Spatial properties of hard x-ray sources driven by tightly focused fs laser

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Objective

Spectrum	Line emission: diffraction, crystallography Bremsstrahlung : x-ray absorption spectroscopy
Ultrashort pulse	Time resolved diffraction, time-gated imaging, ultrafast spectroscopy……
Small source size	Better spatial coherence and better image resolution

Most researches focus on:

- Spectral and temporal properties
- Mechanism for the x-ray generation
- Conversion efficiency
- Source size
- Applications

Information of spatial properties needed!!!

Lasers, target, and experimental environments

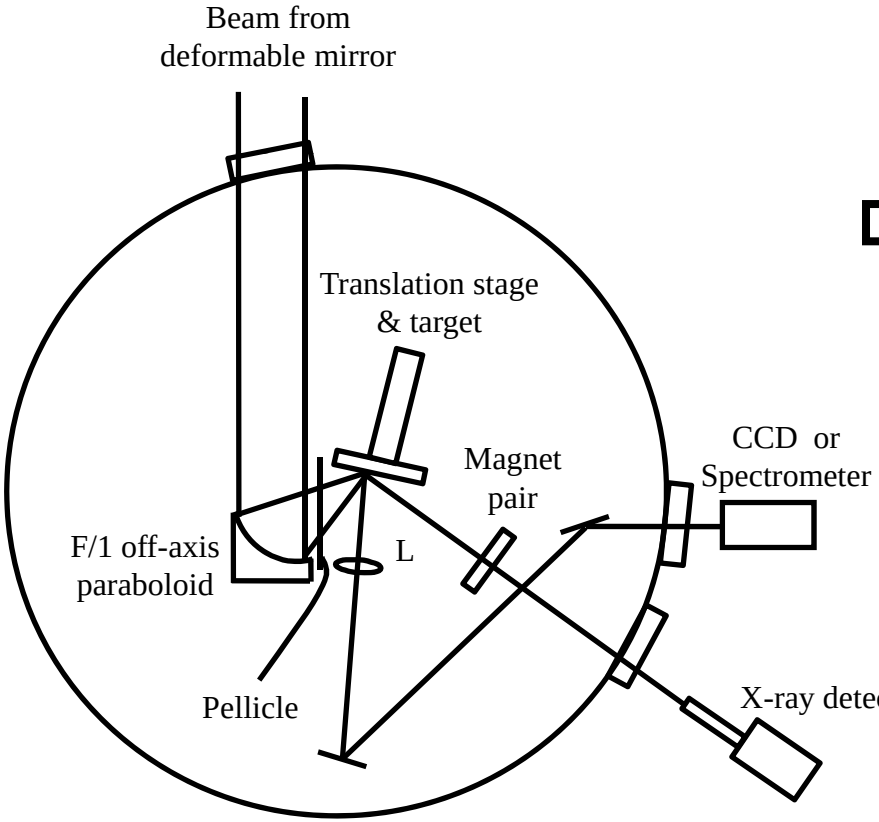
- X-ray energy distribution measurement
  - Single-stage multi-pass-amplifier
  - 22fs, 0.8mJ on target at 400Hz
  - in vacuum
- X-ray source size measurement
  - Regenerative amplifier
  - 33fs, 3mJ on target at 500Hz
  - in flowing helium environment

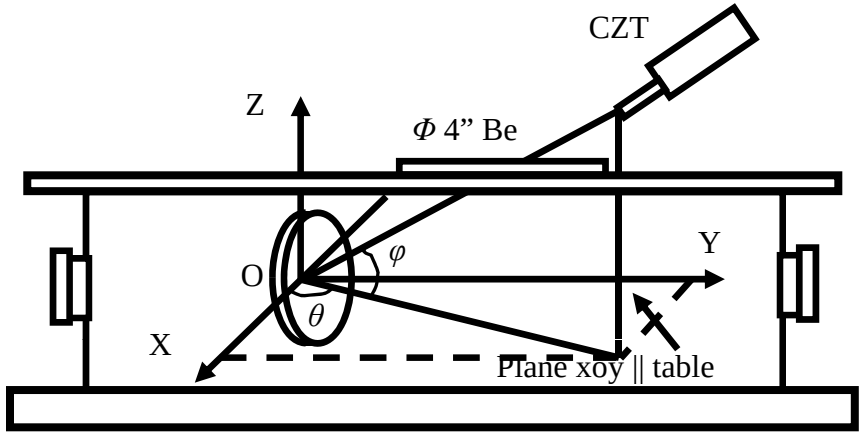
Bixue Hou, et. al., Appl. Phys. Lett. ***92****, 161501 (2008)*

