Nanospectroscopy with the SPELEEM at ELETTRA

(**S**pectroscopic **P**hoto**E**mission and **L**ow **E**nergy **E**lectron **M**icroscope)

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Outline

1. Spectromicroscopy at Elettra
2. The Nanospectroscopy Beamline
3. The SPELEEM microscope

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1. Spectromicroscopy at Elettra

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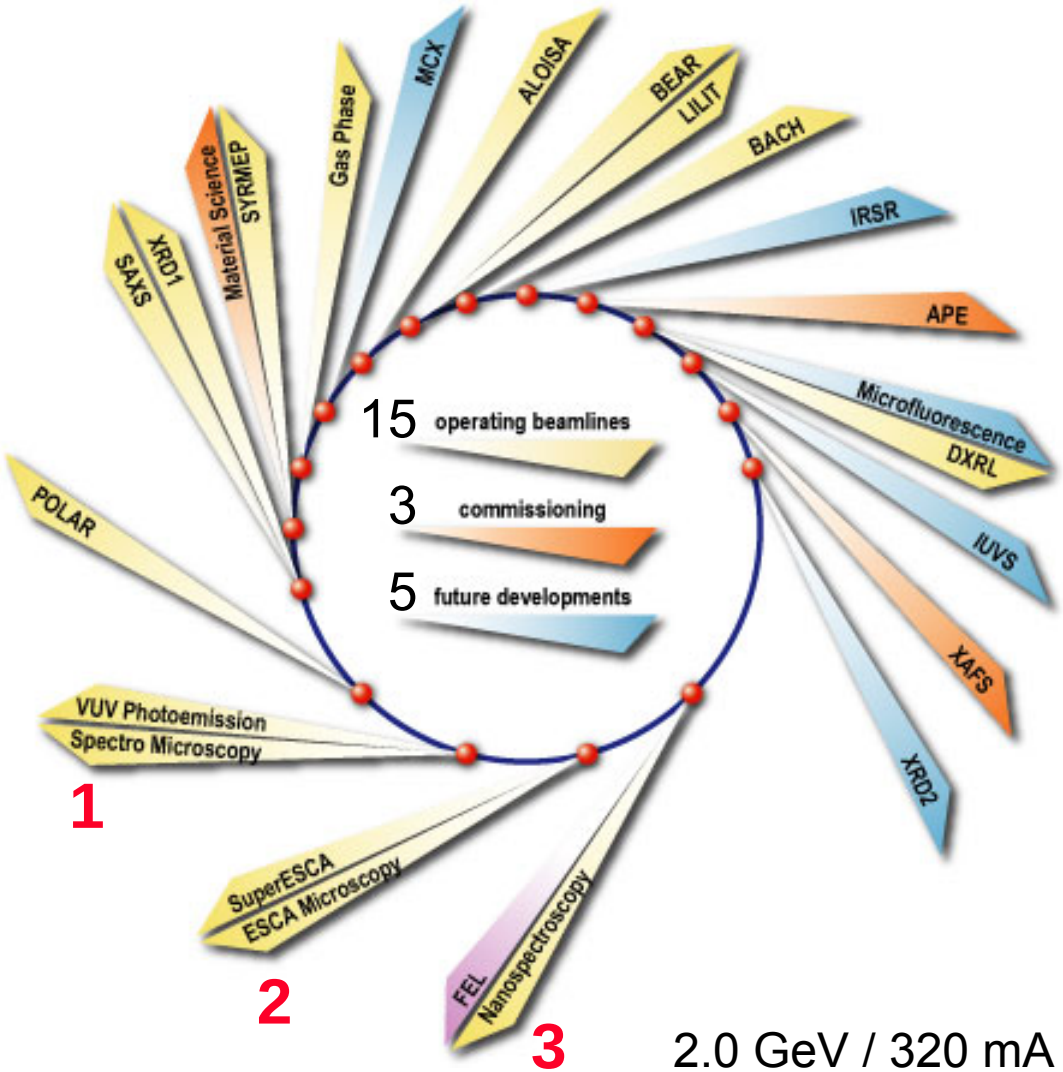
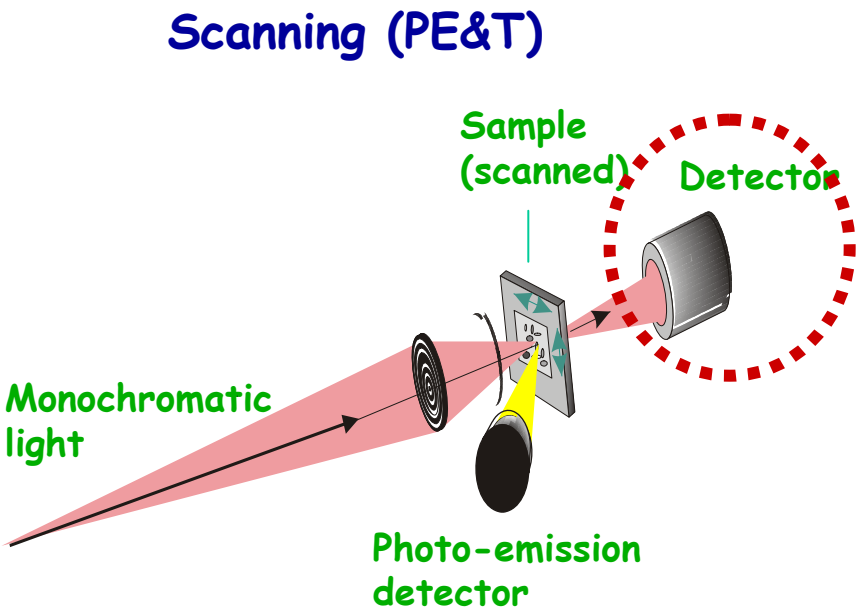
Elettra Beamlines

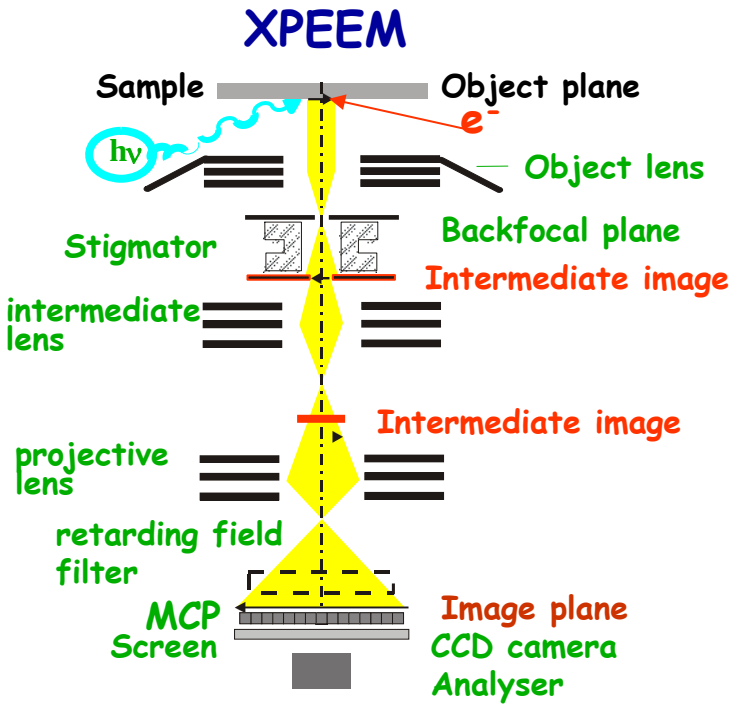


2.0 GeV / 320 mA
2.4 GeV / 140 mA

exit	beamline	source
1.2L	Nanospectroscopy *	id
1.2R	FEL (Free-Electron Laser)	-
2.2L	ESCA Microscopy	id
2.2R	SuperESCA	id
3.2L	Spectro Microscopy	id
3.2R	VUV Photoemission	id
4.2	Circularly Polarised Light	id
5.2L	SAXS (Small Angle X-Ray Scattering)	id
5.2R	XRD1 (X-ray Diffraction)	id
6.1L	Material science	bm
6.1R	SYRMEP (SYnchrotron Radiation for MEdical Physics)	bm
6.2R	Gas Phase	id
7.1	MCX (Powder Diffraction Beamline)	bm
7.2	ALOISA (Advanced Line for Overlayer, Interface and Surface Analysis)	id
8.1L	BEAR (Bending magnet for Emission Absorption and Reflectivity) *	bm
8.1R	LILIT (Lab of Interdisciplinary LIThography)	bm
8.2	BACH (Beamline for Advanced DiCHroism) *	id
9.1	IRSR (Infrared Synchrotron Radiaton Microscopy)	bm
9.2	APE (Advanced Photoelectric-effect Experiments) **	id
10.1L	X-ray microfluorescence	bm
10.1R	DXRL (Deep-etch Lithography)	bm
10.2	IUVS (Inelastic Ultra Violet Scattering)	id
11.1	XAFS (X-ray Absorption Fine Structure)	bm
11.2	XRD2 (X-ray Diffraction)	id

Photoemission Microscopy





Photon optics is demagnifying the beam:

Scanning Instrument

1. Whole power of XPS in a small spot mode.
2. Flexibility for adding different detectors.
3. Rough surfaces can be measured.
4. Limited use for fast dynamic processes.
5. Lower resolution than imaging instruments.

