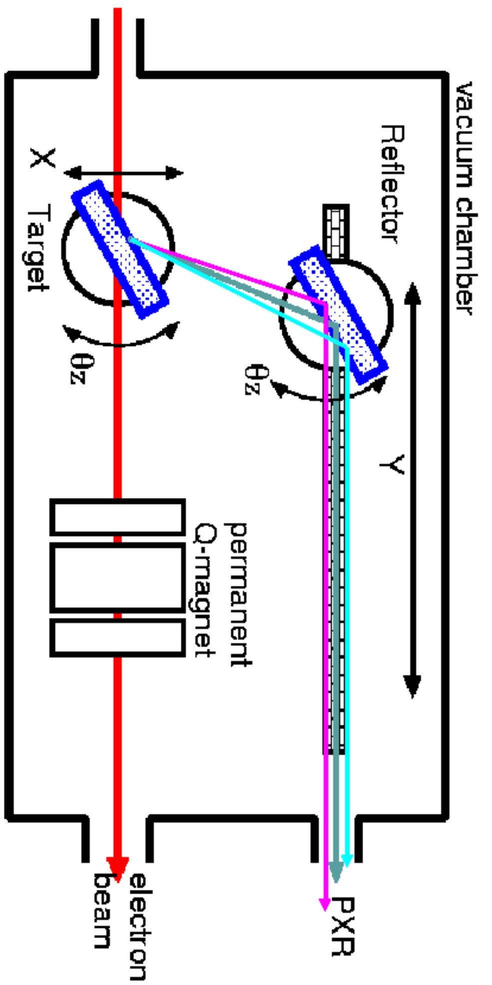
LEBRA: **L**aboratory for **E**lectron **B**eam **R**esearch & **A**pplication

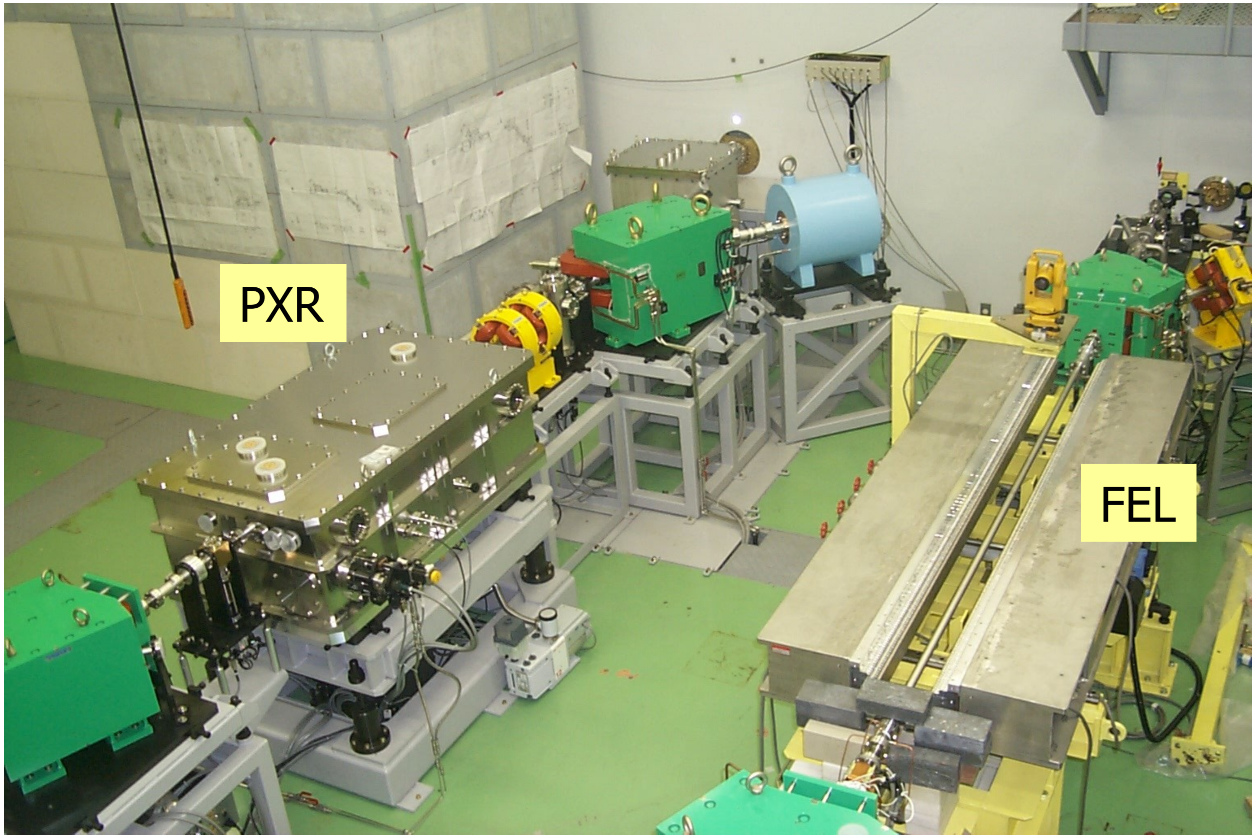


Tunable light-source facility based on
a conventional S-band electron linac

elctron energy: 125MeV(max.), 100MeV(typ.)
average current : 5μA (max.), 1 – 2 μA(typ.)

Beamlines of FEL & PXR





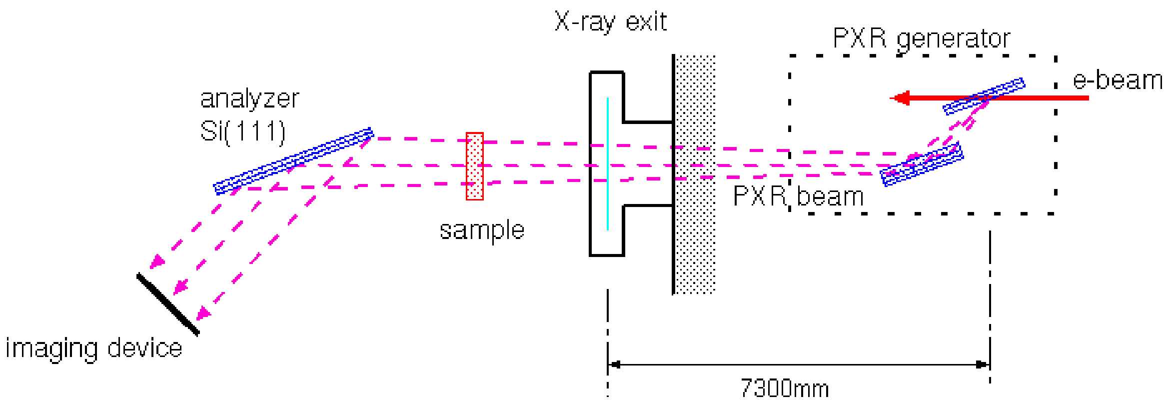
Free electron laser (FEL): 1μm – 6μm (near-IR)

Parametric X-ray radiation (PXR): 5keV – 20keV

Status of LEBRA-PXR

- Electron beam energy: 100MeV
- Macro pulse: ~100mA, 5 – 10μs, 2 – 5Hz
- Average current: 1 – 5μA
- Taget crystal: Si(111) plane
- PXR energy: 5 – 20keV
- Irradiation field: 10cm in diameter @ exit port
- Total flux: > 10^6 – 10^7 photon/s
- Application: Dispersive XAFS (DXAFS)
  Diffraction enhanced imaging (DEI)

Typical result of DEI (symm. target)

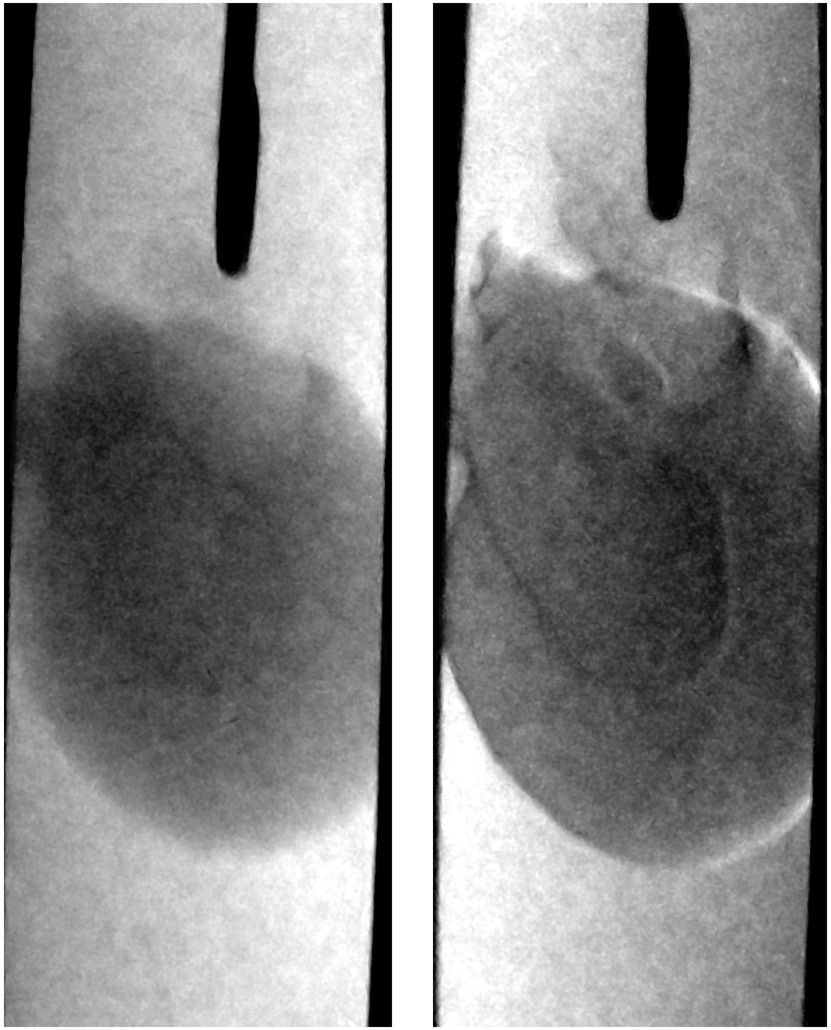


Analyzer-based Phase-contrast imaging
(DEI: Diffraction-enhanced imaging)