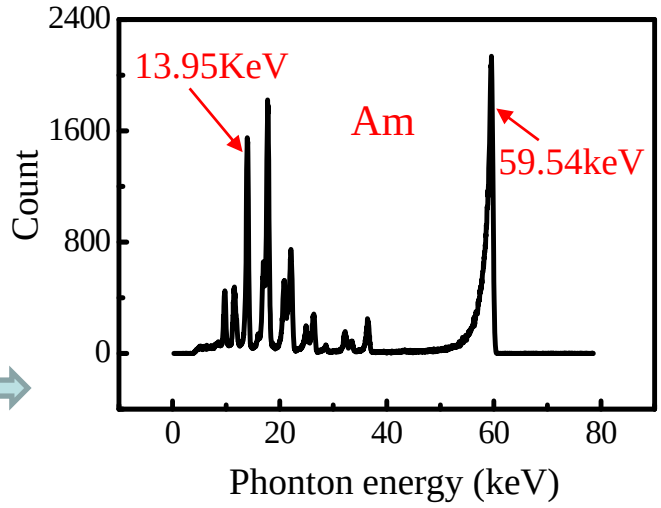
- Focusing: 1.3μm (FWHM) with f/1.2 paraboloidal mirror +Deformable mirror

  Focal intensity: $>2\times10^{18}$W/cm^2
- Target: 10mm-thick, 100mm-diameter polished **Mo** disc