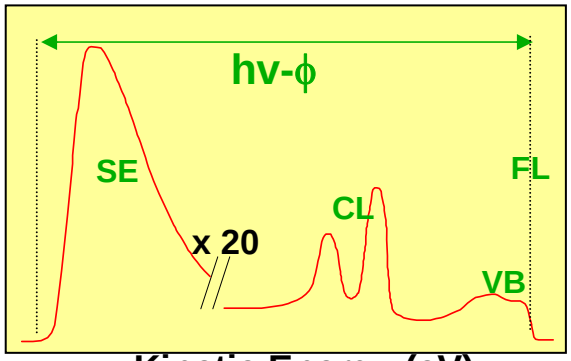
Electron optics to magnify irradiated area:

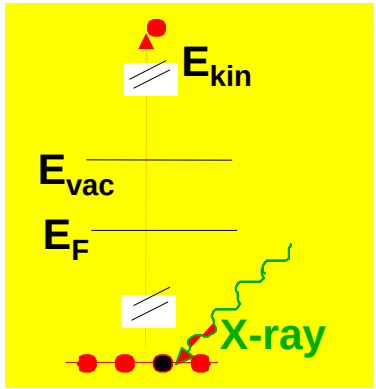
Imaging Instrument

1. High lateral resolution (20 nm).
2. Multi-method instrument (XPEEM/PED).
3. Excellent for monitoring dynamic processes.
4. Poorer spectroscopic ability.
5. Sensitive to rough surfaces.

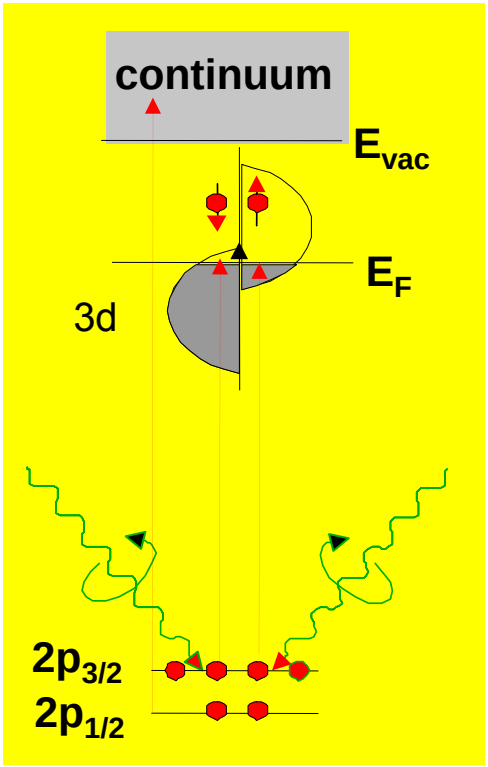
Concepts of Spectromicroscopy

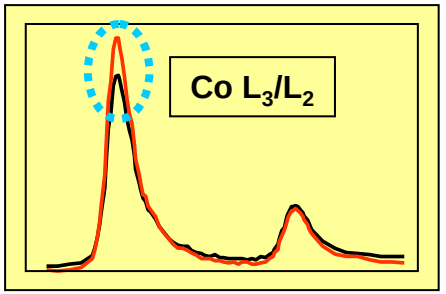
XPS – mode: <u>hv=const</u>
hv in / e^- out
+ energy filtering of electrons





XAS – mode: <u>hv scanned</u>
hv in / e^- out (TEY)





<u>XANES:</u>
tuning on molecular orbitals

<u>XMLD:</u> imaging antiferromagnets

<u>XMCD:</u> imaging ferromagnets

Sum rules: Magnetic moment values

Outline

1. Spectromicroscopy at Elettra

2. The Nanospectroscopy Beamline

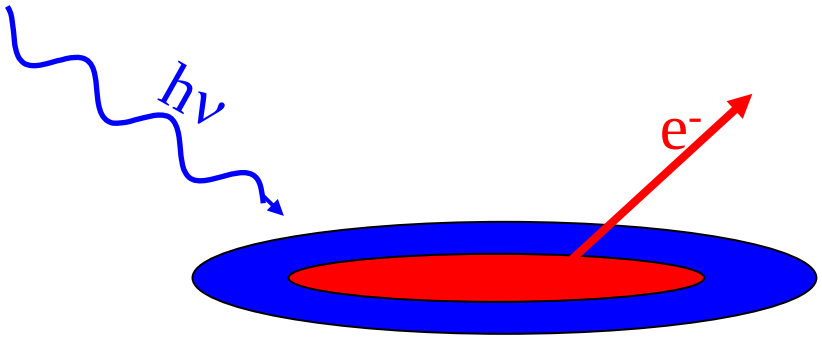
3. The SPELEEM microscope

Requirements

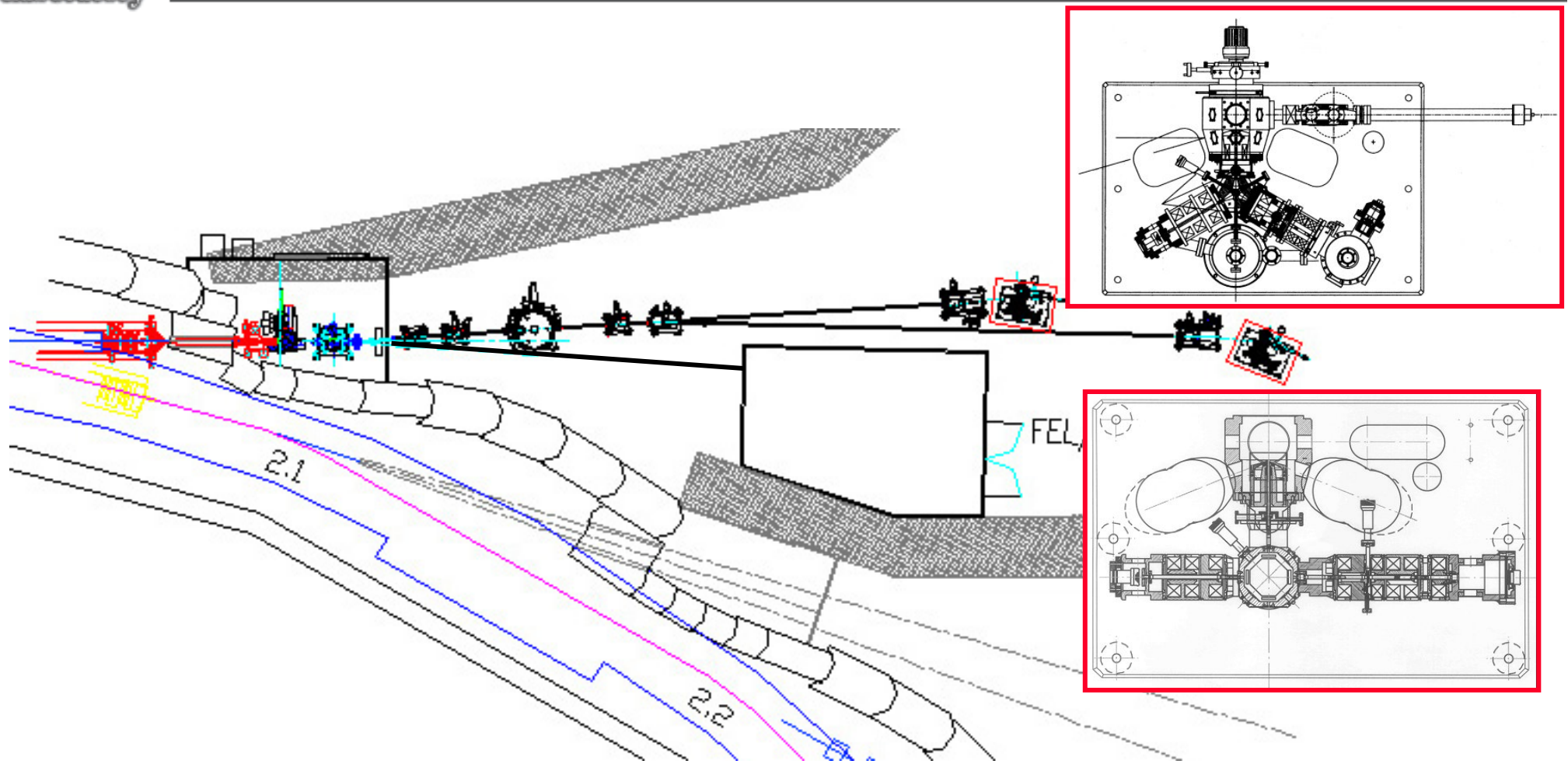
Source: Variable Polarization

Monochromator: Wide spectral range
Medium spectral resolution

Spot: High photon flux density on sample
Small variable spot size (~μm)
Homogeneous illumination



