

SAFIR

Energy dispersive x-ray CCD camera for PIXE-Kossel and imaging purposes

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Energy dispersive CCD camera

PIXE – Kossel

Spectral imaging

Energy dispersive CCD camera

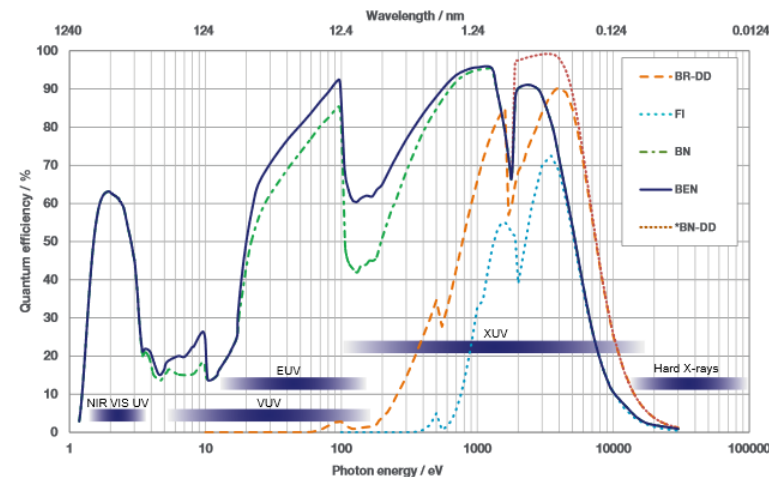
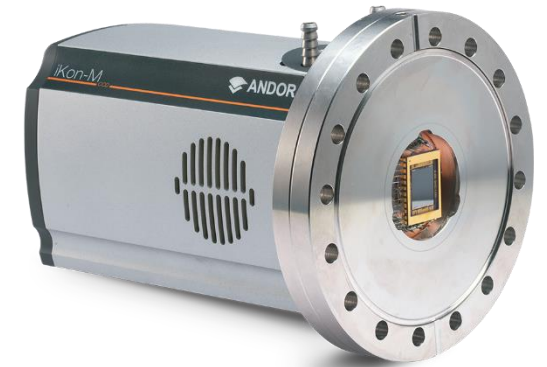
- **Each pixel of the CCD camera is an EDS detector (Energy Dispersive Spectrometer)**
- Functioning equivalent to a SDD (silicon drift detector)
- Work in a large spectral range (5 eV - 20 keV, depending on the CCD)
- Spectral resolution around 150 eV @ 6 keV
- Quantum efficiency > 10% over the whole spectral range
- Single-photon counting mode

Energy dispersive CCD camera

- The pnCCD Color X-Ray Camera[®] (CXC) de PNDetector

- **ANDOR iKon-M**

- Back-illuminated deep-depletion
- Size of pixels
13 μm x 13 μm (1024 x 1024)
- Pelletier cooling
-80°C (low electronic noise)
- Spectral range
from 1 keV up to 20 keV
- Efficiency
>10%
- Software