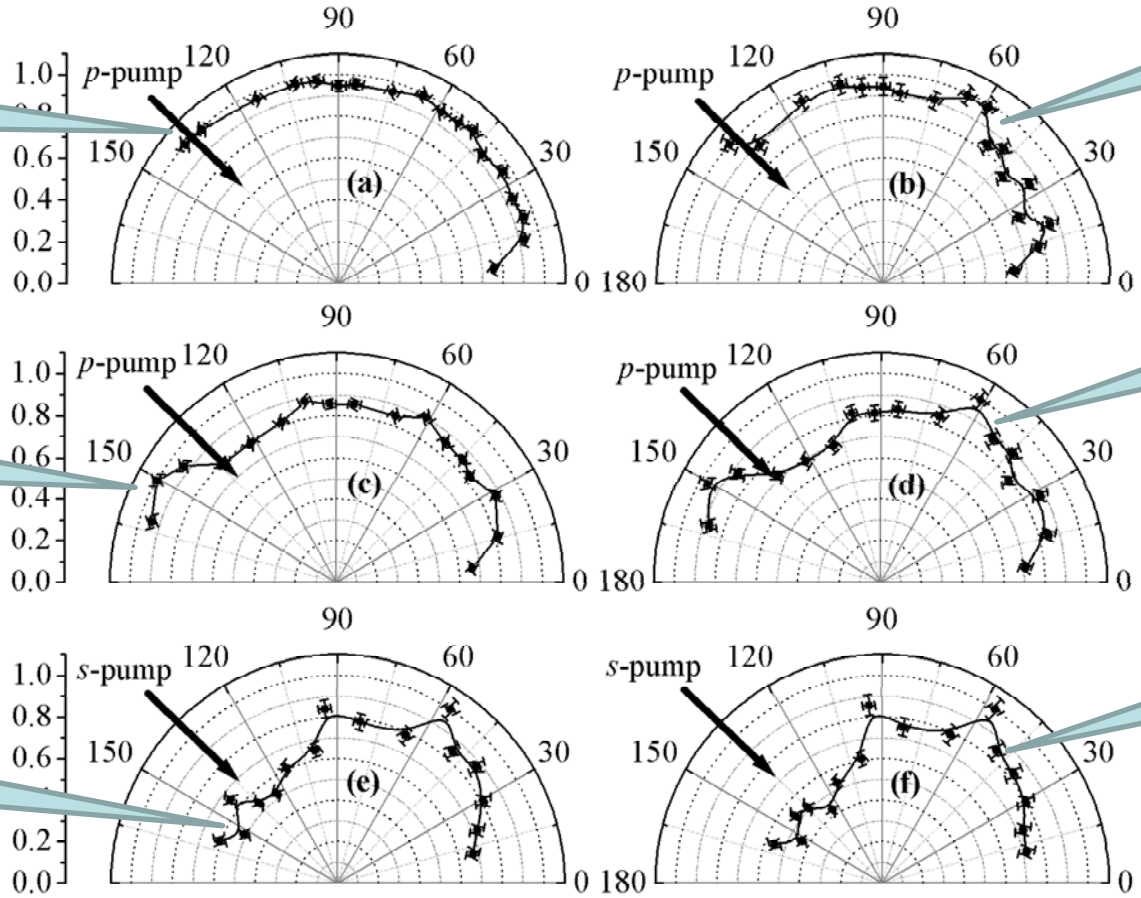
Experimental setup







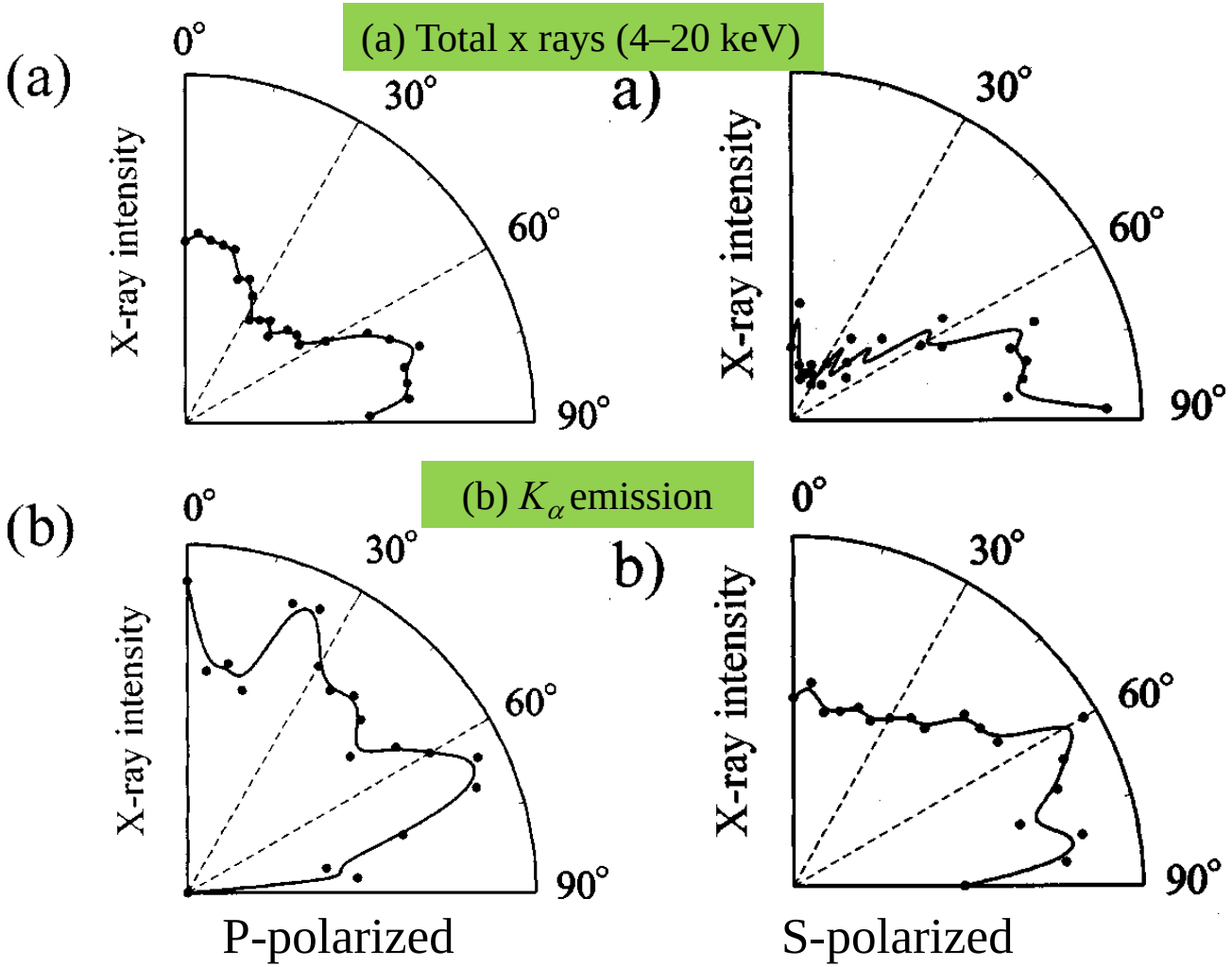
Angular distribution of x-ray emission



Comparing with other results

Laser parameters:
10Hz, 41fs, 70mJ
Intensity: 1.3×10^{17} W/cm^2
Calculated focal spot: ~20μm
Target: Cu