Beamline Layout



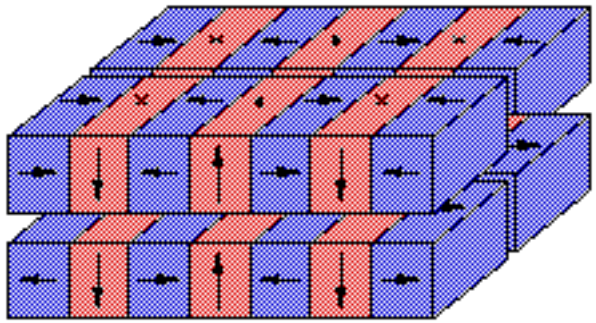
Source Characteristics

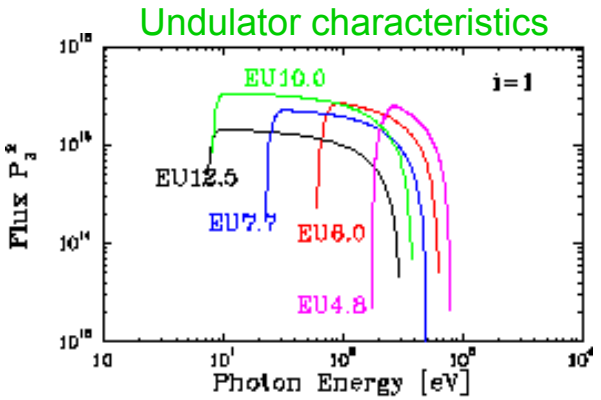
- FEL/Nanospectroscopy undulator
- Sasaki Apple II type undulator

- 2 sections with phase modulation electromagnet
- 2 x 20 periods of length 10 cm

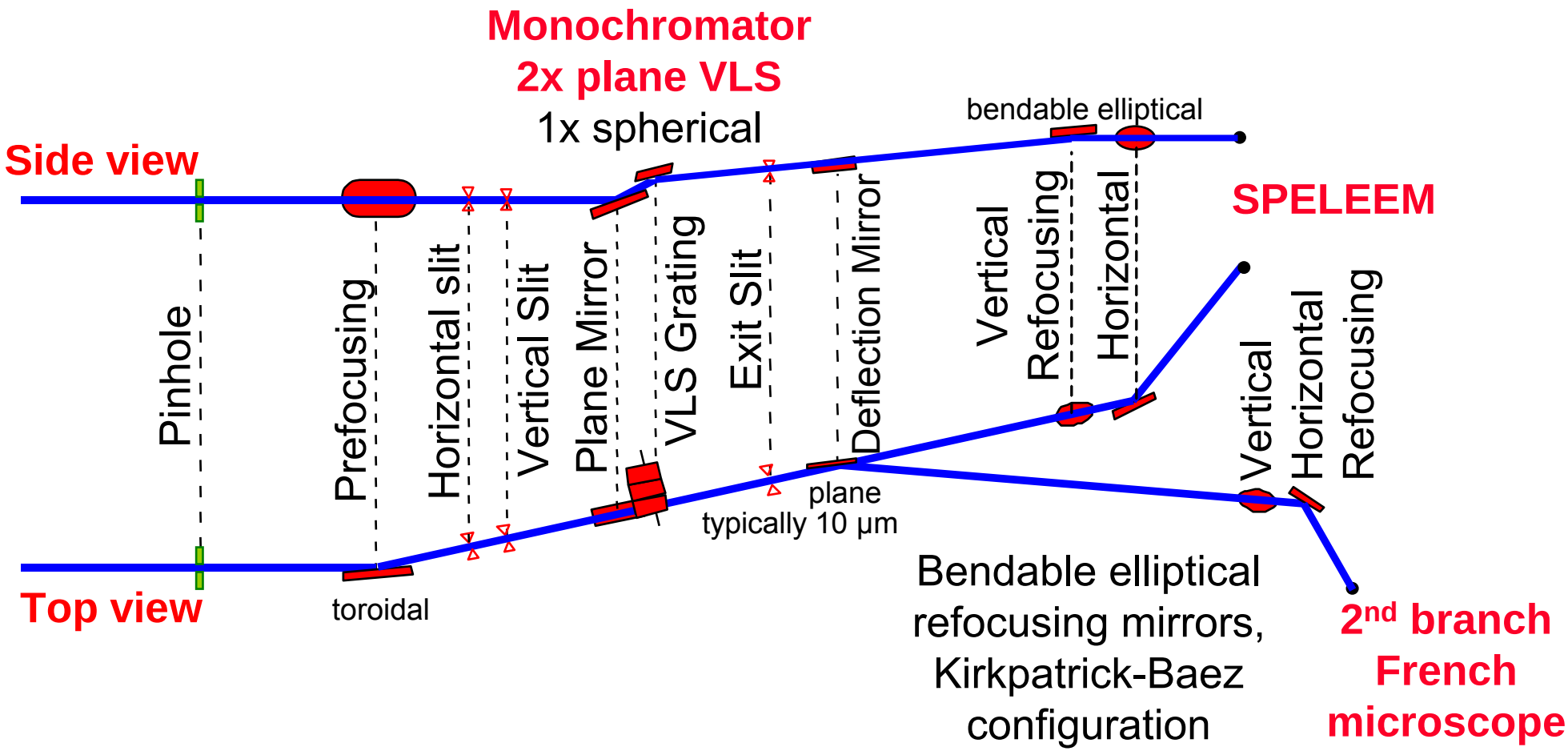
- Polarization: elliptical (horizontal, circular, and vertical)