PXR: 17.5keV

mouse heart

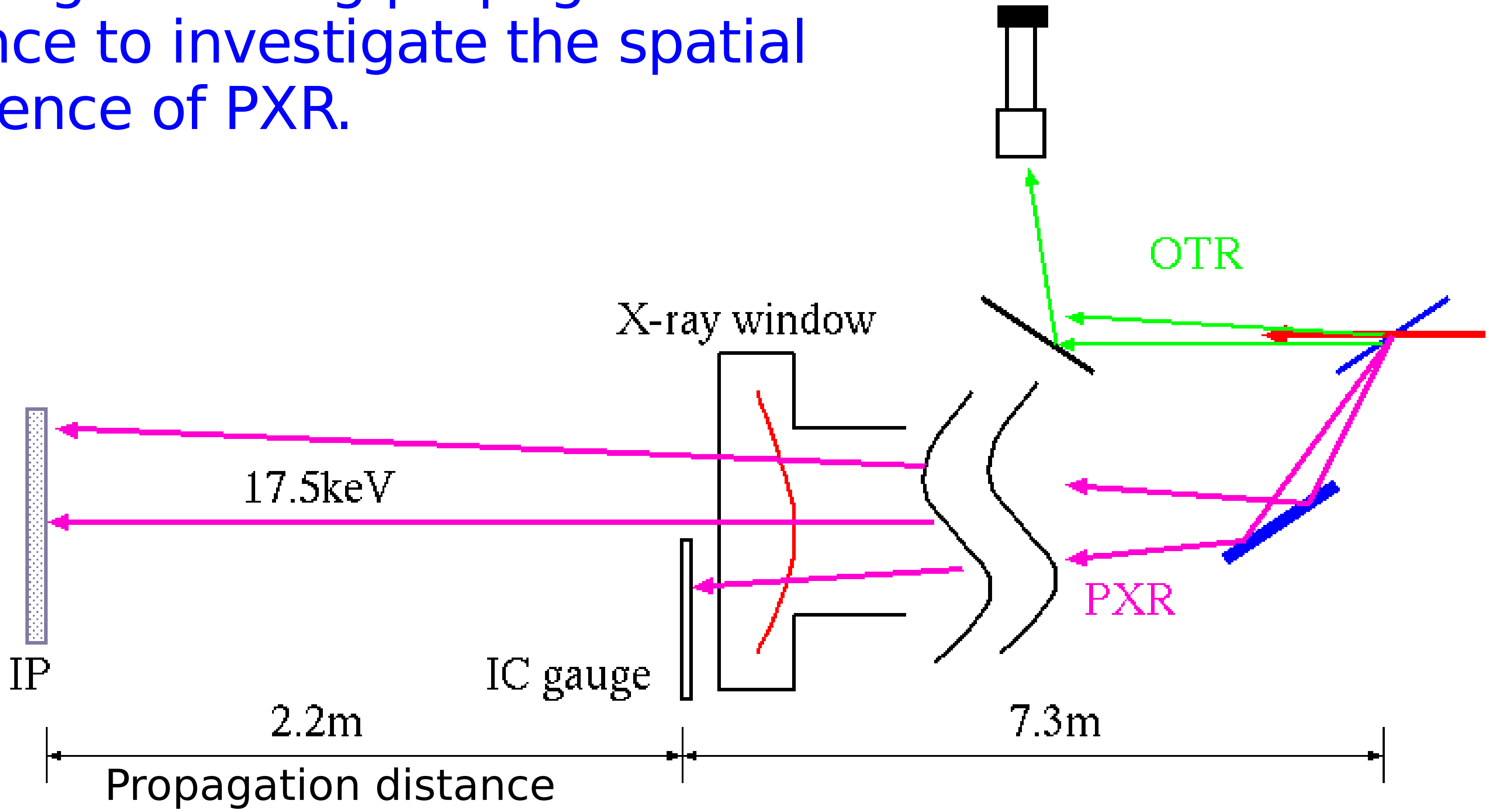
absorption DEI



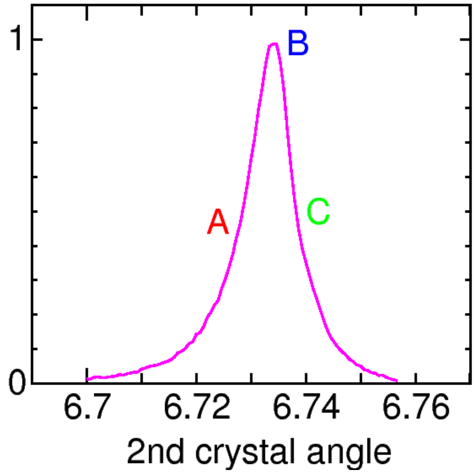
I.I.CCD 5min.

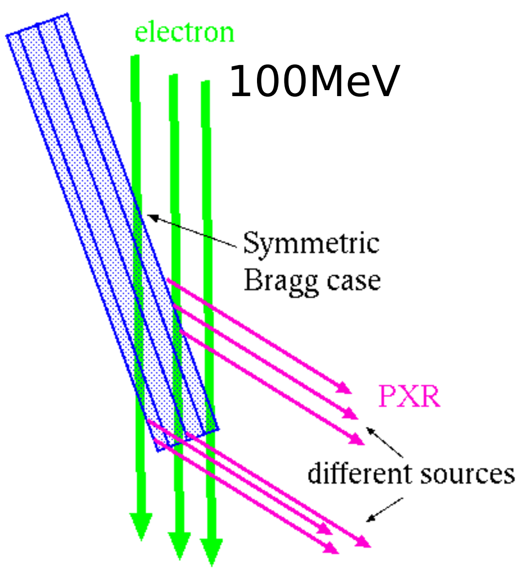
Measurement for spatial coherence

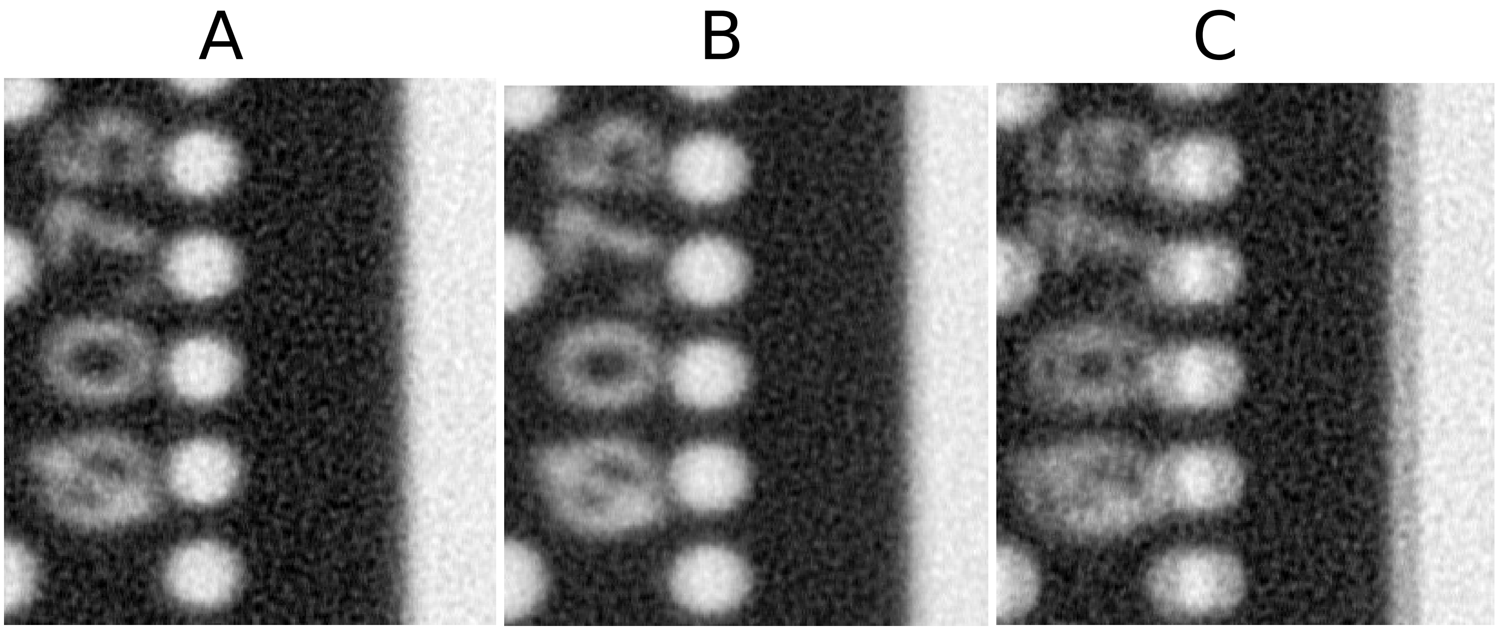
Imaging with long propagation distance to investigate the spatial coherence of PXR.



Edge effect of the target crystal







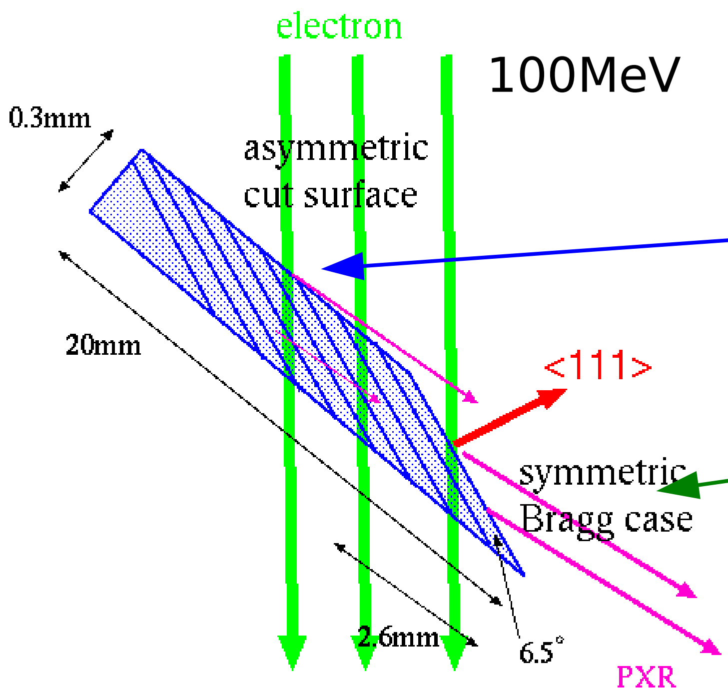
same e-beam size (2.2 x 1.2mm)

Propagation distance: 220cm

Front surface and side surface of the target act as different X-ray sources.

Two X-ray beams have slightly different directions and induce the double image.

Asymmetric cut target (arrgt.1)



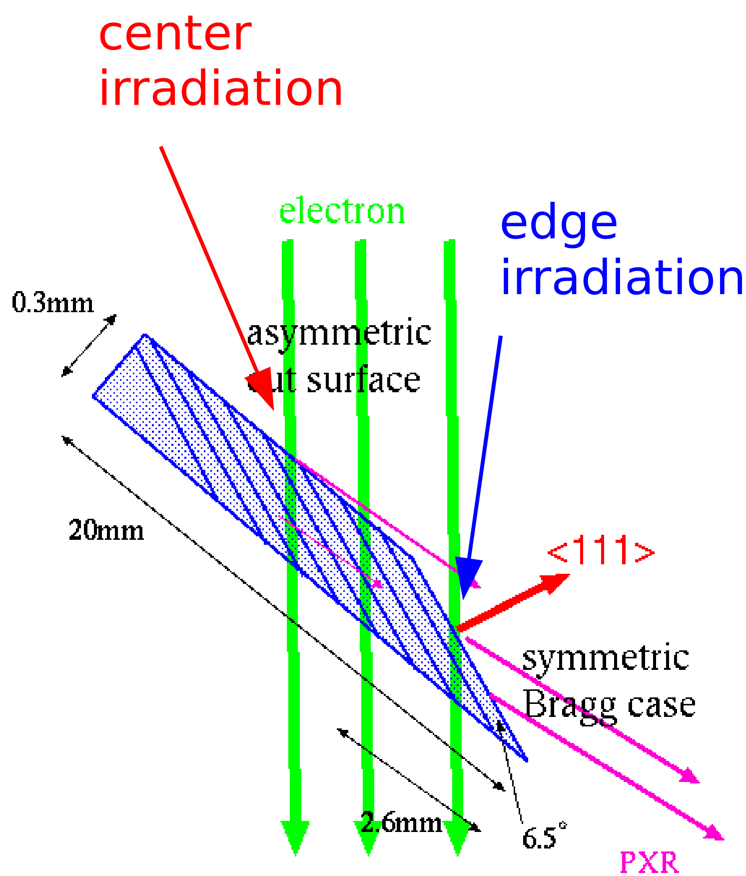
Front and rear surfaces:
asymmetric cut

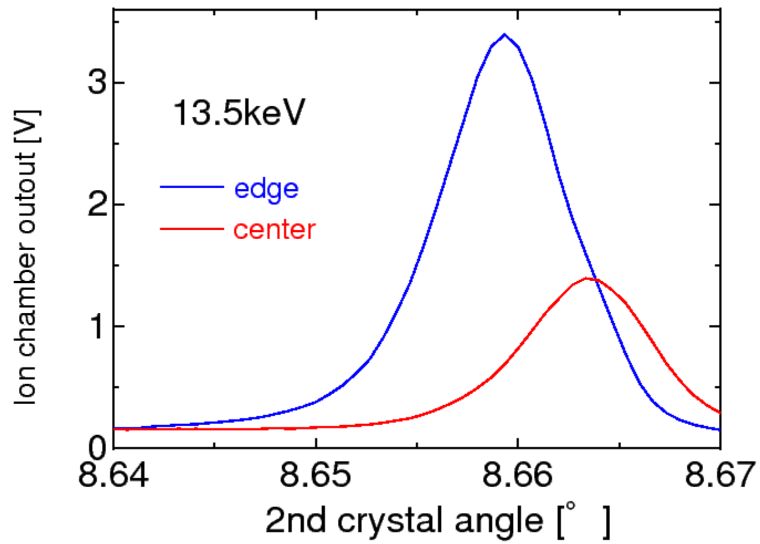
Knife-edge surface:
symmetric Bragg case