Hironaka, et. al, Appl. Phys. Lett. ***77****, 4110 (2000)*

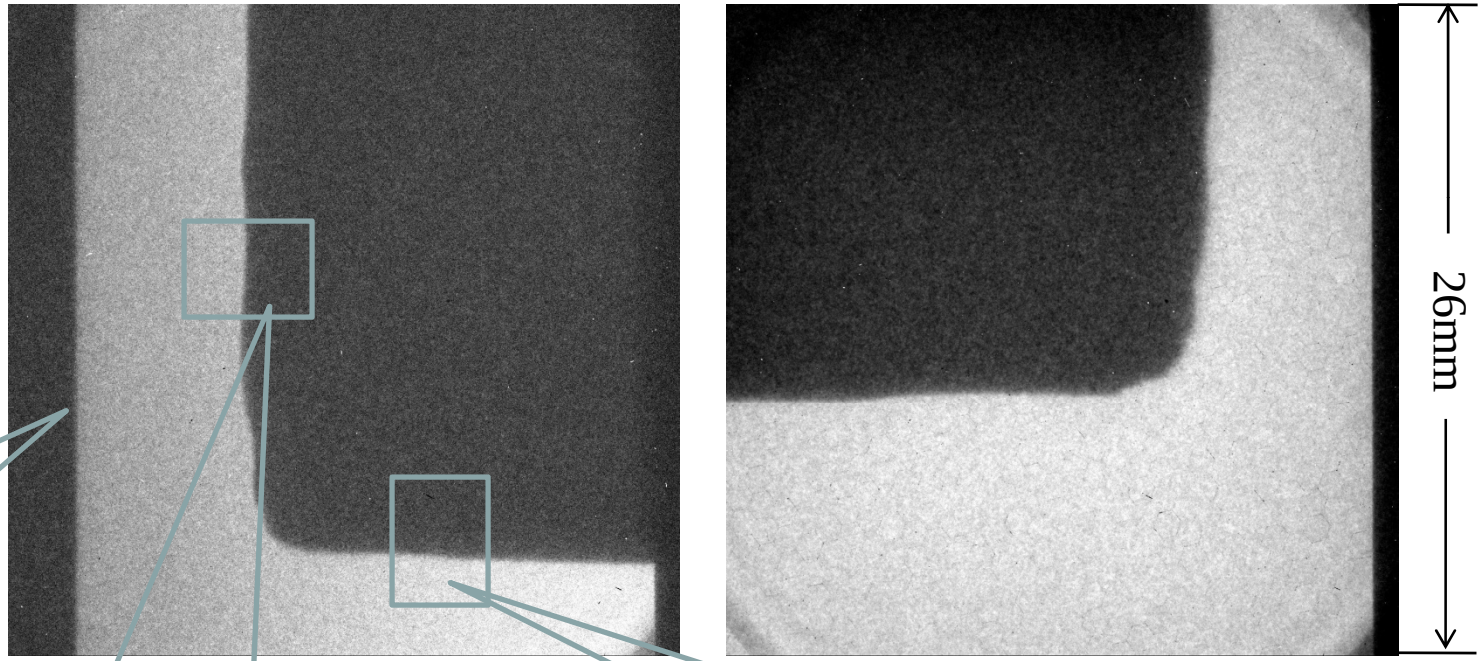


Projection images of GaAs edge

@ 0.3 °

@ 81 °

Magnification :
44

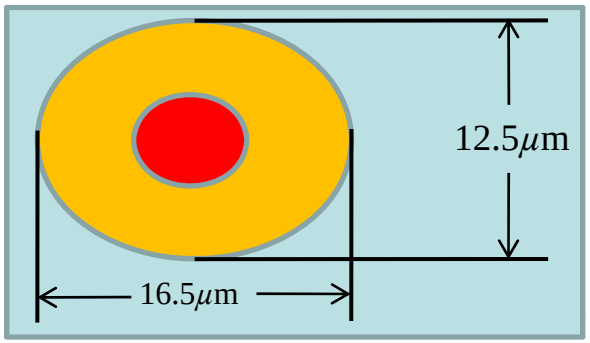


Target surface

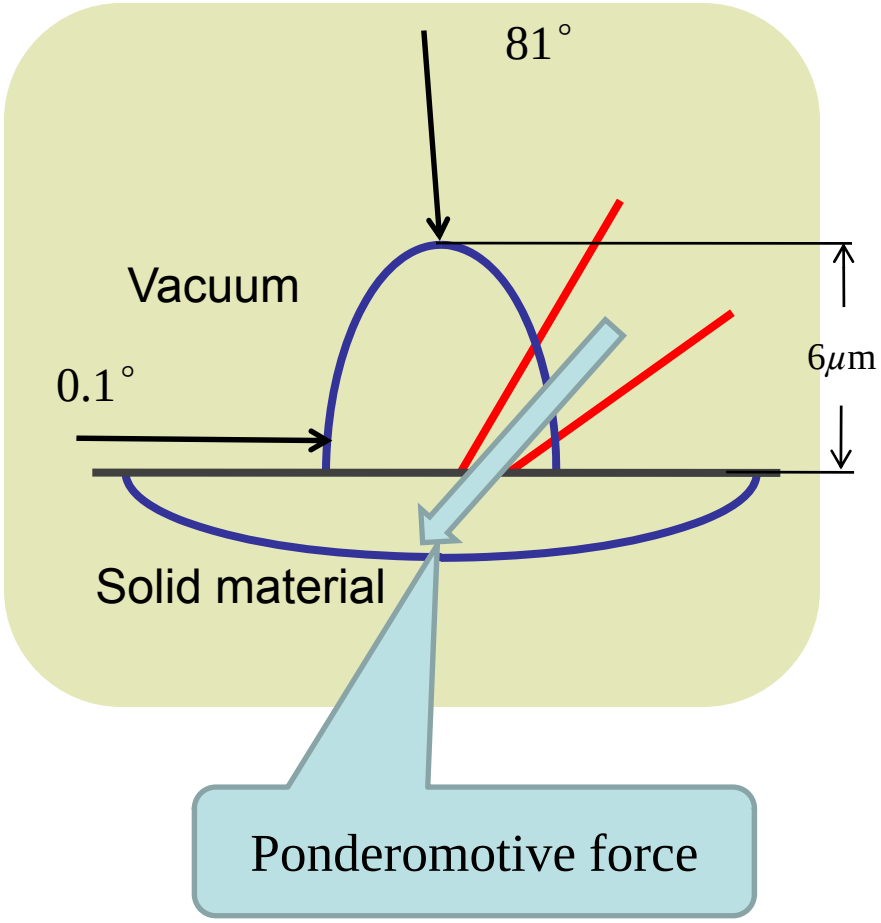
Measure the horizontal size

Measure the vertical size