- Source dimension: 560 μm x 50 μm





Optics



D. Cocco, M. Marsi, M. Kiskinova, K. C. Prince, T. Schmidt, S. Heun, and E. Bauer: Proc. SPIE **3767** (1999) 271.

elettra Synchrotron Light Laboratory

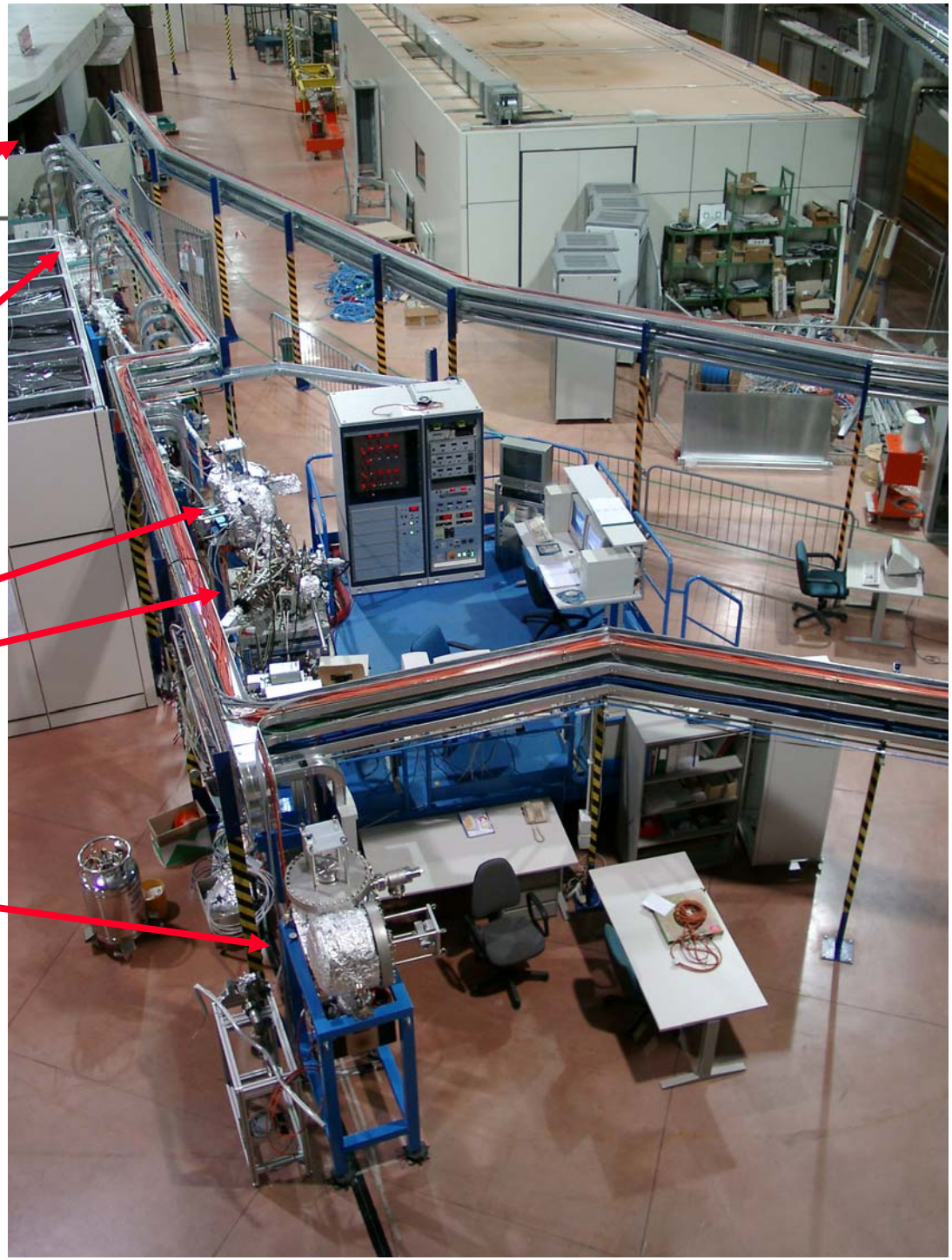
Front End

Monochromator

Refocusing Mirrors

SPELEEM

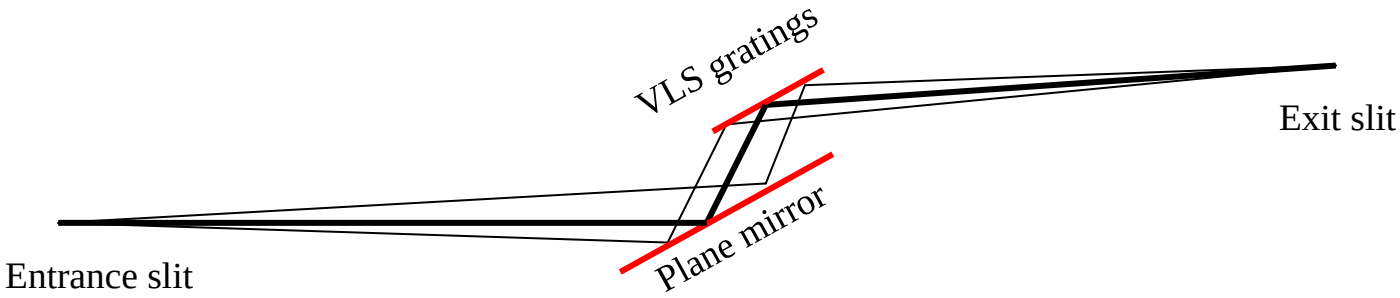
2nd Branch



Monochromator

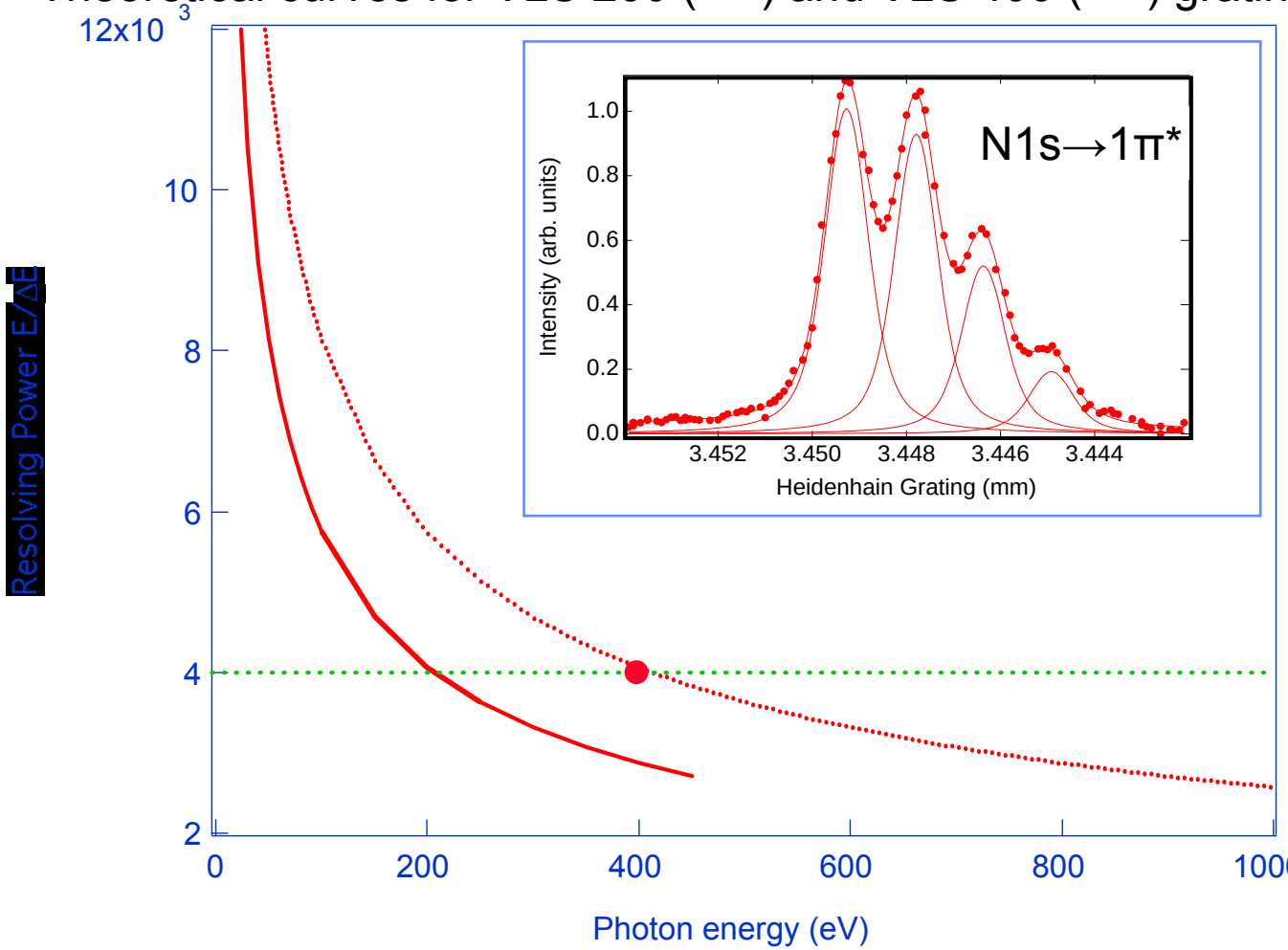
- 2 VLS (variable line spacing) gratings of low groove density
  - 200/mm for 20 - 250 eV
  - 400/mm for 200 - 1000 eV

- 1 spherical grating (5 - 40 eV)



Energy Resolution

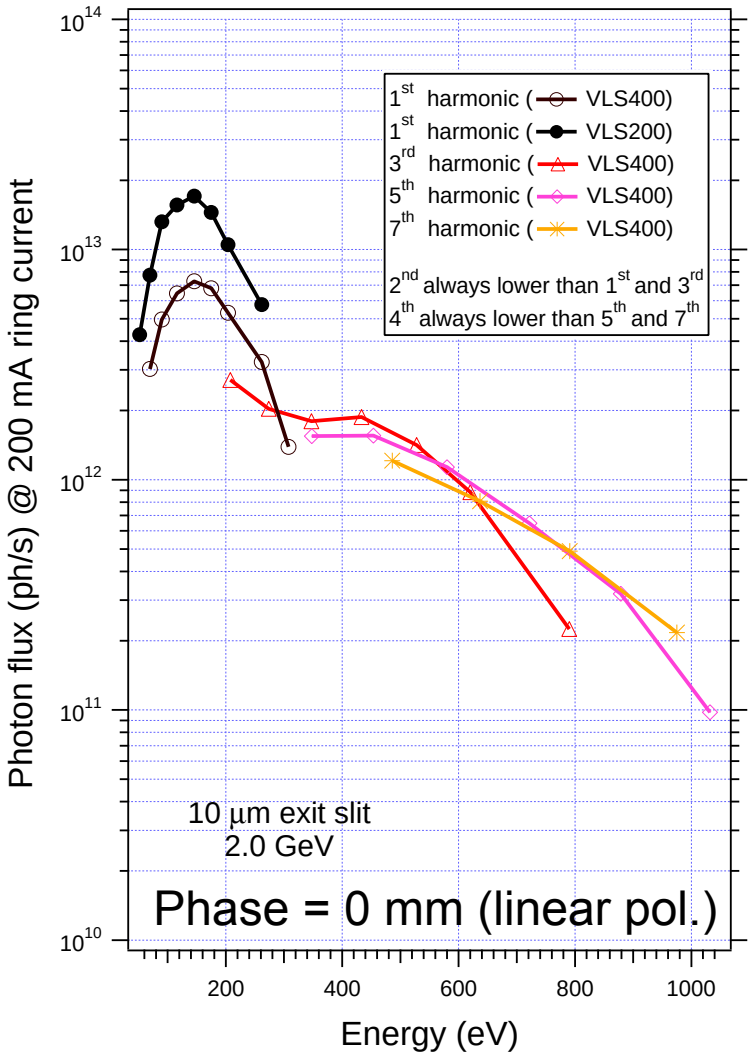
Theoretical curves for VLS 200 (—) and VLS 400 (·····) gratings

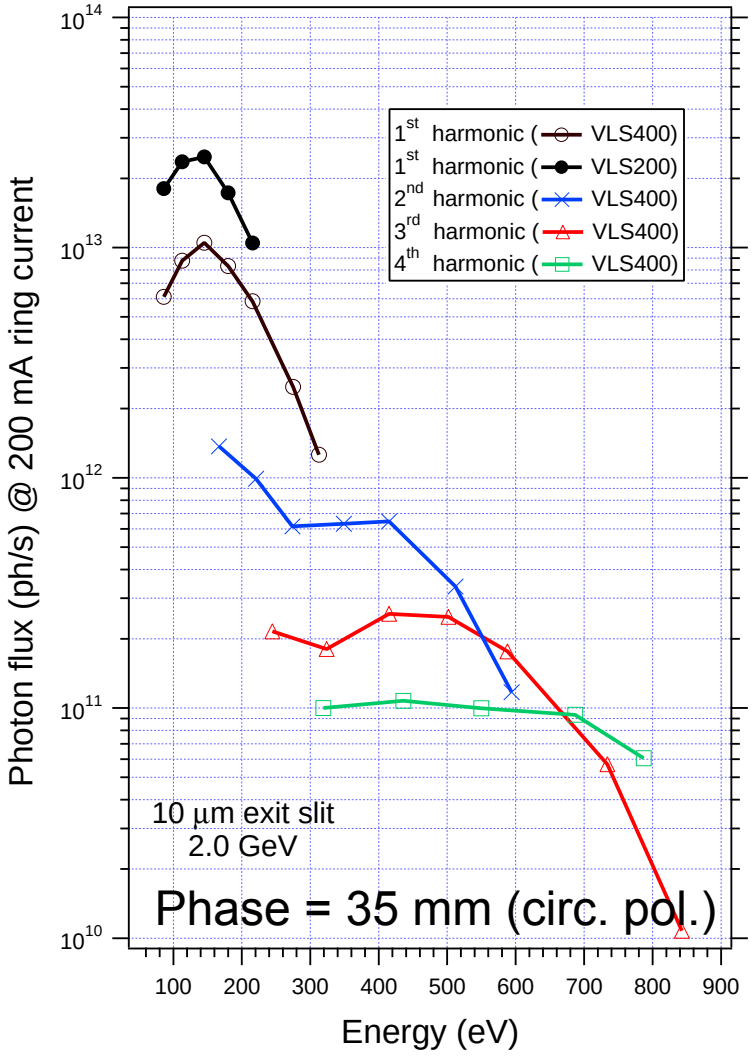


E/ΔE ~ 4000
@ 400.8 eV

A. Locatelli, A. Bianco, D. Cocco, S. Cherifi, S. Heun, M. Marsi, M. Pasqualetto, and E. Bauer: J. de Physique IV, submitted.