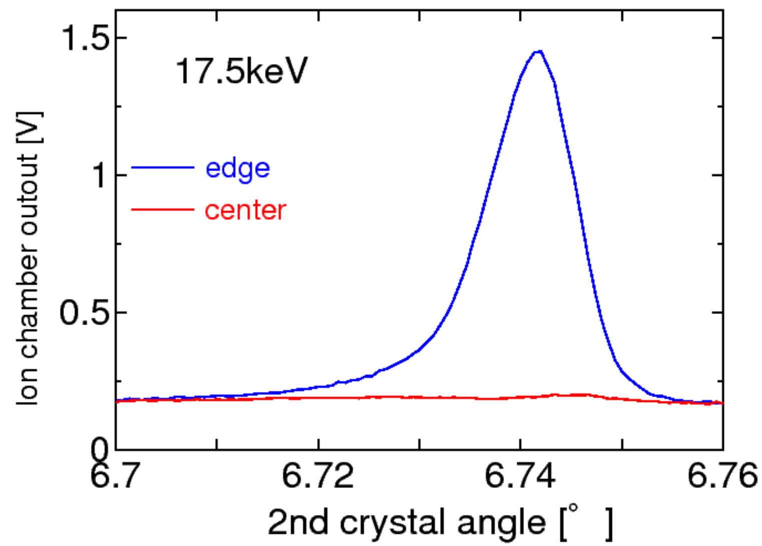
In this arrangement,

- electron path < X-ray path on the asymmetric surface
  -> Intensity of PXR from front surface is much reduced
- Front and rear surfaces are invisible from 2θ direction at 17.5keV. (Bragg angle = 6.5 deg.)

Rocking curve of 2nd crystal (arrgt.1)

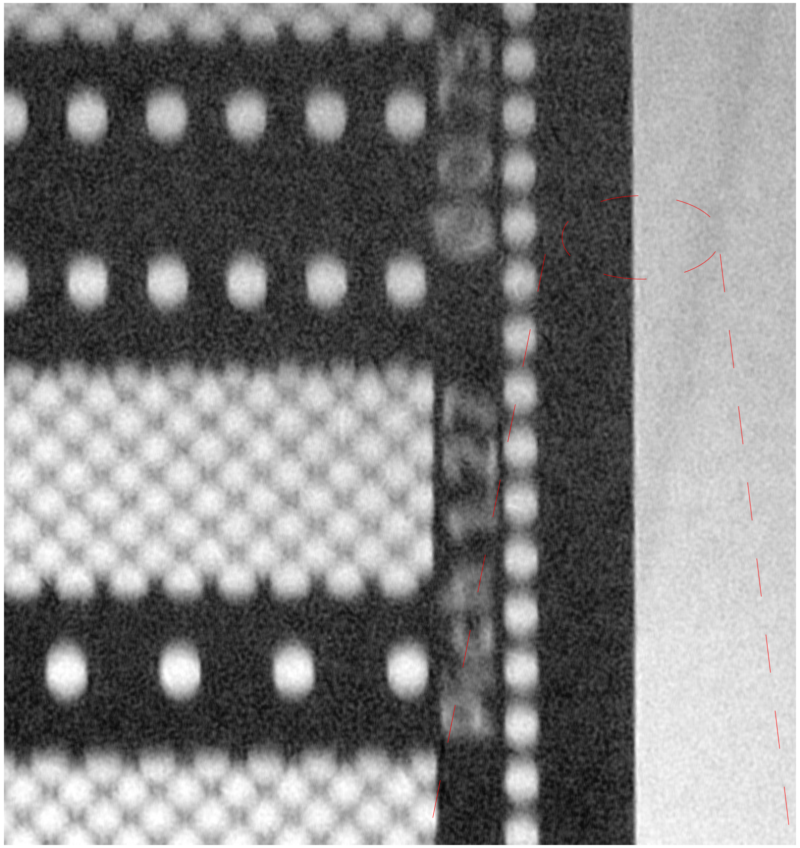




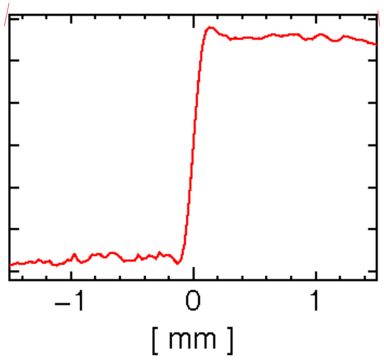


- Intensity:
  symmetric surface > asymmetric surface
- 2nd crystal angles are slightly different.

Results in arrgt.1 (Imaging)



IP: 30min

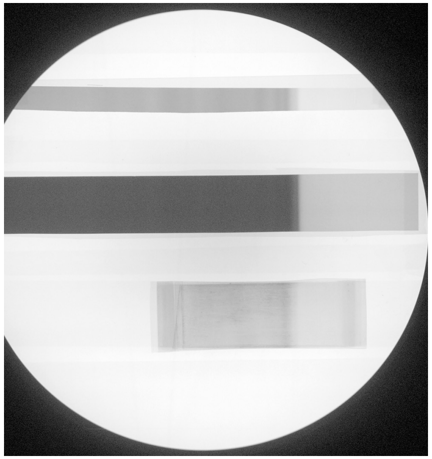


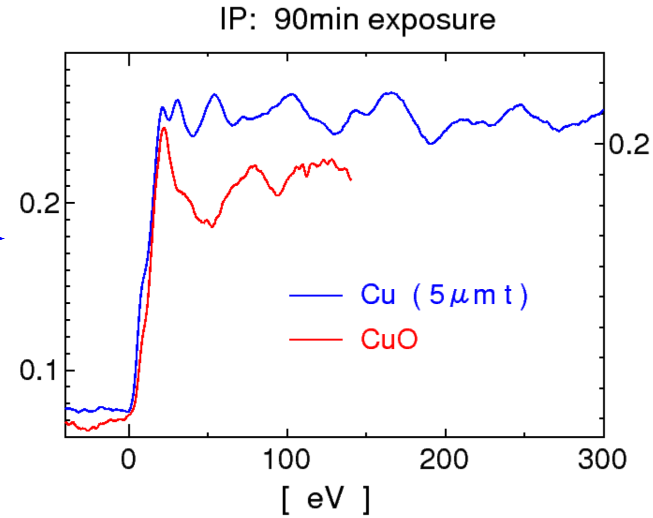
Horizontal image doublet is substantially suppressed and the edge is well defined at 17.5keV.
(edge irradiation)

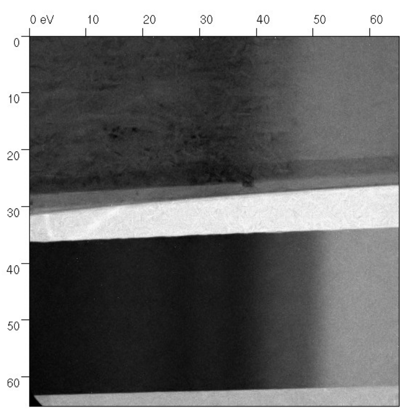
e-beam size (H1.5 x V1.5mm)

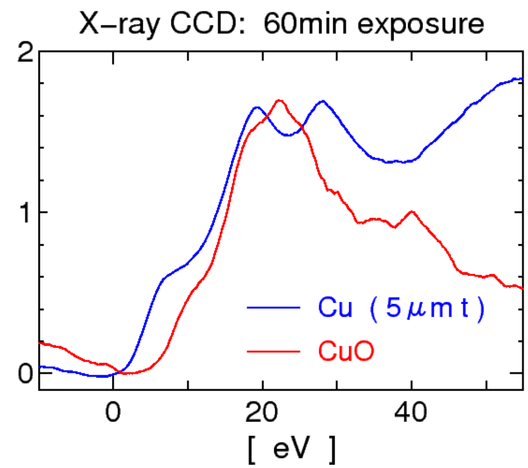
Propagation distance: 220cm

Energy resolution of DXAFS measurement





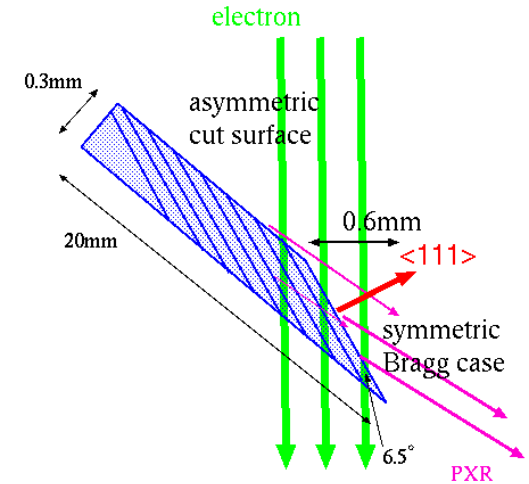




Cu K-edge
8.981keV

PXR:
Bragg angle~12.8°

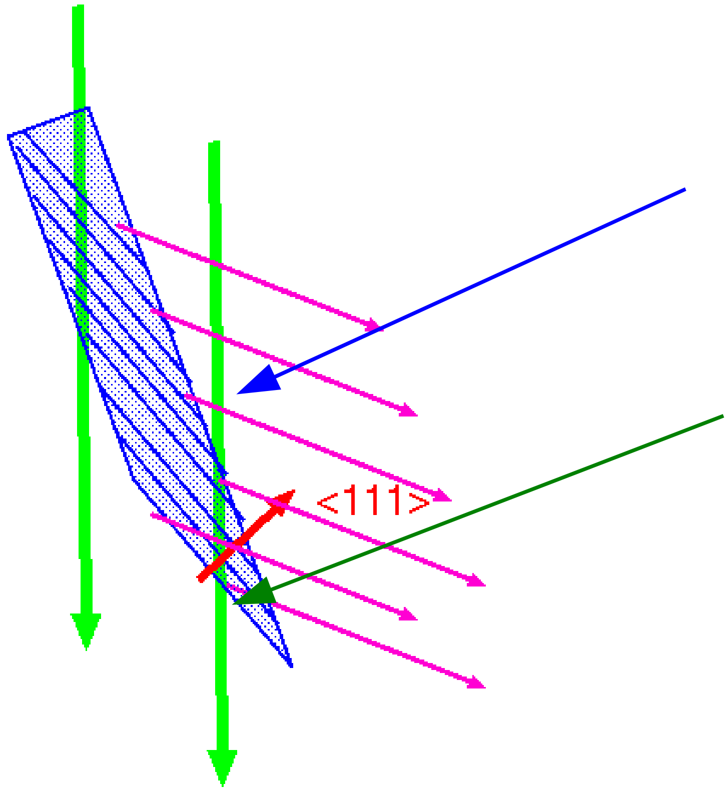
horizontal size of the symmetric surface: ~0.6mm



DXAFS resolution depends on the horizontal source size.