Source shape and 2-location model



Angle	H-size (μm)	Compare	V-size (μm)
0.1°	6.0±0.5	<	7.0±0.5
0.3°	5.5±0.5	<	8.5±1
4.2°	10.5±0.5	~	9.0±0.5
8°	10.0±0.5	~	9.5±0.5
23°	13.0±1	>	9.5±0.5
81°	16.5±2	>	12.5±1.5



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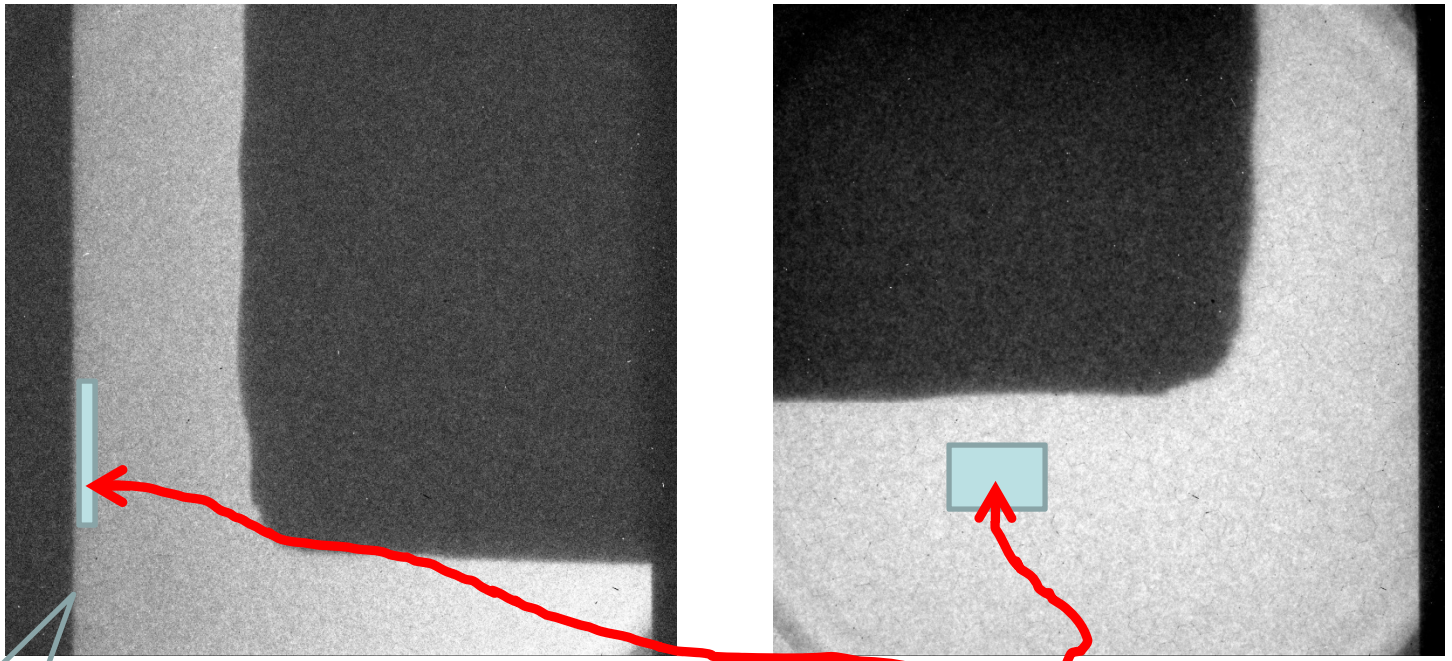