P. Walter (LAMS), P. Sarrazin (SETI), I. Ismail (LCPMR)

Energy dispersive CCD camera

PIXE – Kossel

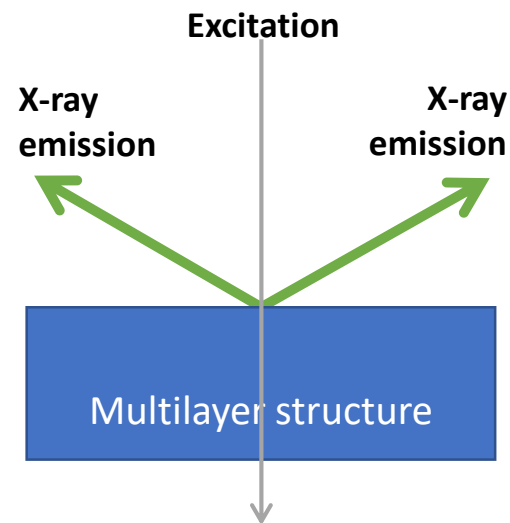
Spectral imaging

PIXE – Kossel

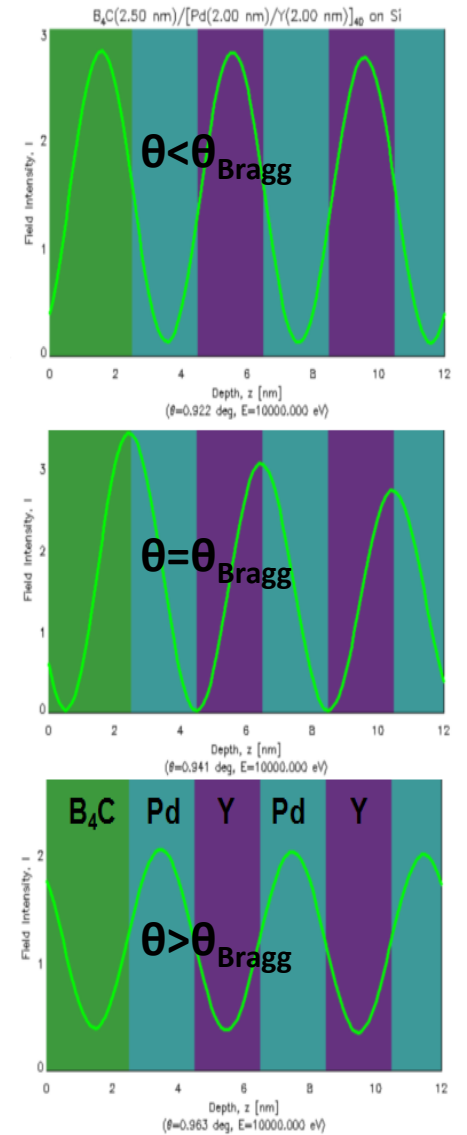
Principle of Kossel diffraction

(GEXRF = grazing exit x-ray fluorescence)

- Generation characteristics x-rays
- Interference between emitted radiations
- Diffraction of the radiation emitted by the atoms of the multilayer by the multilayer structure itself under a given detection angle (Bragg for a periodic structure)
- Study of thin films
- Excitation
 - Protons (PIXE)
 - X-rays (XRF)
 - Electrons (XES)



Pd / Y
periodic
multilayer



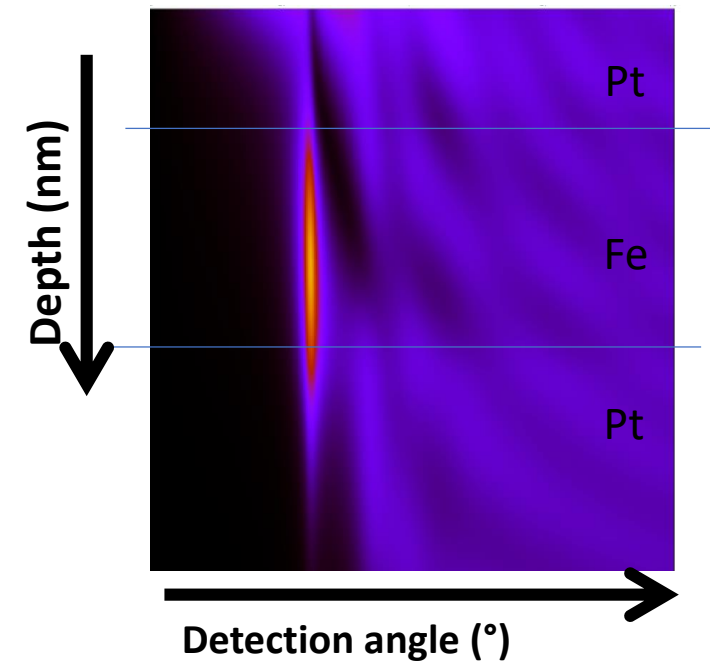
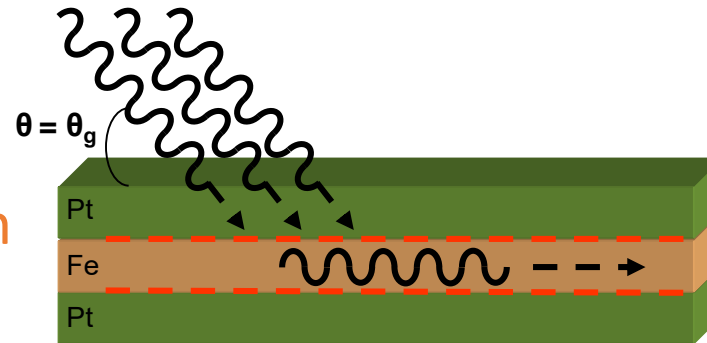
Depth distribution of the electric field