Resolution of spectra ~ 3eV, corresponding to 0.6mm

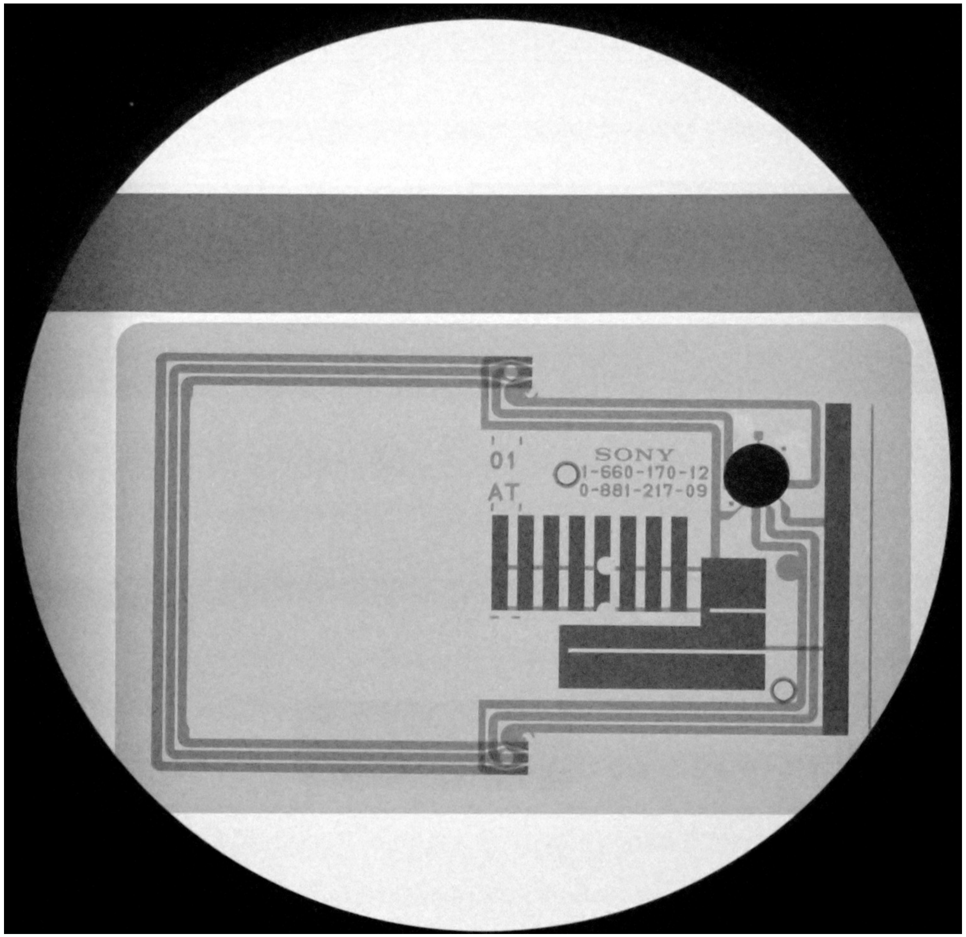
Asymmetric cut target (arrgt.2)



In this arrangement,

- X-ray path < electron path on the asymmetric surface
  -> Absorption of PXR is reduced
- Only front asymmetric surface is visible from
  2θ direction

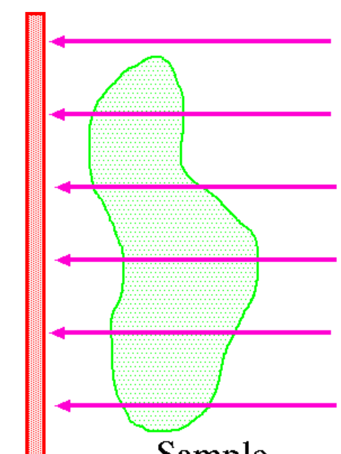
Absorption imaging in arrgt.2



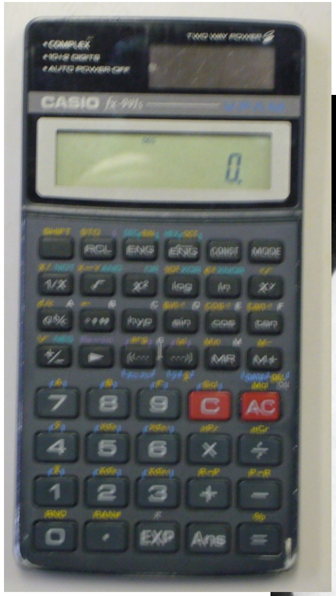
In this arrangement,

- PXR intensity rather improves, even if the e–beam is wider than the surface of the target crystal.
- Imaging with shorter exposure is possible. (Flux > 10^7 /s)

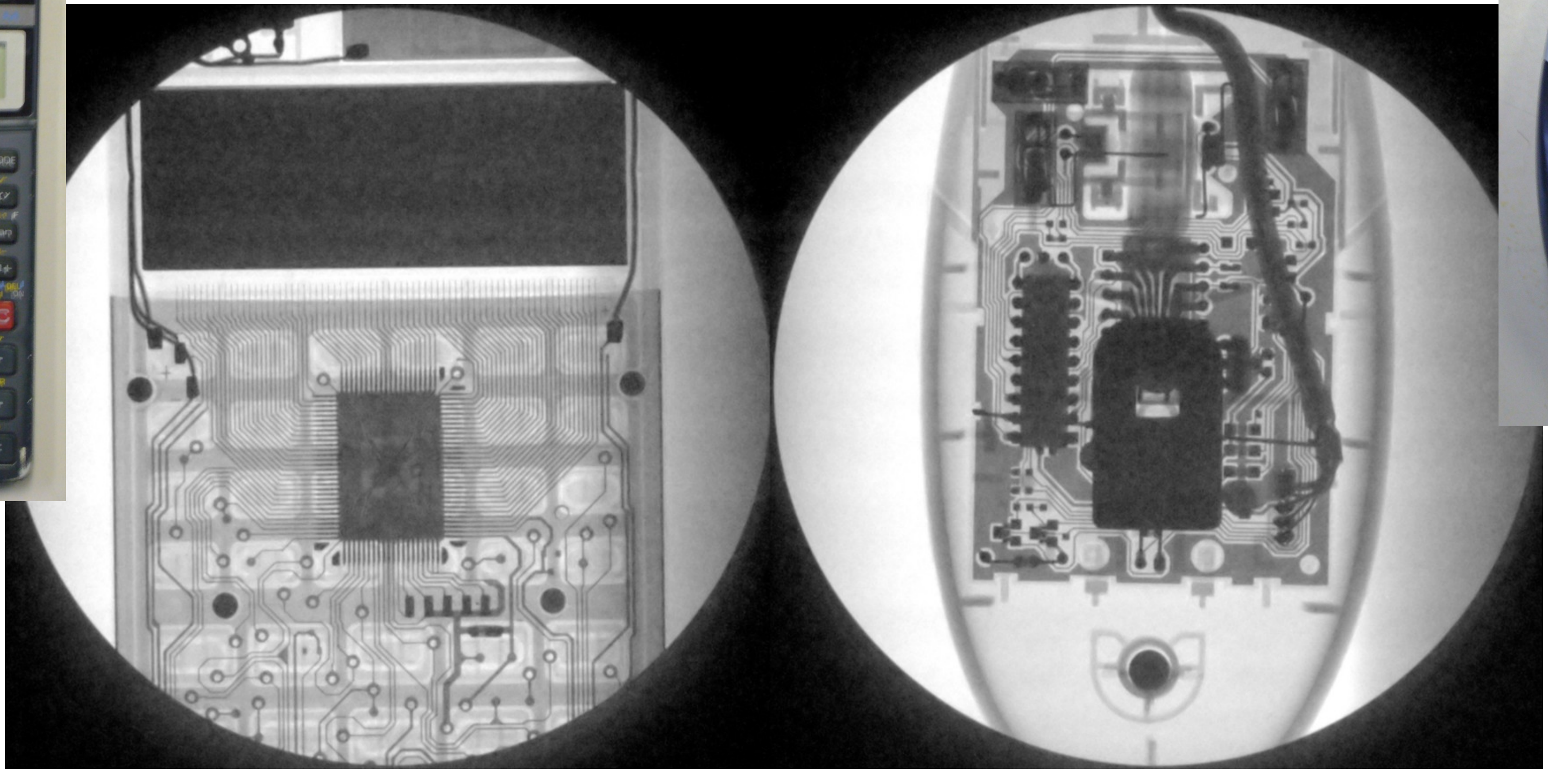
IC card@14keV
e-beam:
100mA, 5μs, 5Hz (2.5μA)
exposure: 30s (macro-pulse duty: 0.75ms)

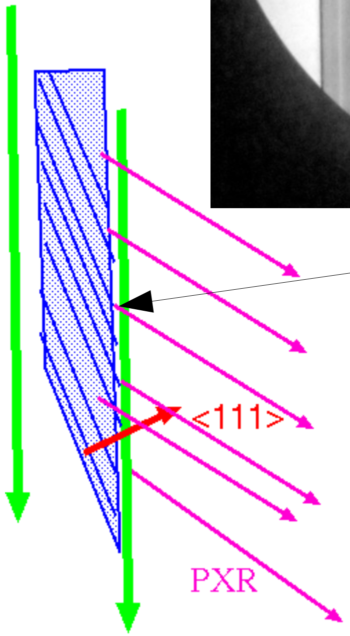


Absorption imaging in arrgt.2



PXR: 16keV





Only a part of the e-beam hits the surface.