Photon Flux



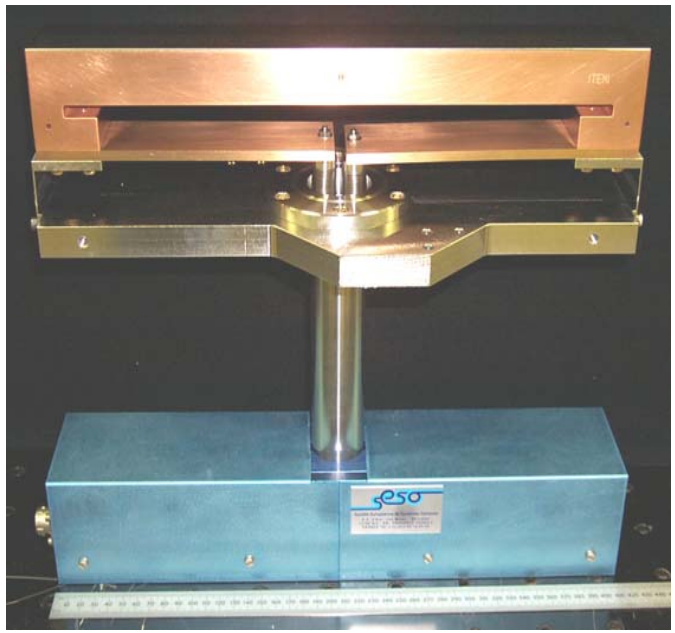


A. Locatelli, A. Bianco, D. Cocco, S. Cherifi, S. Heun, M. Marsi, M. Pasqualetto, and E. Bauer: J. de Physique IV, submitted.

Photon Beam Refocusing

- Need:
  - Homogeneous micro-spot
  - Highest photon flux in the field of view of the microscope
- Two adaptive plane elliptical mirrors («bendable mirrors»)
- Bend by applying unequal moments to their ends
- Kirkpatrick-Baez configuration
- Theoretical spot size:

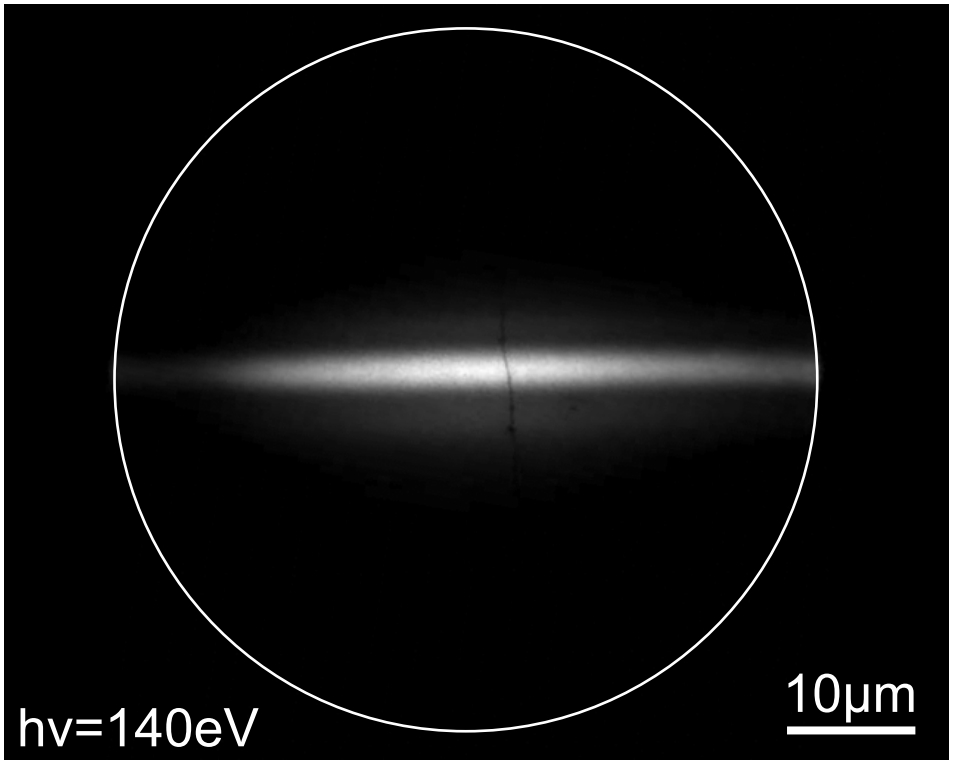
  1.6 μm (vert) x 6.1 μm (hor)



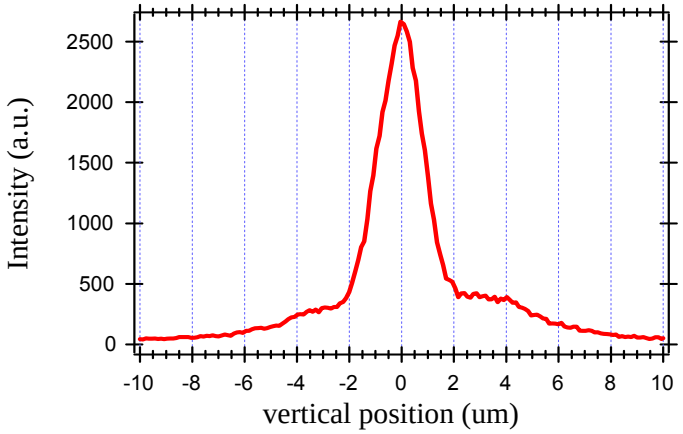
A. Bianco, G. Sostero, and D. Cocco: Proc. SPIE, submitted.

Best Focus: Spot Size on Sample

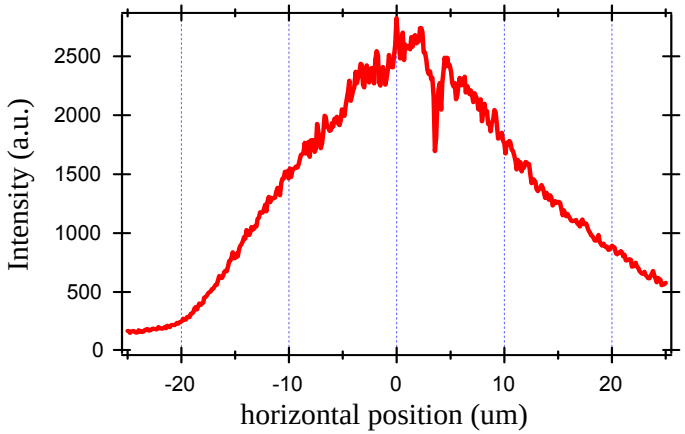
Best Focus



vertical line profile (FWHM 2 µm)



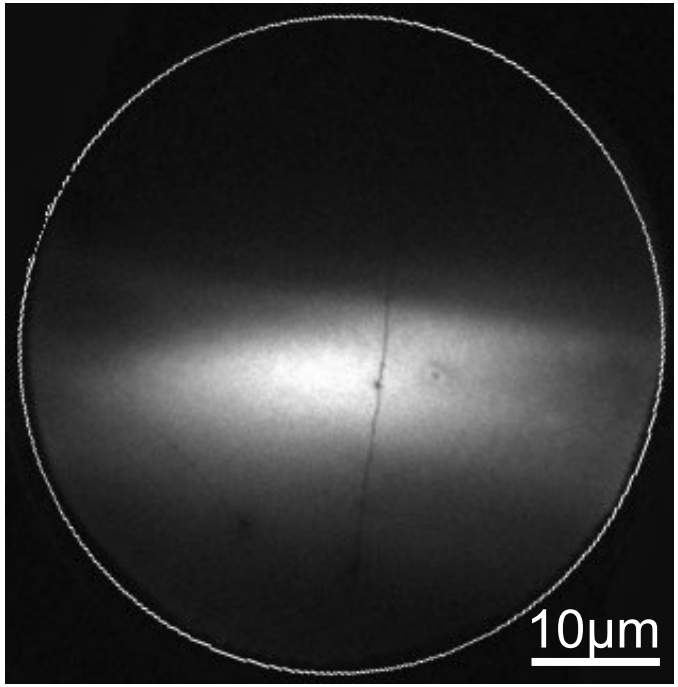
horizontal line profile (FWHM 25 µm)
corrected for grazing incidence: 7 µm