PIXE – Kossel

Study of a Pt/Fe/Pt waveguide

Planar x-ray waveguide

- A “light” guiding material between two “heavy” cladding materials
- Total reflection

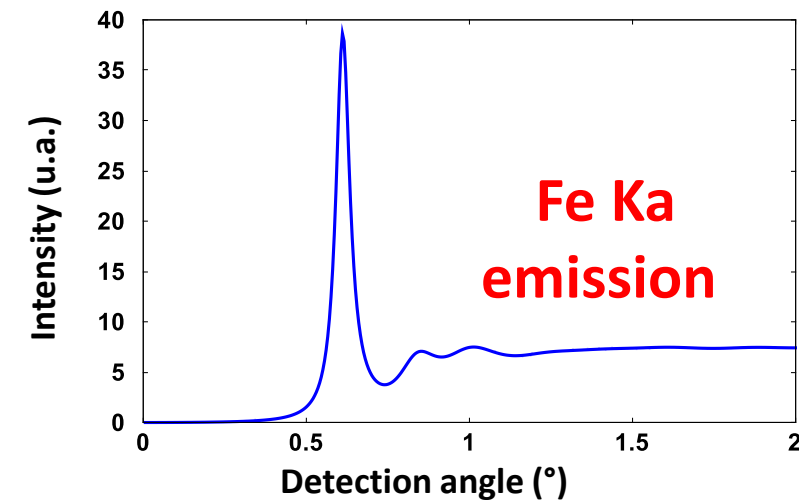


Simulations of the depth and angular distribution of the electric field and of the Kossel curve

Kossel curve: observation of the angular distribution of the emitted characteristic radiation

Modeling Kossel curves

depth distribution of the emitting atoms

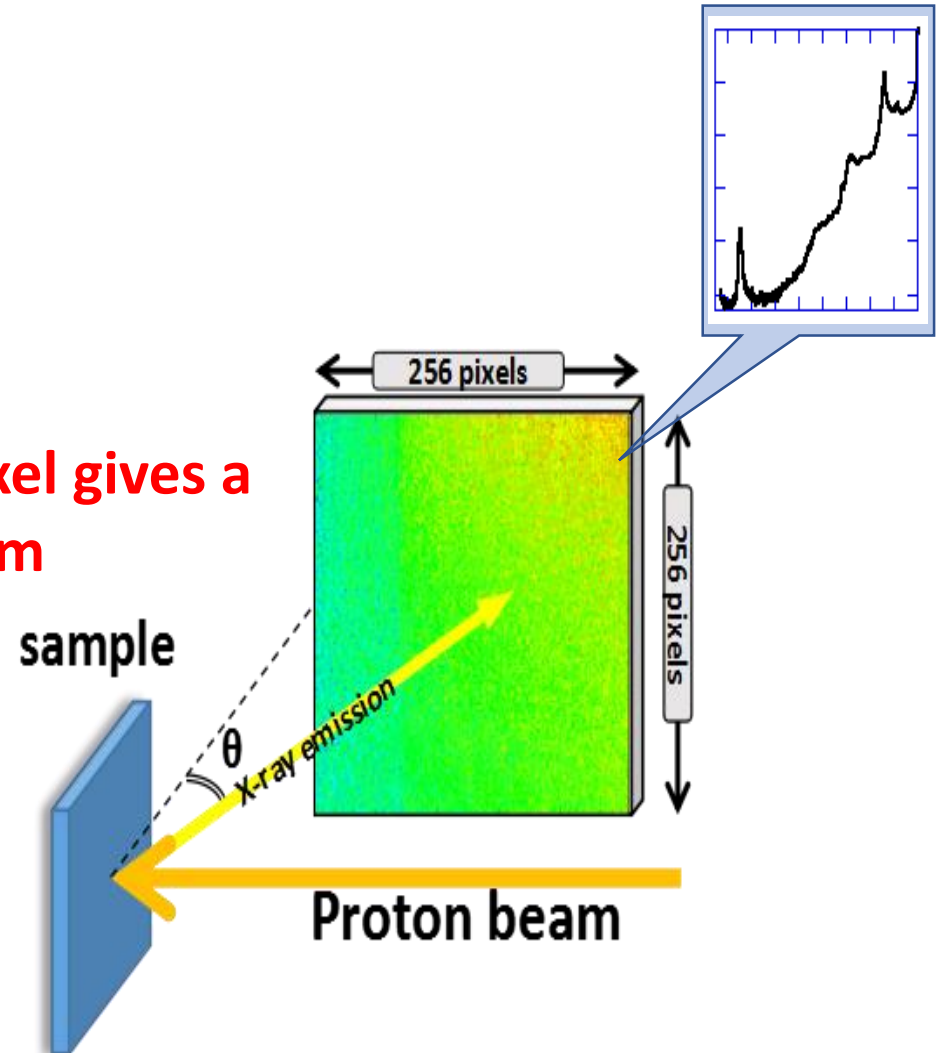
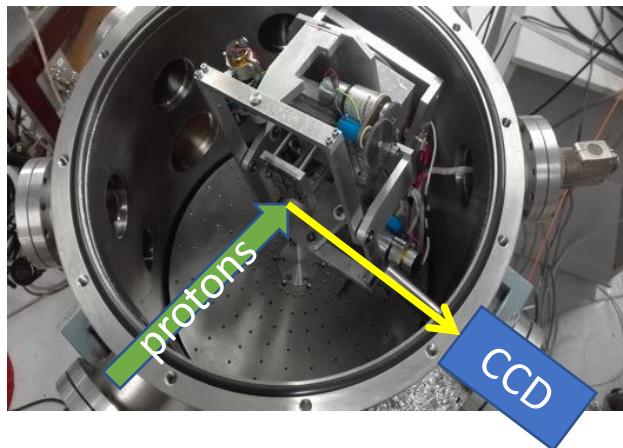