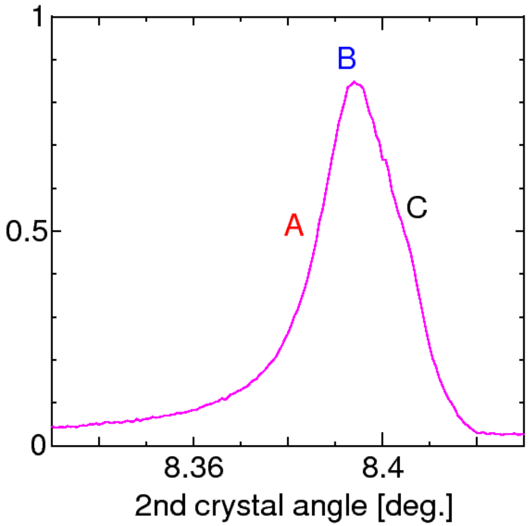
e-beam:

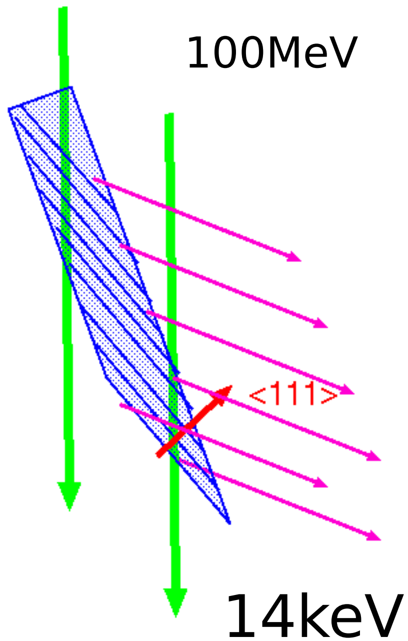
105mA, 10 μ s, 2Hz (2.1 μ A)

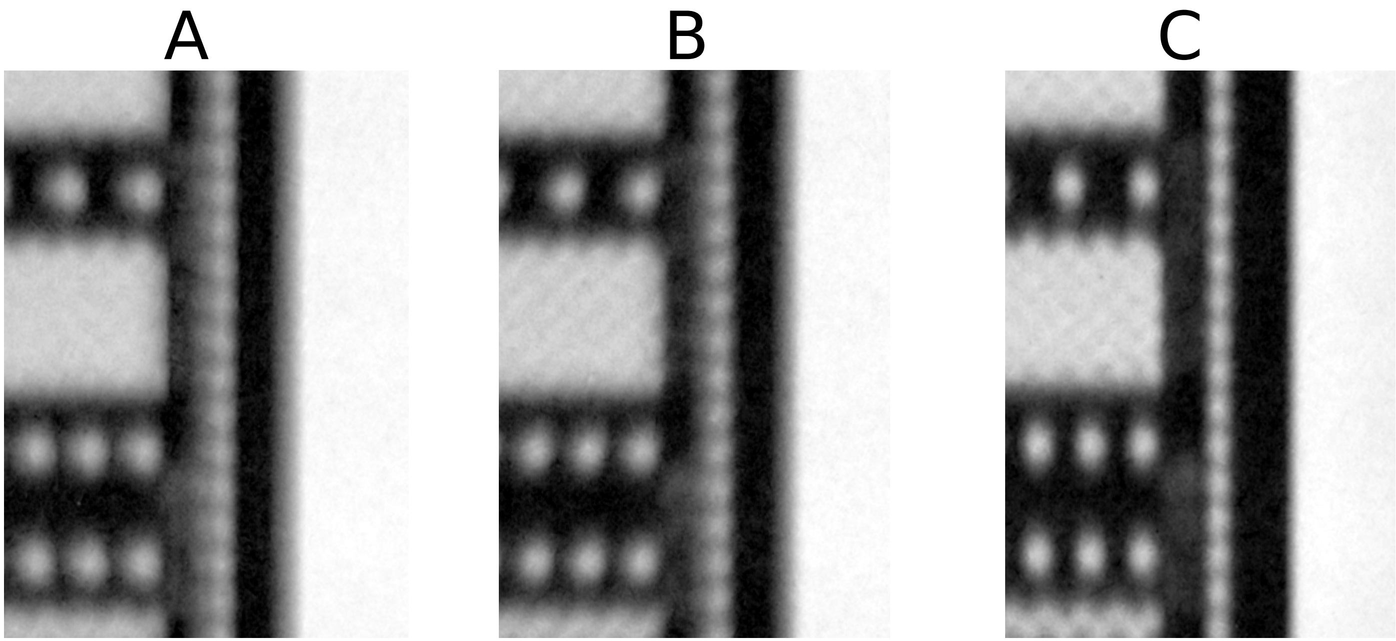
exposure: 60s

(macro-pulse duty: 1.2ms)

Edge effect of the target crystal







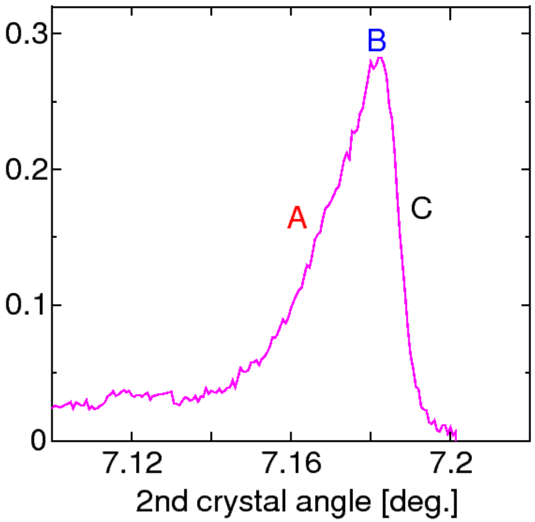
same e-beam size (H1.0 x V2.5mm)

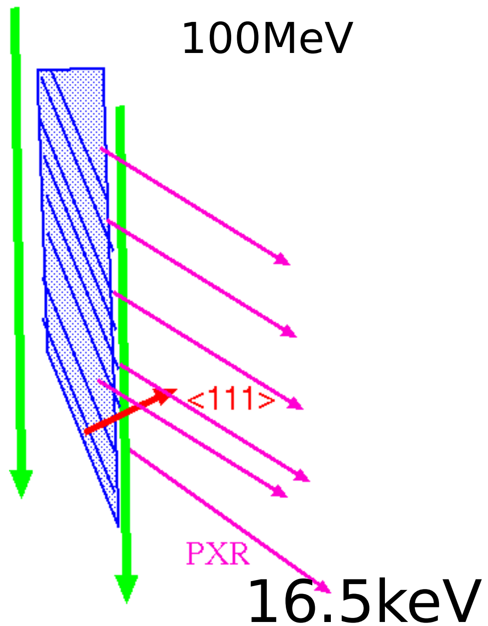
Propagation distance: 220cm

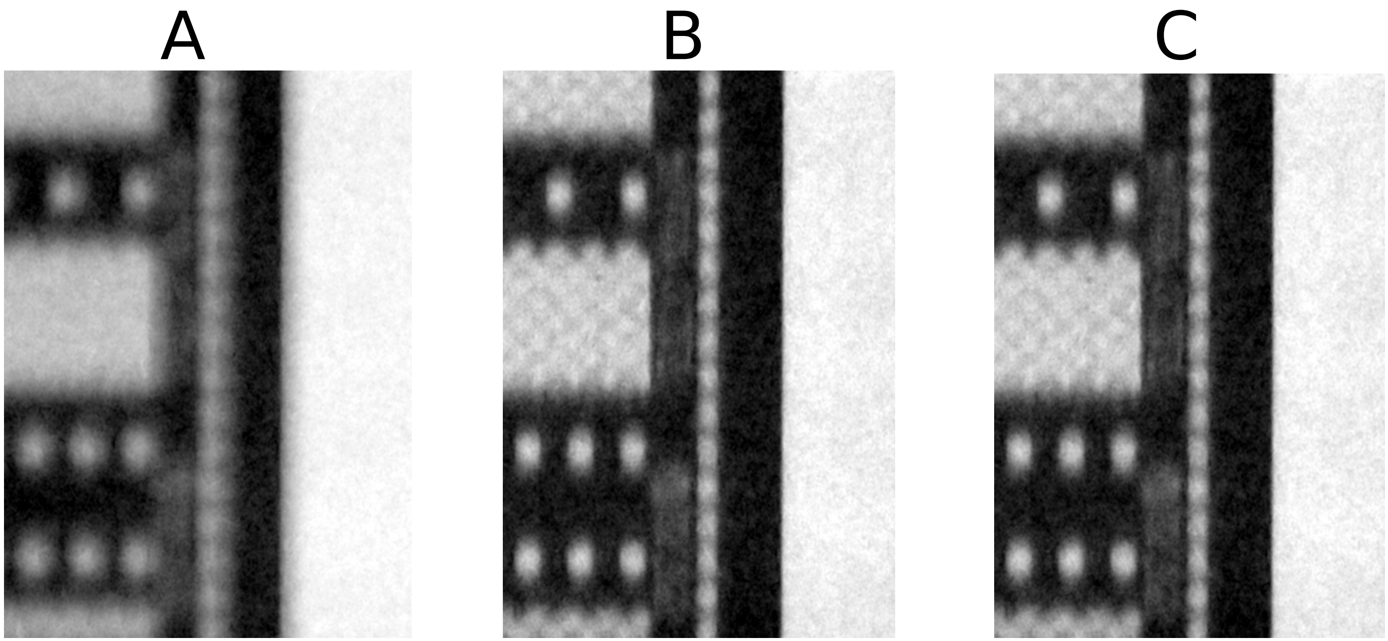
The doublet of the image due to the edge effect is enhanced.

Two coherent X-ray beams maybe exist.

Edge effect of the target crystal





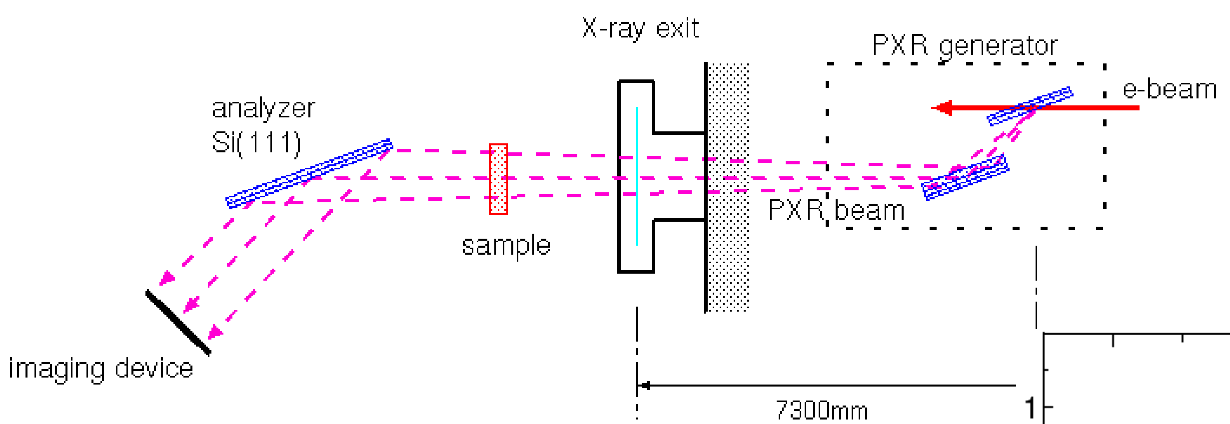


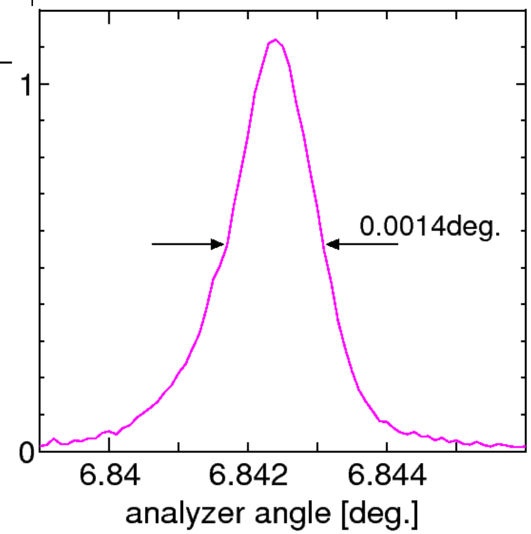
same e-beam size (H1.0 x V2.5mm)

Propagation distance: 220cm

In the case of the near grazing incidence,
the edge effect is suppressed and
the horizontal spatial coherence improves.