Target surface

Ratio of averaged pixel gray values: 1202/168=7.2

Conclusion

✓ Spatial energy distribution of x-ray emission is measured

- p-pump **more isotropic than** s-pump
- Total x-ray **more isotropic than** Ka x-ray
- Tightly focus **more isotropic than** Loose focus

✓ Source sizes are measured from different direction

- From 0° to a couple of degree: V> H
- From a couple of degree to 10° : V~H
- From 10° up: V<H

✓ We observed that laser -based x-ray source is 3-dimensional

Objective

Spectrum

Line emission (narrow band): diffraction, crystallography

*A. Rousse, et. al. Nature, **410**, 65 (2001), A. Bonvalet, et. al. Opt. Lett. **31**, 2753 (2006)*

Bremsstrahlung (broadband): x-ray absorption spectroscopy

*Y. Jiang, et. al. J. opt. Soc. Am. B, **20**, 229 (2003)*

Ultrashort pulse duration

Time resolved diffraction, time-gated imaging, ultrafast spectroscopy *C. Rischel, et. al., Nature, **390**, 490 (1997)*

Small source size

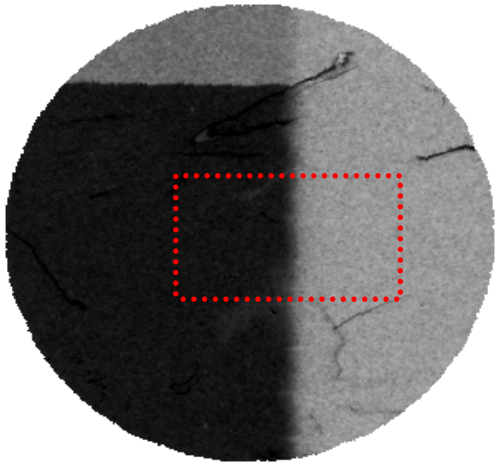
Better spatial coherence -------- phase contrast imaging

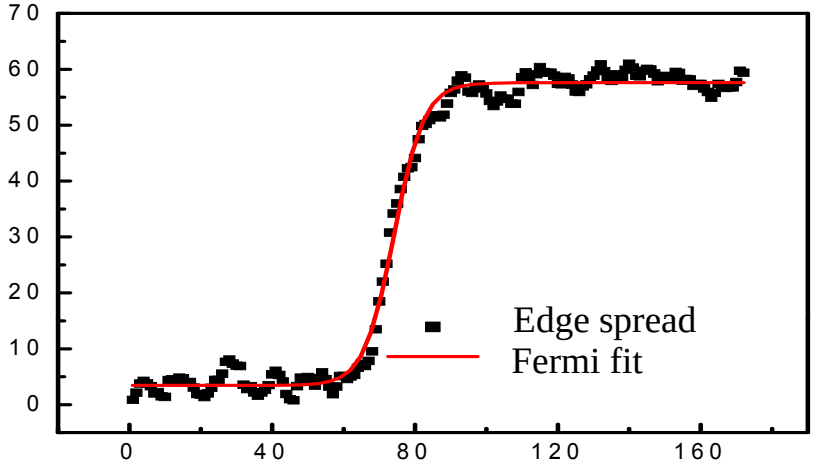
*D. Boschetto, et. al. Appl. Phys. Lett. **90**, 011106 (2007)*

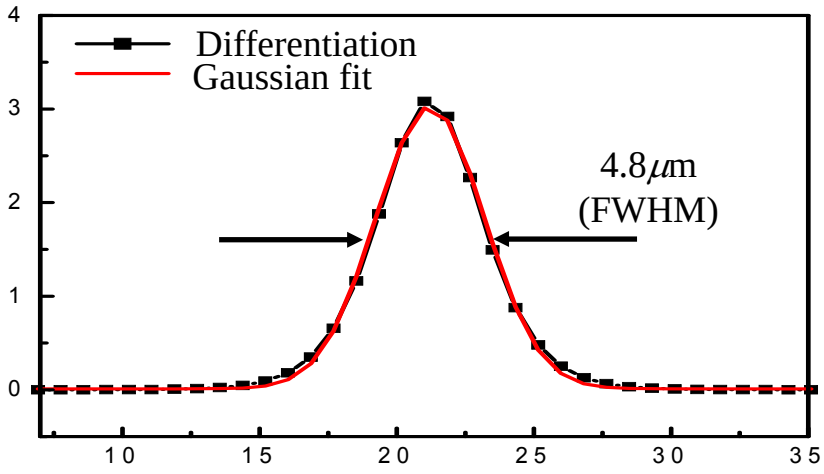
Better image resolution -------- medical imaging