PIXE – Kossel

- **Experimental process**
- Be filter (protons dangerous for pixels)
- Bining 256 x 256 pixels (52 x 52 μm)
- No angular scan
- “Short” acquisition time, 2h

Each pixel gives a spectrum

Top view of the goniometric chamber



PIXE – Kossel

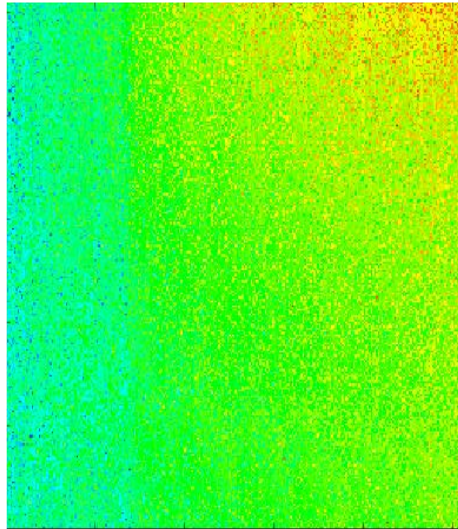
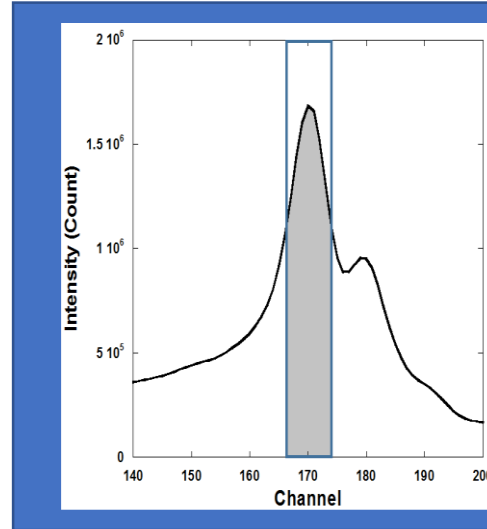
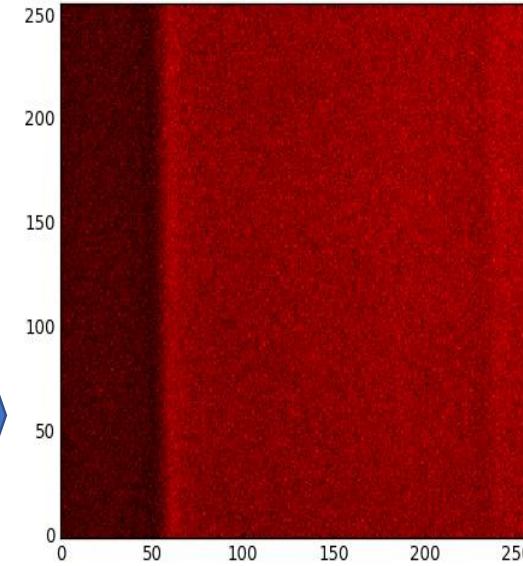