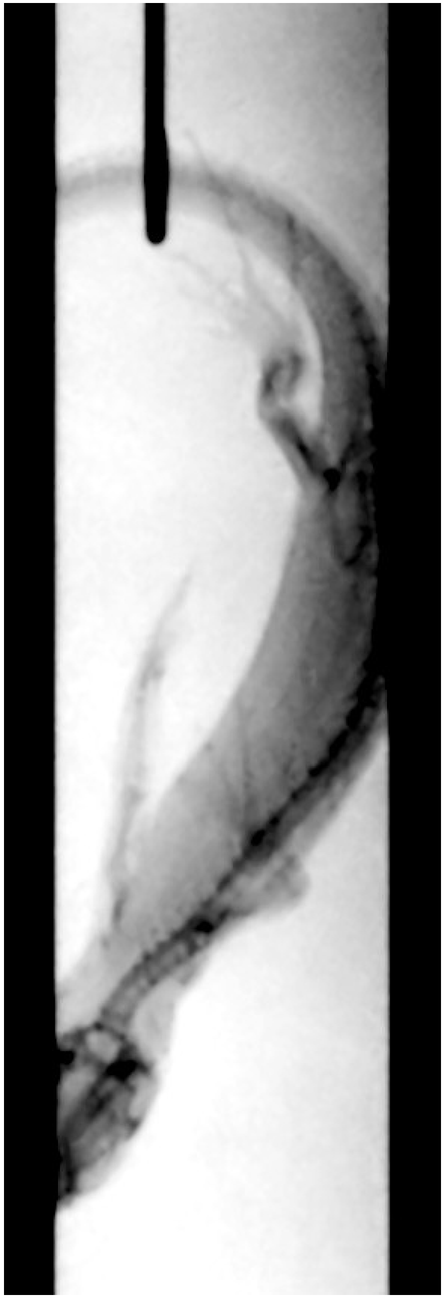
Diffraction enhanced imaging (DEI) in arrgt.2





Analyzer-based Phase-contrast imaging
(DEI: Diffraction-enhanced imaging)

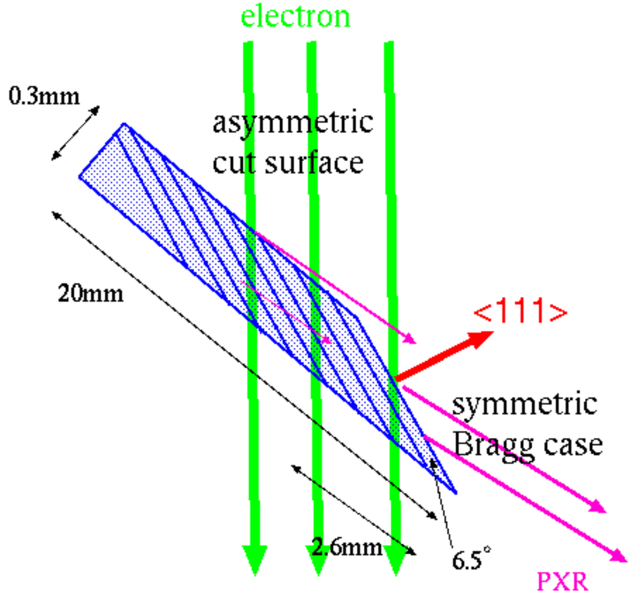
sample: lizard
PXR: 16.5keV
Average current: 2 μ A
exposure: 5min (IP)



In this arrangement,

- DEI is also possible
- relatively short exposure time
- phase accuracy may be worse (possibly)

Summary



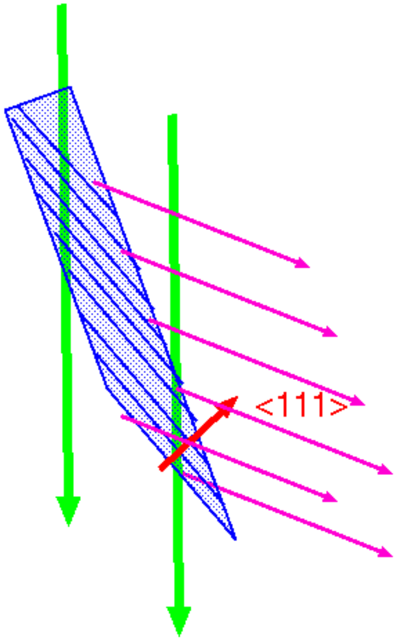
- Mainly the knife-edge surface in a symmetric Bragg case contributes PXR emission.
- The edge effect disappears.
- The spatial coherence and the spectral resolution tend to improve.
- The intensity becomes rather weak.
  The contribution from the deep volume in the target seems to be little.

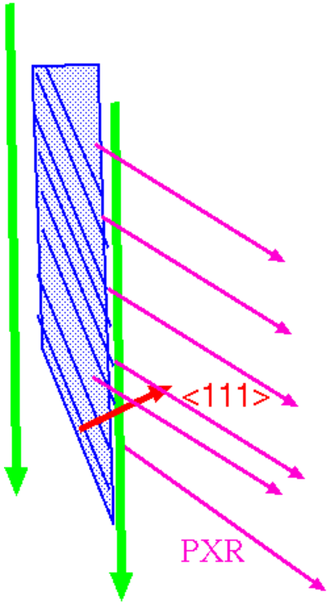
Summary

- The intensity rather improves and imaging with shorter exposure is possible.

- The edge effect seems to be enhanced.

- DEI is possible.
  It indicates that the use of asymmetric cut surface dose not destroy the coherence of PXR.





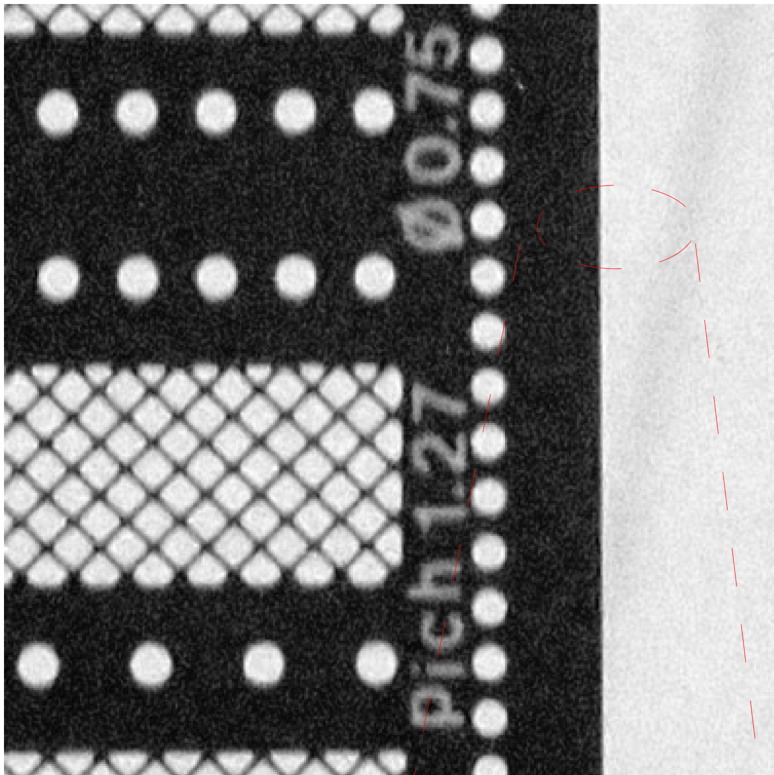
Acknowledgments

- The "Academic Frontier" Project for Private University: matching fund subsidy from MEXT, 2000-2004 & 2005-2007

Thank you for your kind attention !!

Appendix

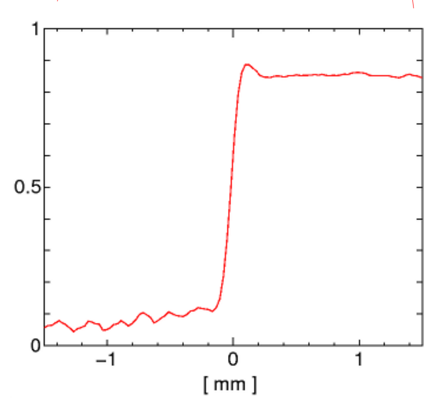
Results in arrgt.1 (Imaging)



Horizontal image doublet was strongly suppressed and the edge was well defined at 17.5keV.
(edge irradiation)

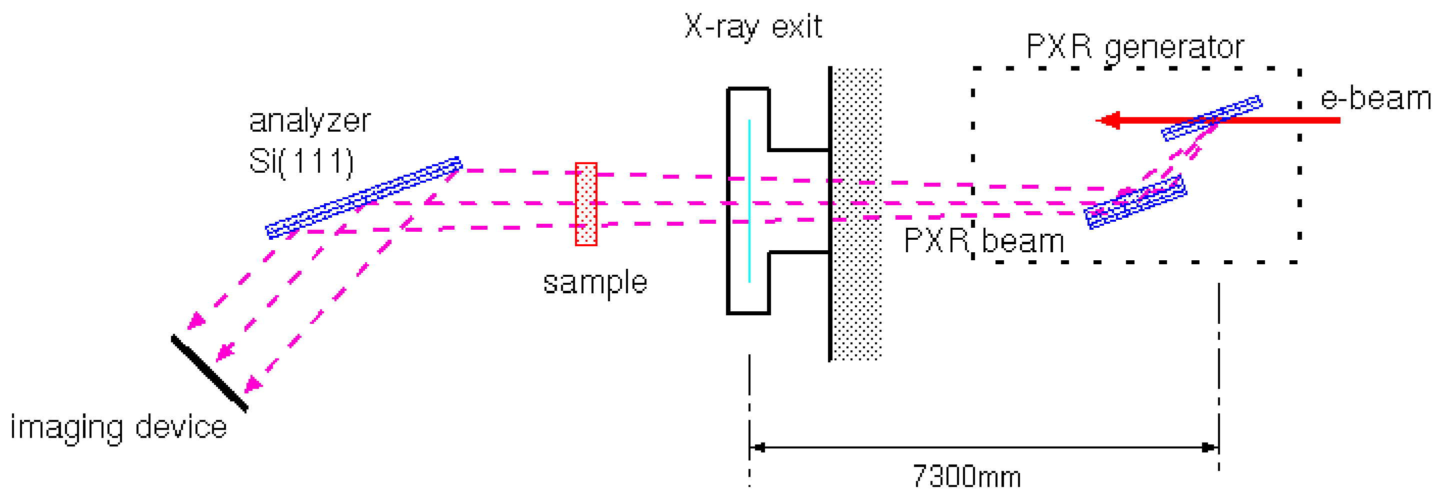
Propagation:
220cm

IP: 30min

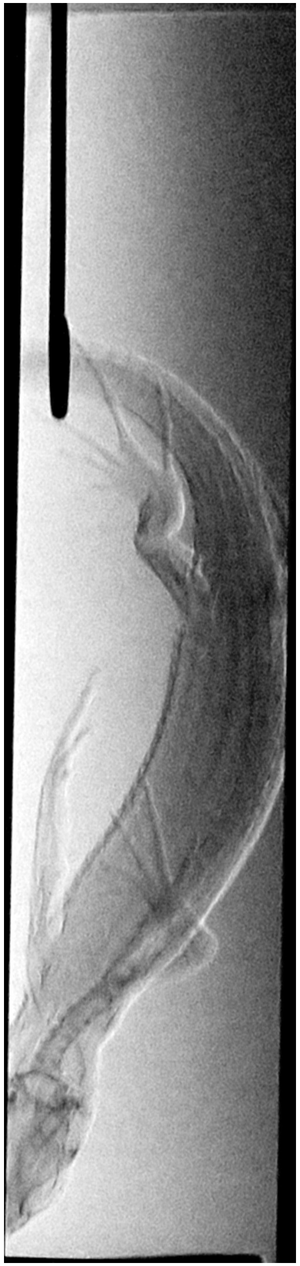


e-beam size (H1.5 x V0.7mm)