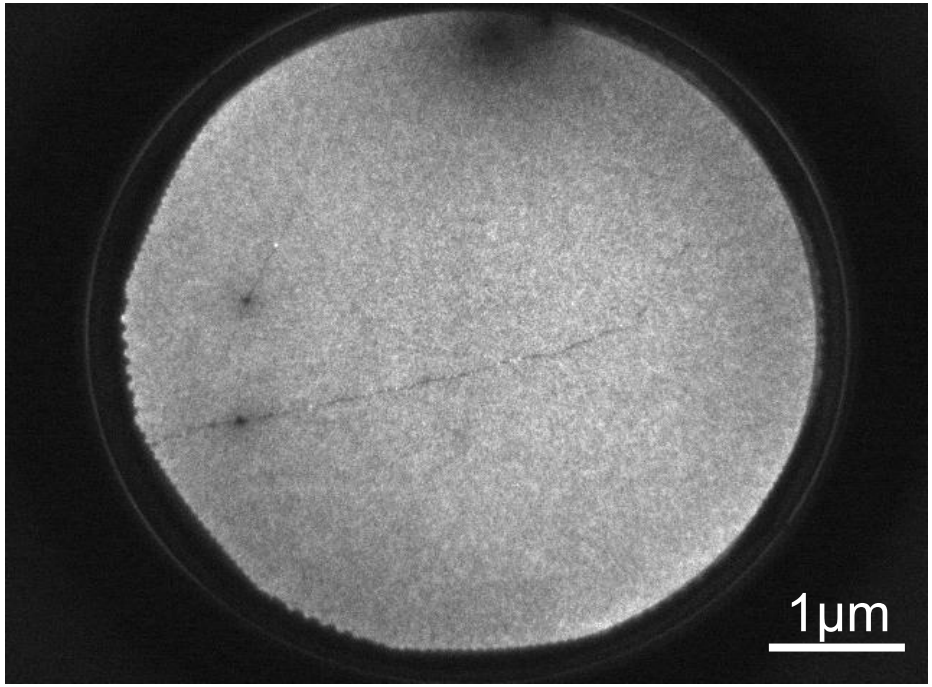
A. Bianco, G. Sostero, and D. Cocco: Proc. SPIE, submitted.

Increased Spot Size

Field of view ~50 μm
HRM roll misalignment (-700 steps)



XPEEM image at 5μm FOV
Homogeneous illumination

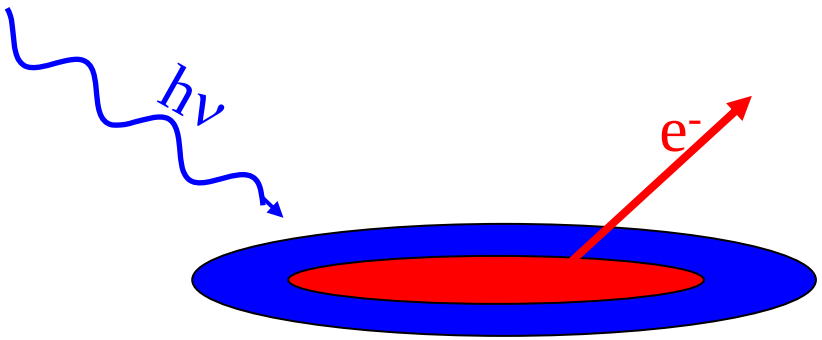


Summary

Source: Sasaki Apple II type undulator
Polarization: circular, elliptical, and linear

Monochromator: Spectral range: 20 - 1000 eV
Spectral resolution: $E/\Delta E \sim 4000$ @ 400 eV

Spot: Flux on sample: 10^{11} - 10^{13} ph/s/200mA
Focused spot size: 2 μm x 7 μm
Vertical spot size from 2 μm to 10 μm



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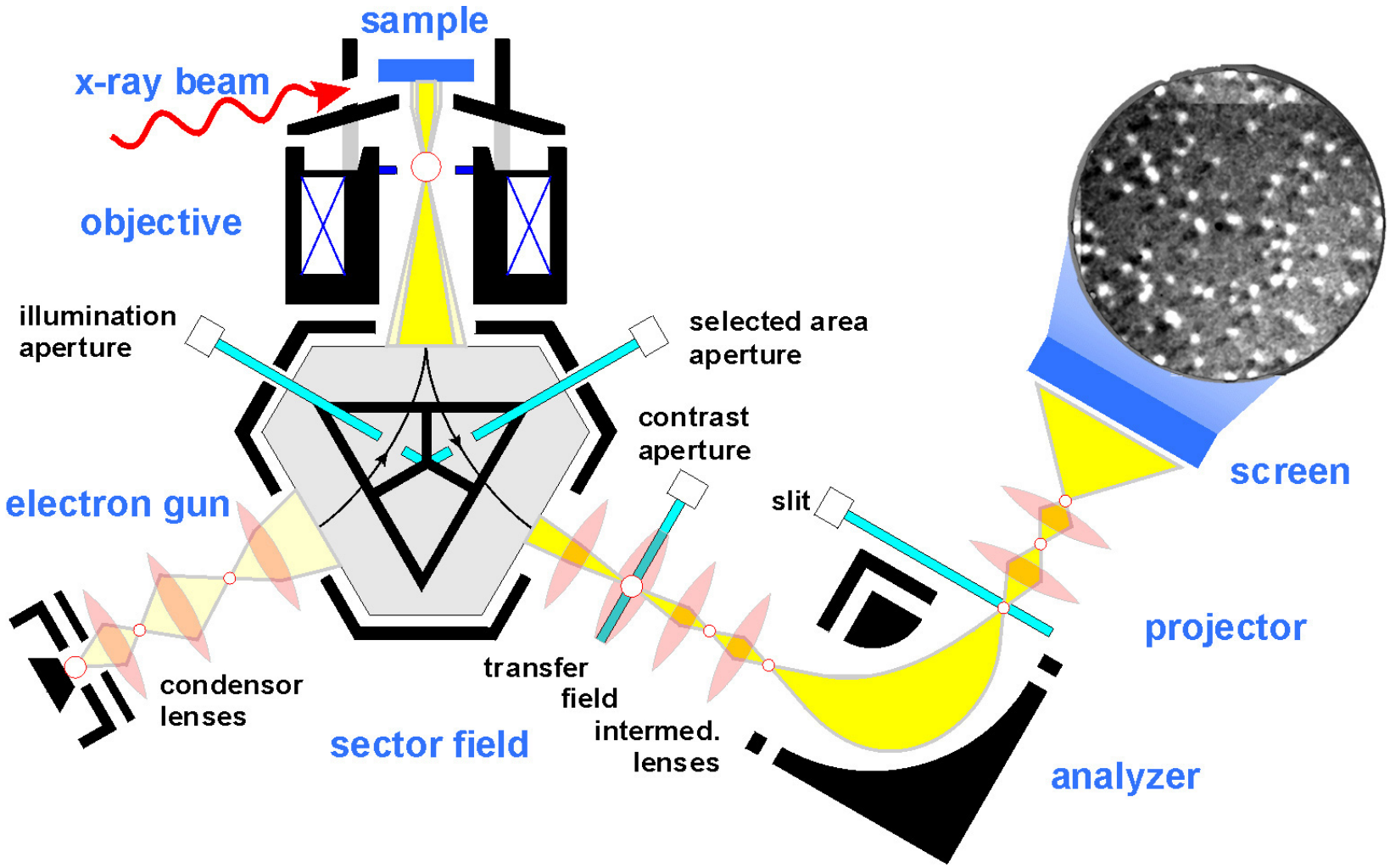
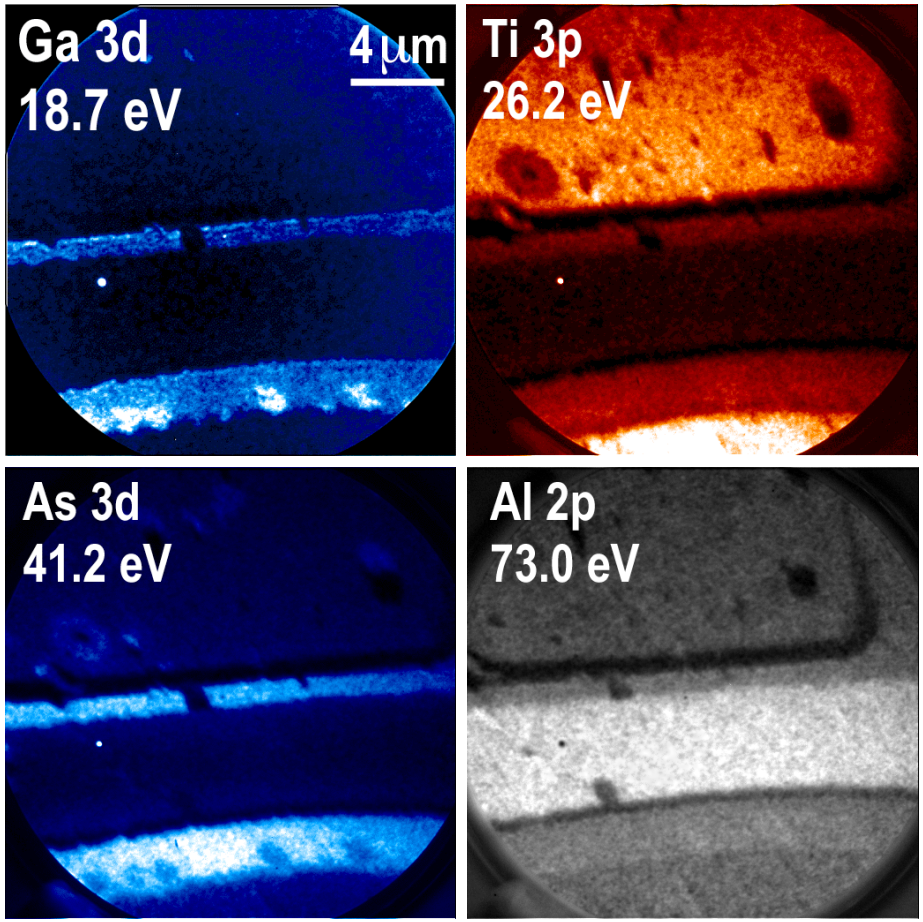
The SPELEEM