Image obtained with the intensity collected over the full spectral range

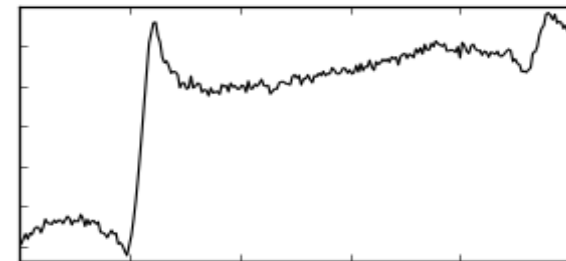


Selection of a spectral range (characteristic emission)



Spectral image

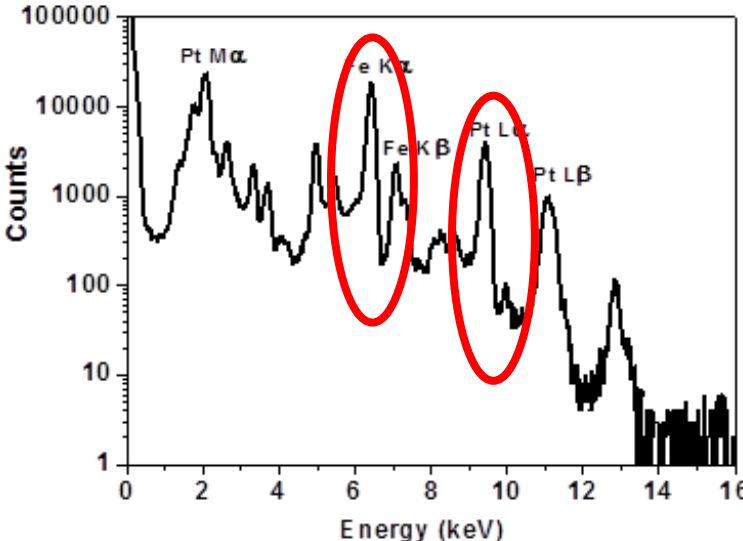
Column integration



Detection angle

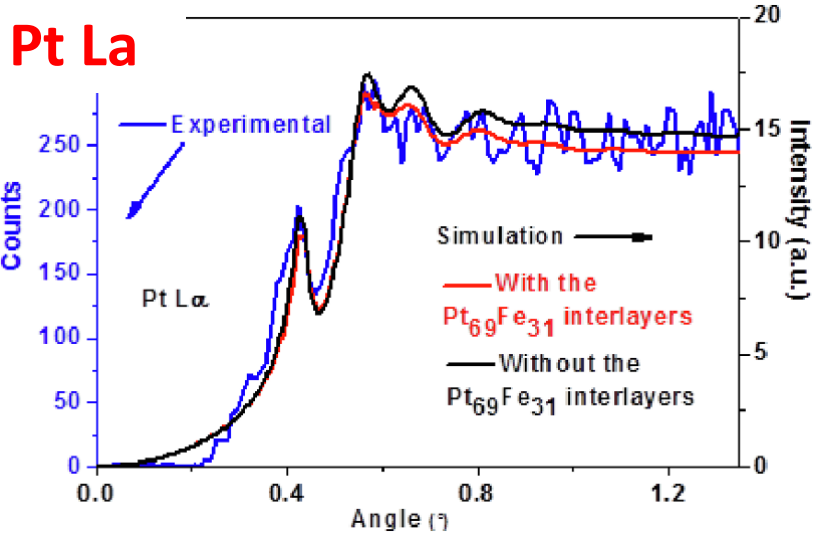
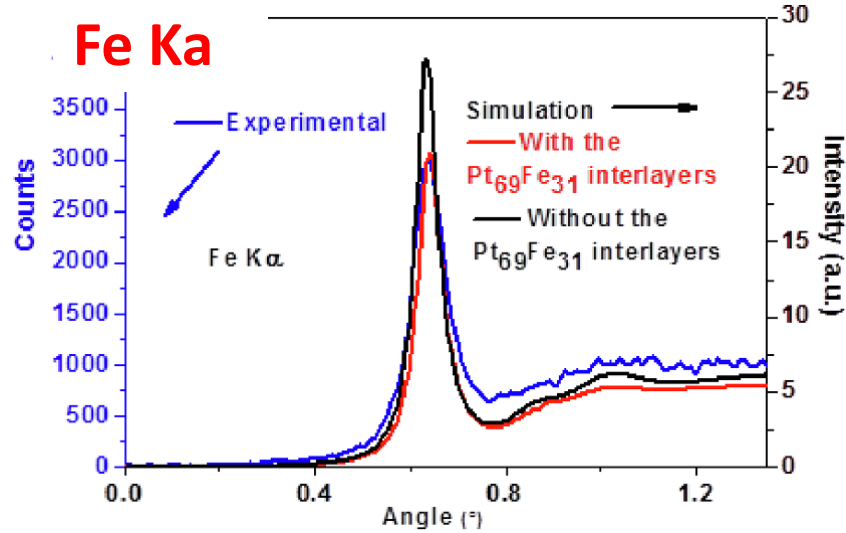
Kossel curve
Angular distribution of the intensity of a characteristic x-ray line