Diffraction enhanced imaging (DEI) in arrgt.1



Analyzer-based Phase-contrast imaging
(DEI: Diffraction-enhanced imaging)



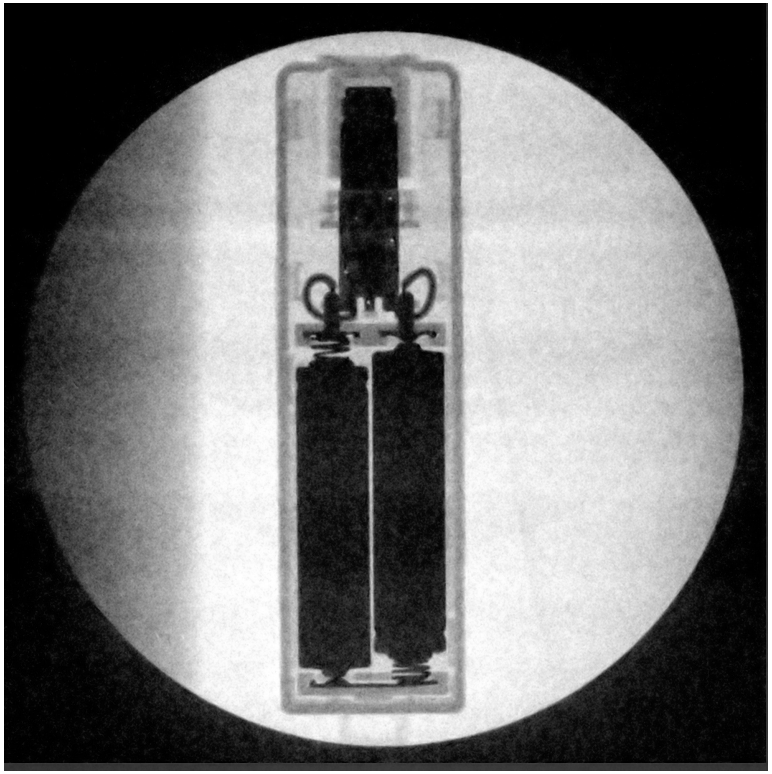
sample: lizard
PXR: 17.5keV
Average current: 2 μ A
exposure: 60min. (IP)

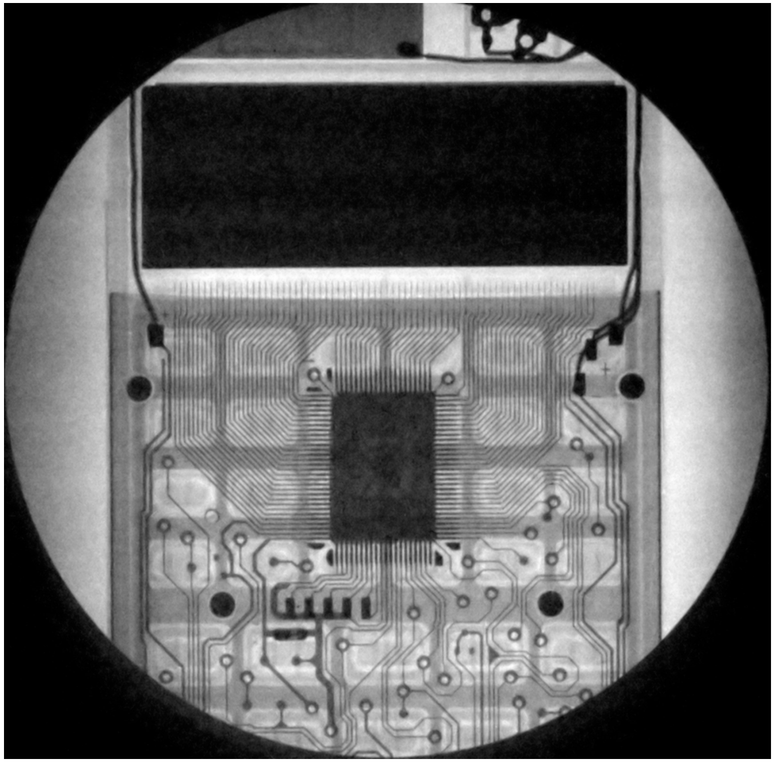
In this arrangement,

Quality of DEI is rather good.

Longer exposure time is necessary.

Absorption imaging

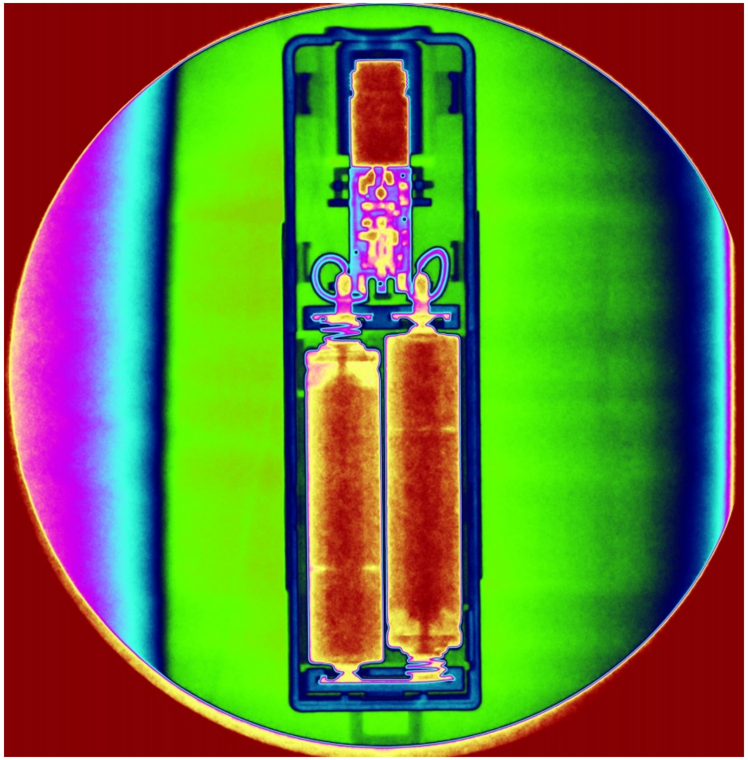




laser pointer@16.0keV
average current: 2.2 μ A
exposure: 10s（IP）

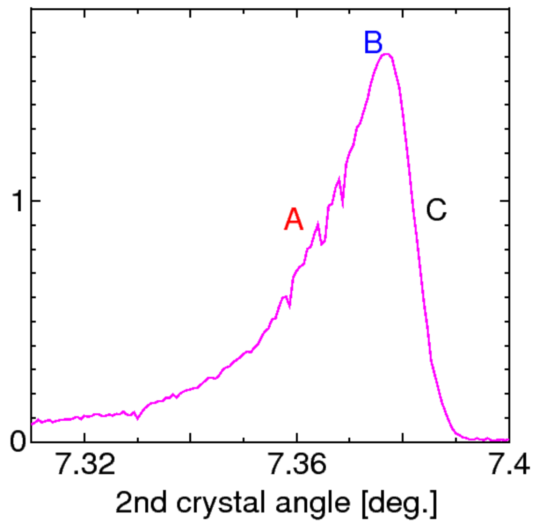
calculator@16.0keV
average current: 1.2 μ A
exposure: 30s（IP）

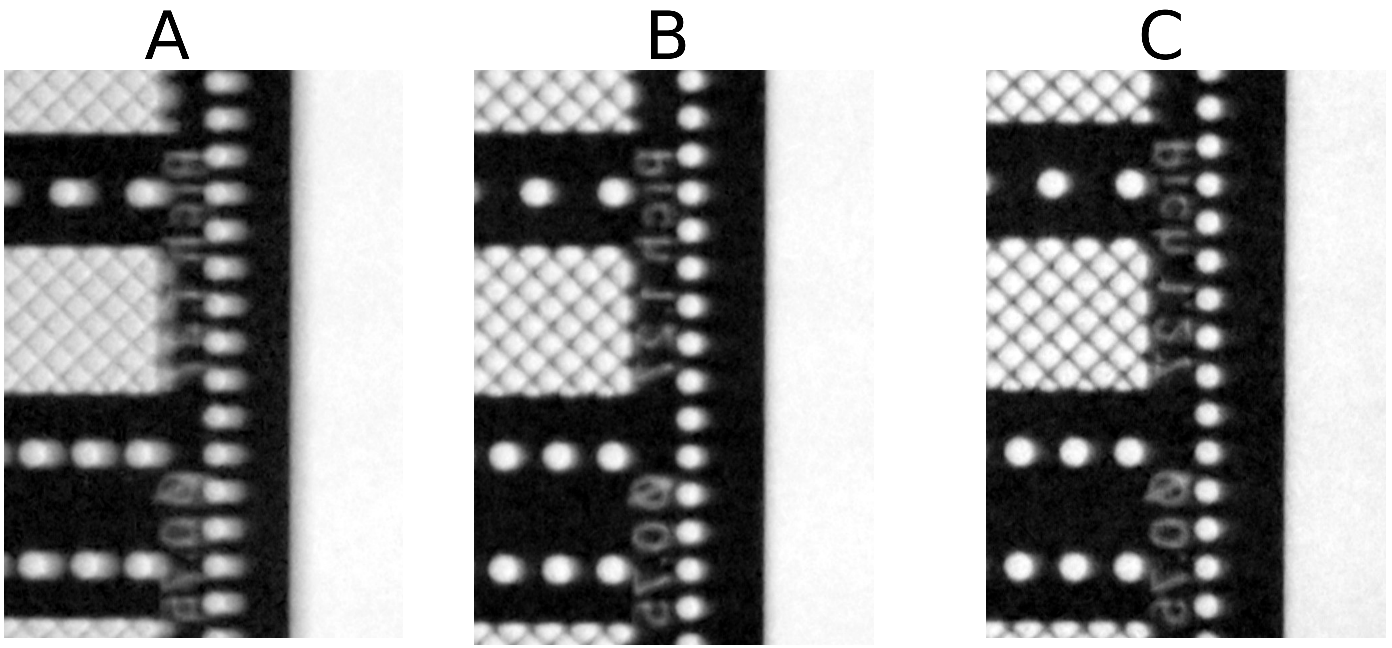
Absorption imaging

laser pointer@16.0keV
average current: 2.5 μ A
exposure: 180s （IP）

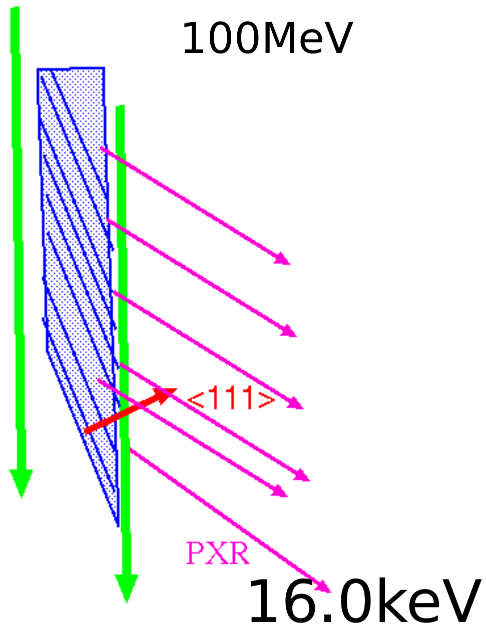
Edge effect of the target crystal





same e-beam size (H1.0 x V1.0mm)