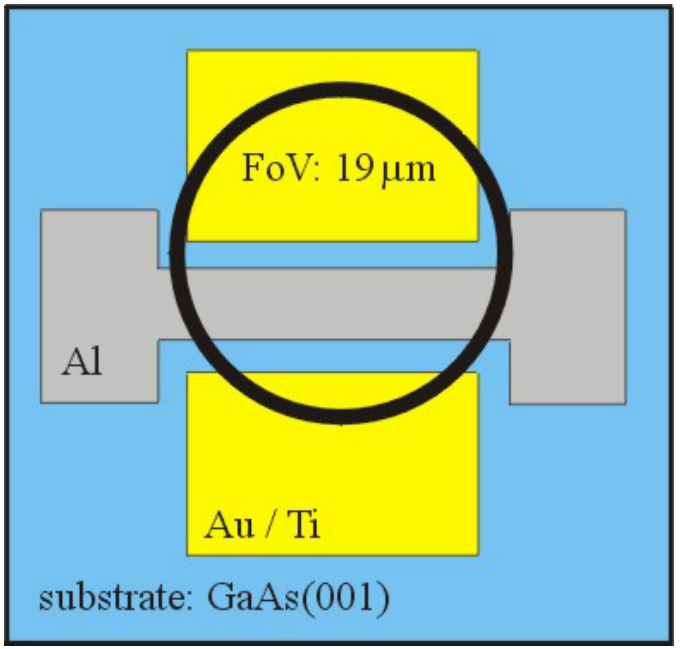
Spectroscopic photoemission and low energy electron microscope



Spectroscopic Microscopy



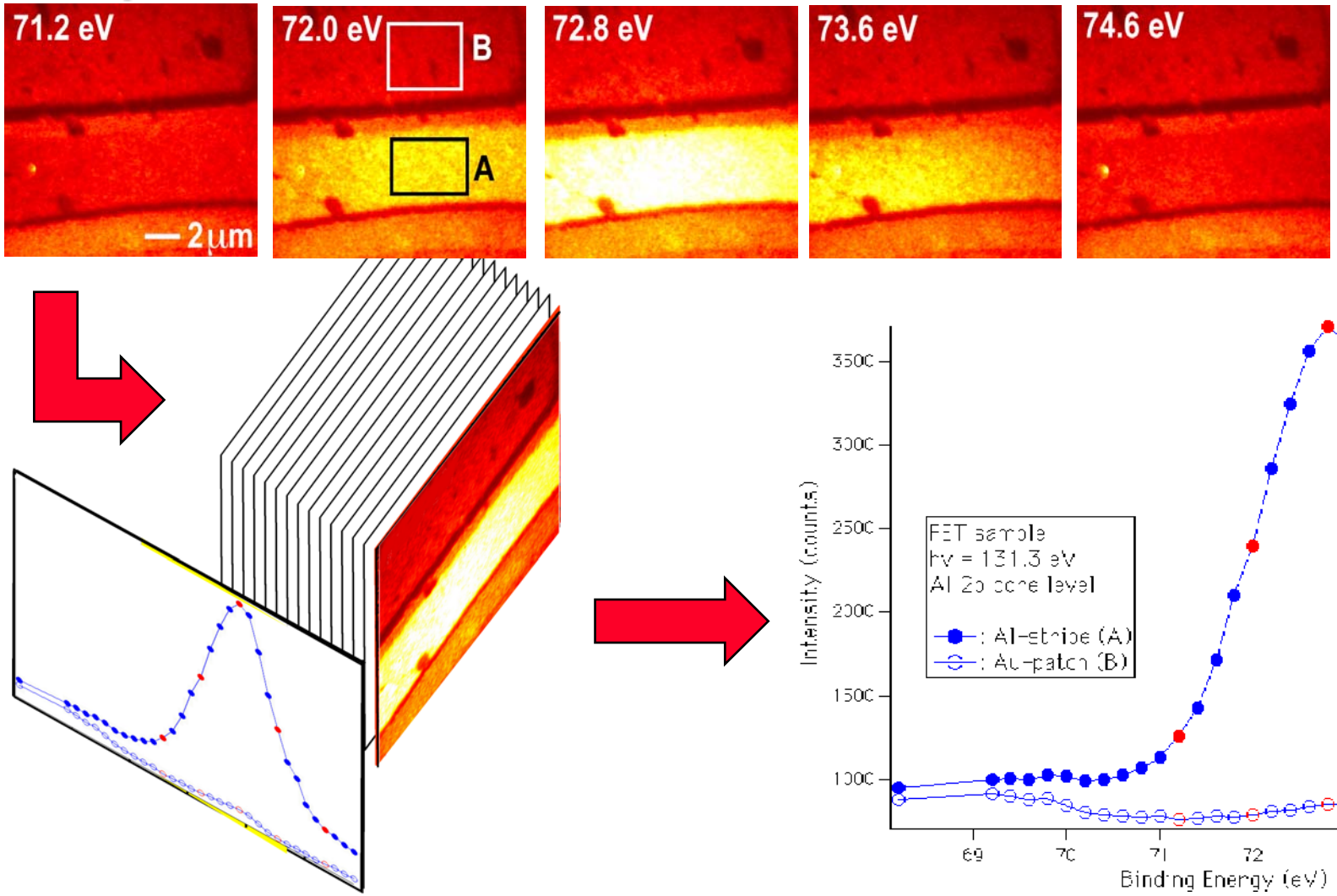
Images from a Field Effect Transistor (FET) at different binding energies.
Photon energy hv = 131.3 eV.



Sample from M. Lazzarino, L. Sorba, and F. Beltram, Laboratorio TASC-INFM, Trieste, Italy

S. Heun, Th. Schmidt, B. Ressel, E. Bauer, and K. C. Prince, Synchrotron Radiation News Vol. 12, No. 5 (1999) 25.

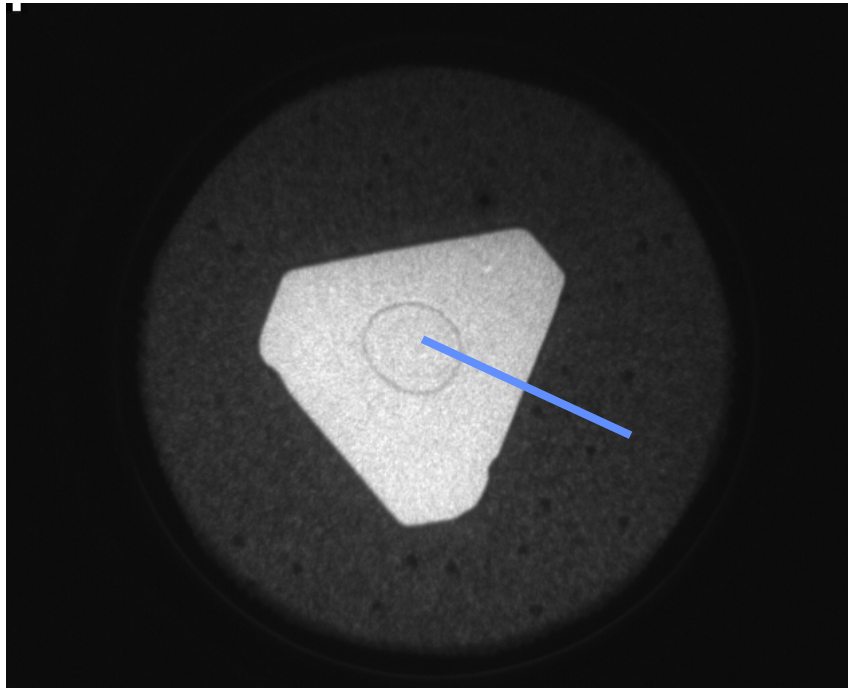
XPEEM



S. Heun, Th. Schmidt, B. Ressel, E. Bauer, and K. C. Prince, Synchrotron Radiation News Vol. 12, No. 5 (1999) 25.

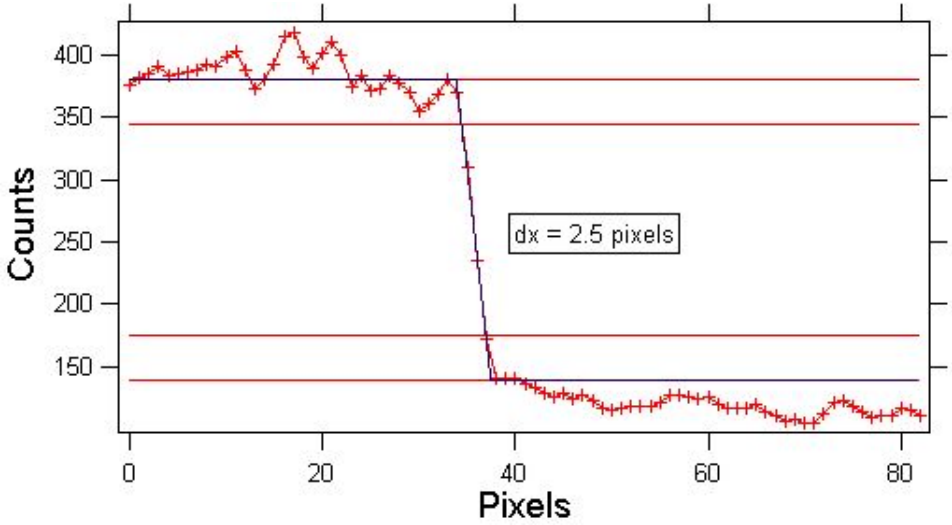
Lateral Resolution of LEEM

FoV = 2.65 µm
STV = 7.5 eV
12.5 µm energy slit
30 µm contrast aperture
100 ms int. time, 2x2 binning