PIXE – Kossel

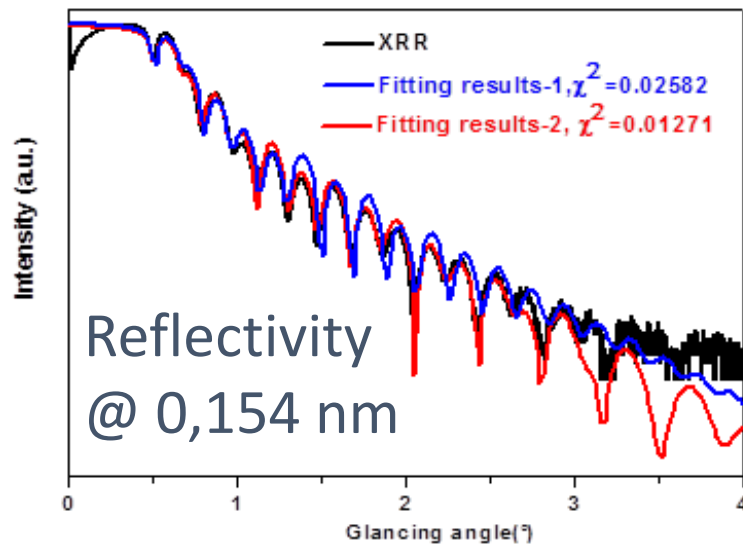
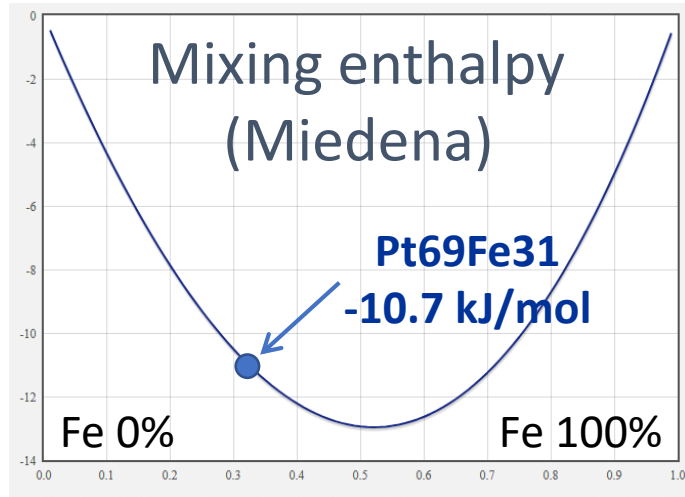


X-ray spectrum of the **Pt/Fe/Pt waveguide**
Fe Ka and Pt La emissions

Kossel curves



PIXE – Kossel



Structure with 5 layers
Pt / PtFe / Fe / PtFe / Pt

	Thickness / Roughness (nm) (± 0.05 nm)	Density (g/cm ³)
Pt	3.83 / 0.57	bulk
Pt ₆₉ Fe ₃₁	1.62 / 0.90	16 \pm 2
Fe	5.19 / 1.20	bulk
Pt ₆₉ Fe ₃₁	1.41 / 0.79	16 \pm 2
Pt	10.25 / 0.39	bulk
Si substrate	- / 0.50	bulk