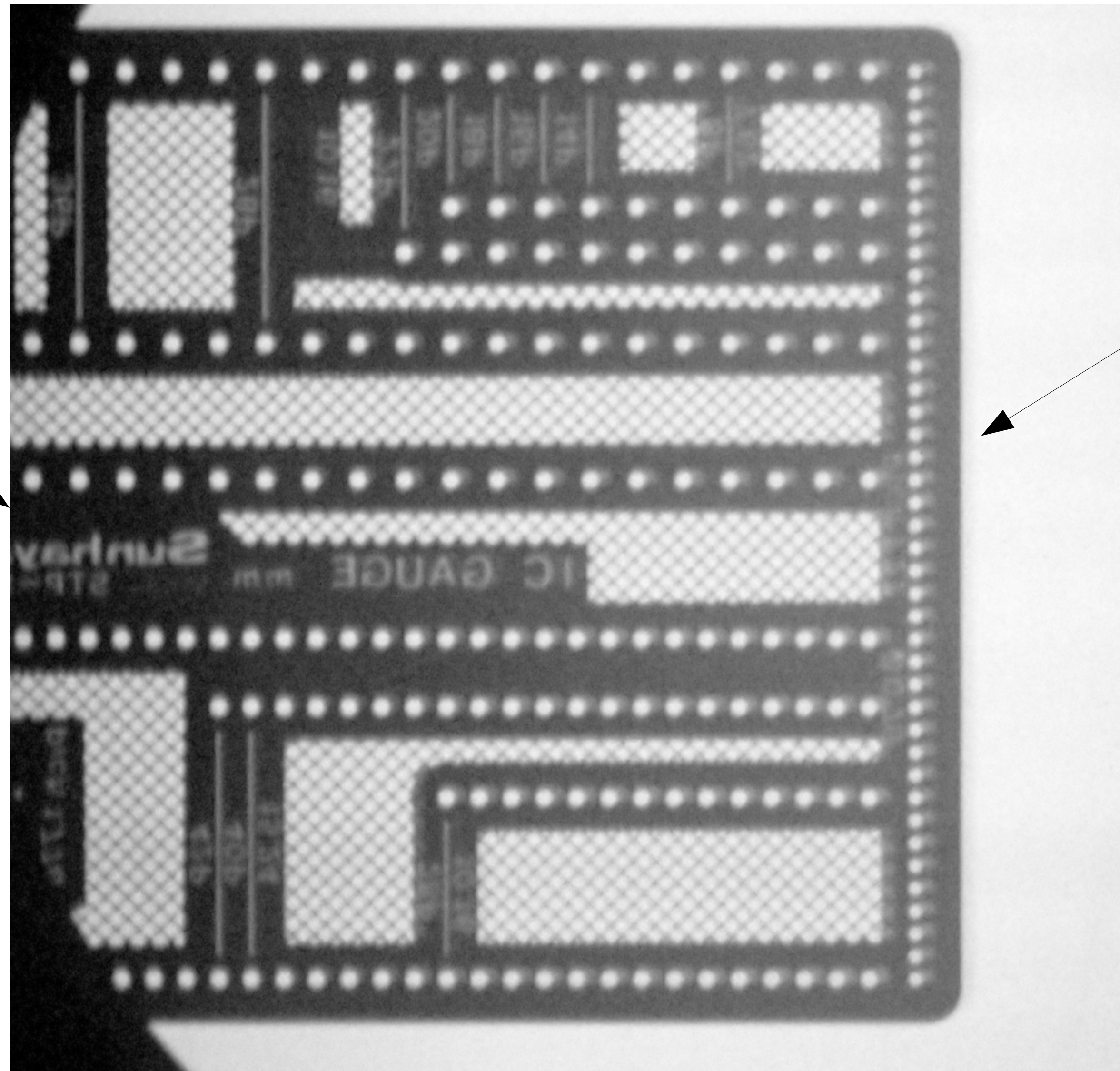
Propagation distance: 220cm



In the case of the near grazing incidence, the edge effect is suppressed and the horizontal spatial coherence improves.

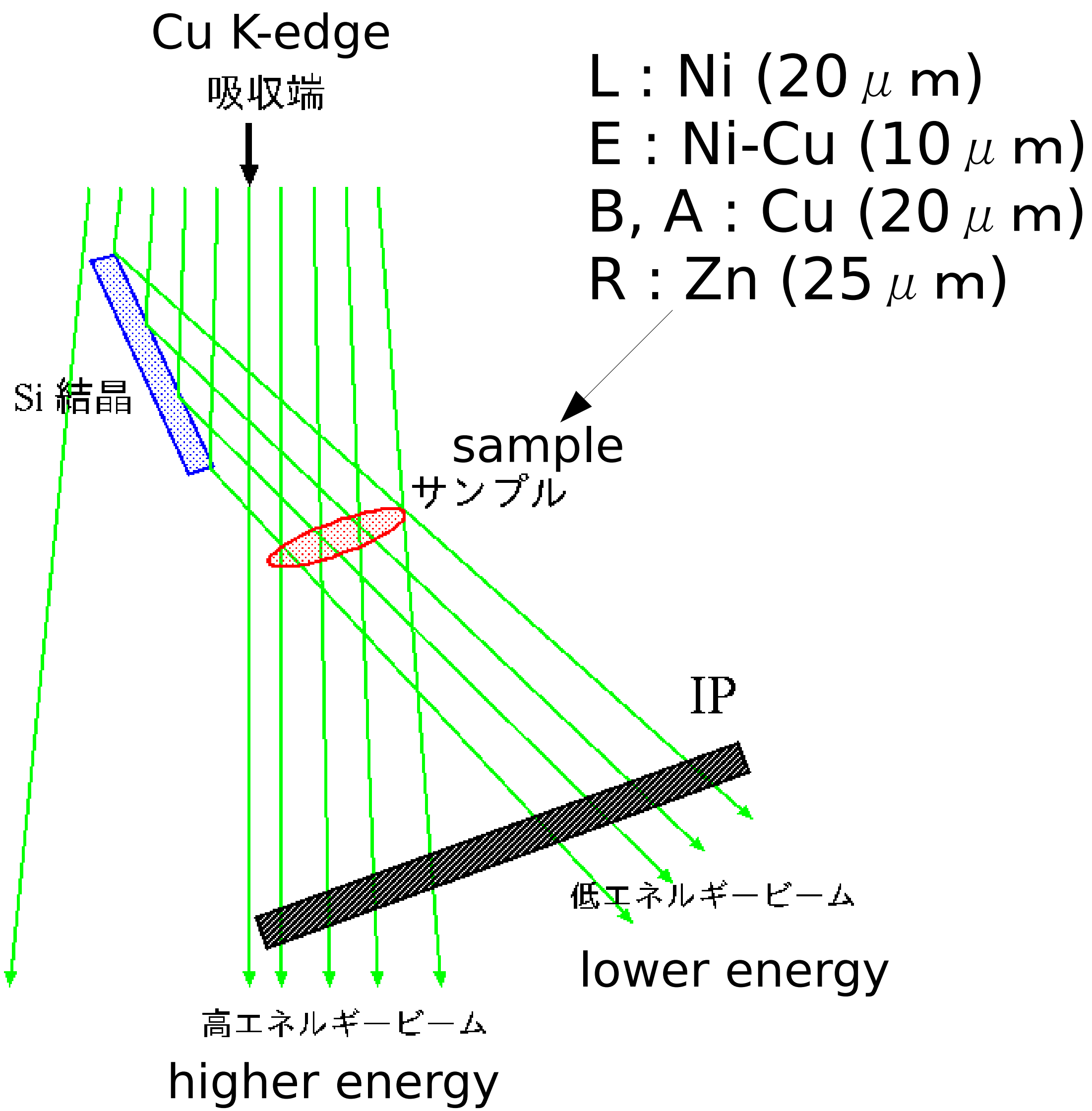
LEBRA

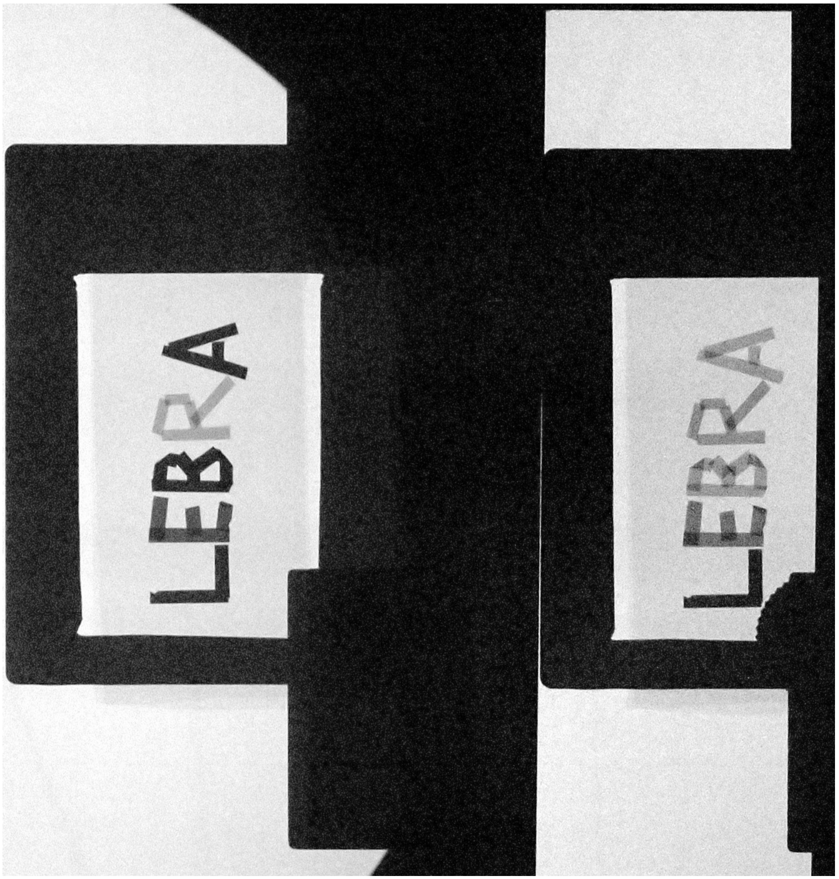
singlet



doublet

Simultaneous imaging by 2color beams

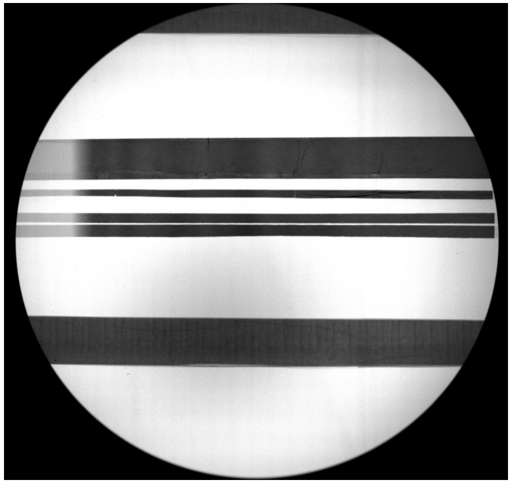




higher energy lower energy

Cu can be detected!

EXAFS analysis using PXR-DXAFS



higher