Pb on Si (111)
LEEM – lateral resolution
13/11/2002 image_003

Profile line width = 3 pixels

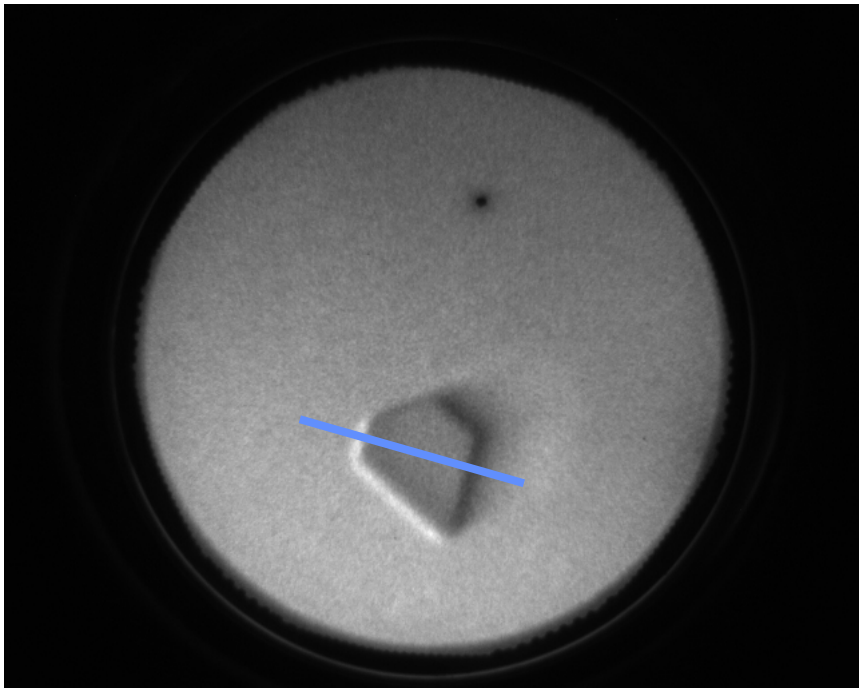


Evaluated spatial resolution is **15 nm**.

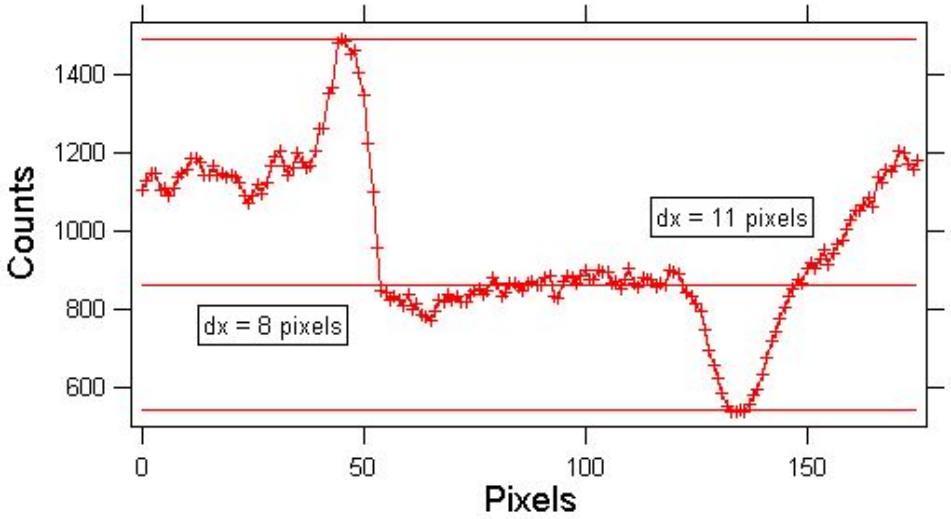
Lateral Resolution of XPEEM

FoV = 2.65 µm
STV = 1.2 eV, hv = 54.5 eV
12.5 µm energy slit
20 µm contrast aperture
15 s int. time, 2x2 binning

Pb on Si (111)
XPEEM – lateral resolution
imaging secondaries
12/11/2002 image_025



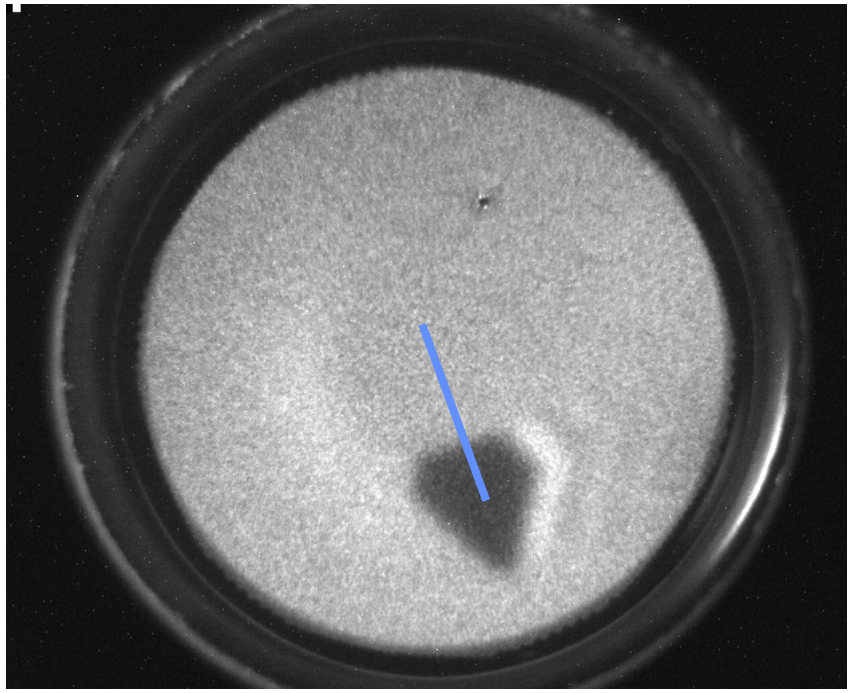
Profile line width = 7 pixels



Evaluated spatial resolution is **40 nm**.

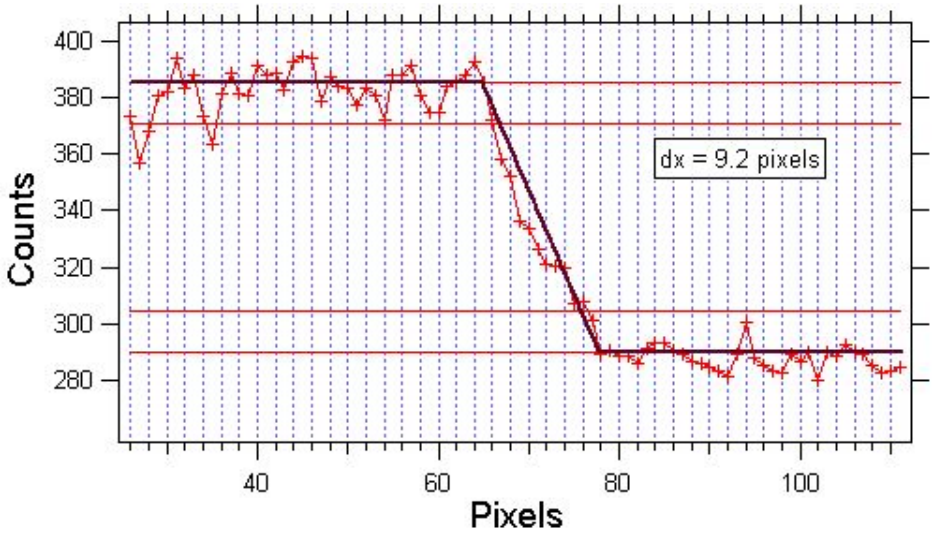
Lateral Resolution of XPEEM

FoV = 2.65 µm
STV = 43.2 eV, hv = 144.0 eV
12.5 µm energy slit
30 µm contrast aperture
240 s int. time, 2x2 binning



Pb on Si (111)
XPEEM – lateral resolution
core level imaging – Si 2p
12/11/2002 image_033

Profile line width = 7 pixels



Evaluated spatial resolution is **55 nm**.

Energy Resolution of XPEEM

Pb on Si (111)
XPEEM – energy resolution
Pb 5d – Voigt fit
13/11/2002 scan_002

FoV = 2.65 µm
hv = 130.0 eV
12.5 µm energy slit
30 µm contrast aperture
30 s int. time, 4x4 binning

Energy resolution
better than **0.45 eV**.