*A. Krol, et. al., Med. Phys. **24**, 725, (1997)*

Knife-edge measurement



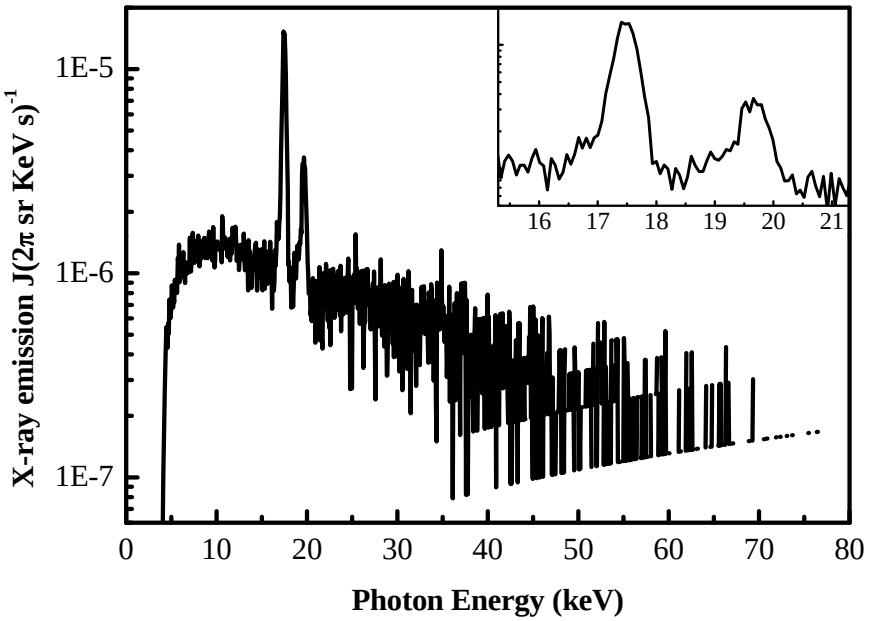


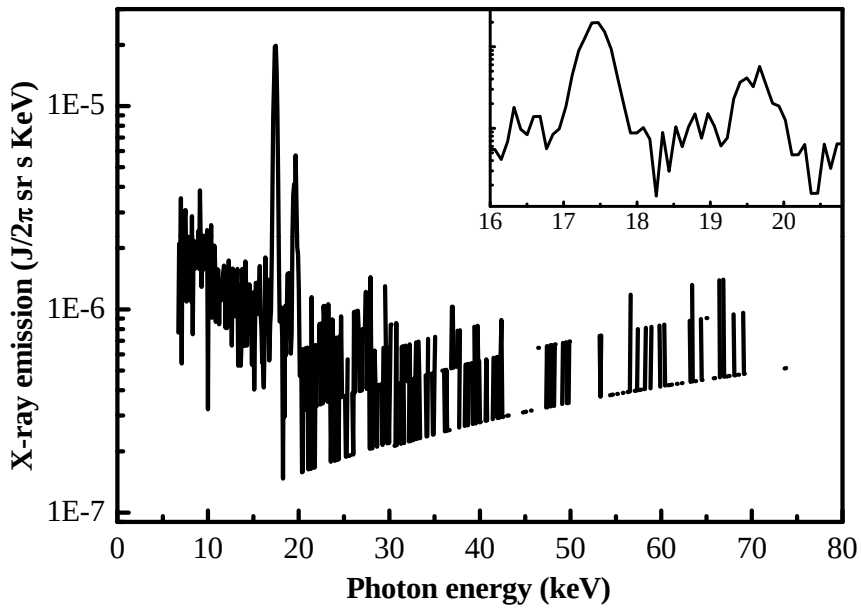


Fermi function:

$$f(x) = a + \frac{b}{1 + e^{(x-c)/d}}$$

X-ray spectra from Mo target



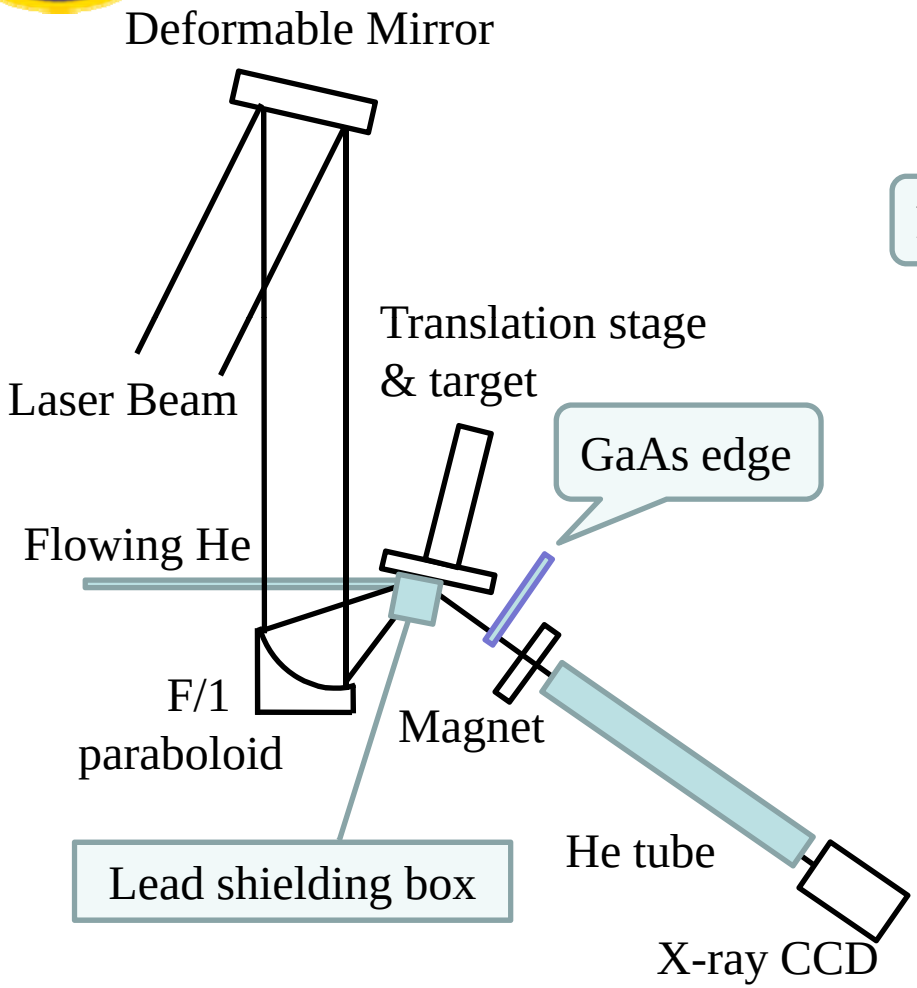


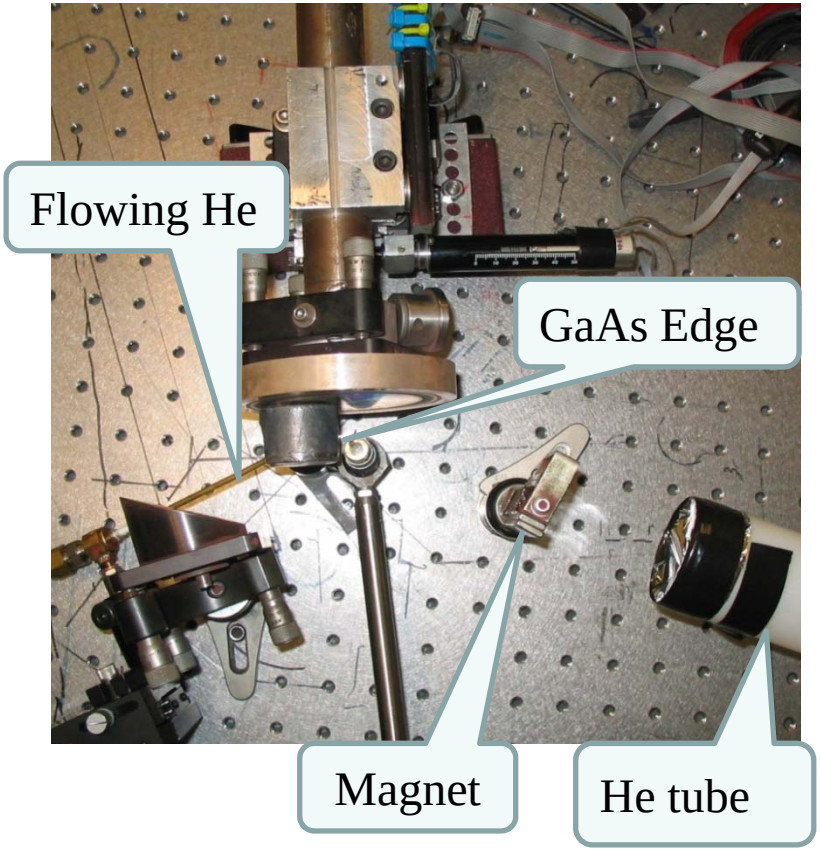
X-ray spectrum in Vacuum

X-ray spectrum in Flowing Helium

Bixue Hou, et. al., Opt. Express ***16****, 17695(2008)*

X-ray generation in flowing helium





Bixue Hou, Appl. Phys. Lett, ***92****, 161501, 2008*