Interfaces PtFe
 ≈ 1.5 nm

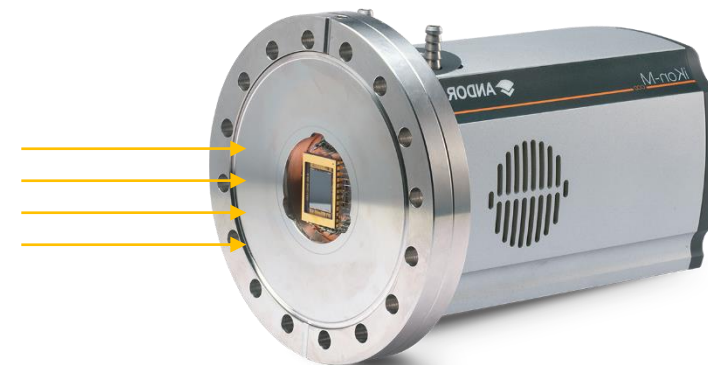
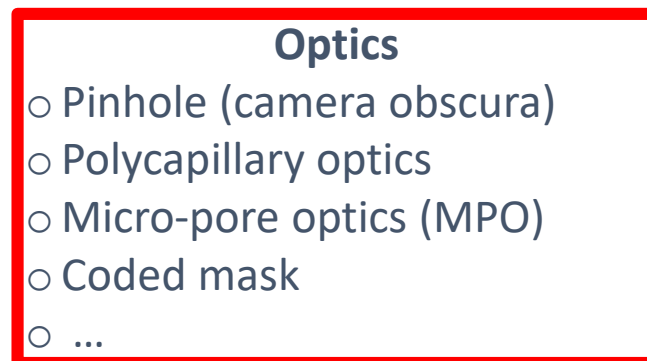
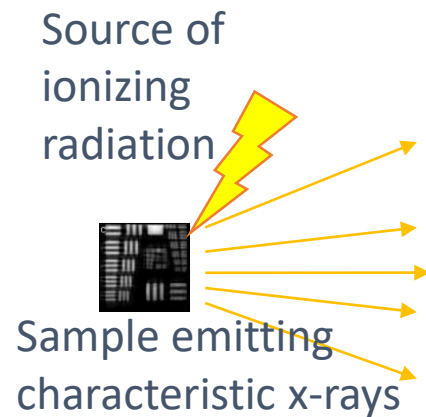
Energy dispersive CCD camera

PIXE – Kossel

Spectral imaging

Spectral imaging

- **Full field x-ray fluorescence X (FF-XRF) in fact FF-PIXE!**
- Spectral imaging without scanning of the beam or sample
- Isotropic radiation of the characteristic emission
- Need to put an optics between the emitting sample and the detector (CCD camera)
- So that one pixel of the CCD corresponds to one point of the sample

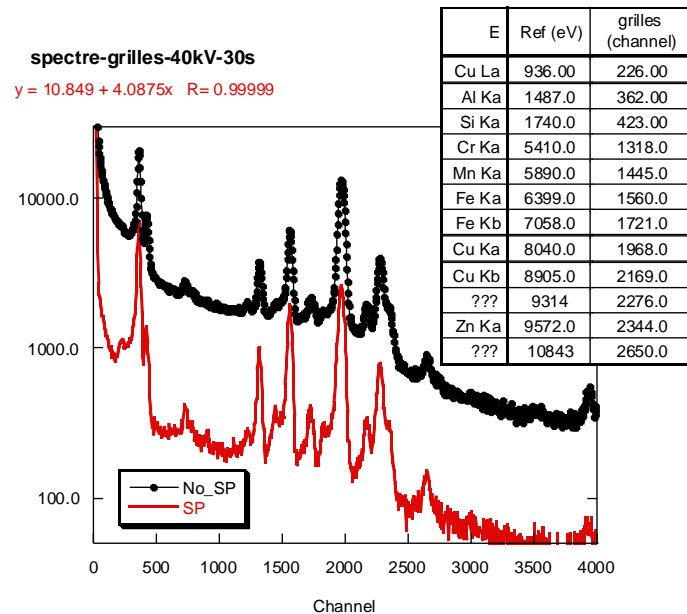


Spectral imaging

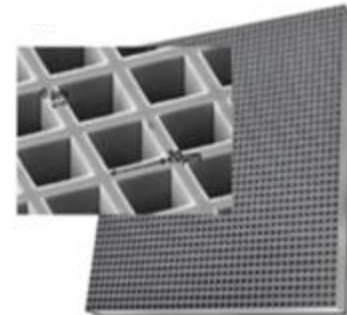
- First try with MPO at LCPMR with an x-ray tube (30 kV – 400 μA – 2h) FF-XRF



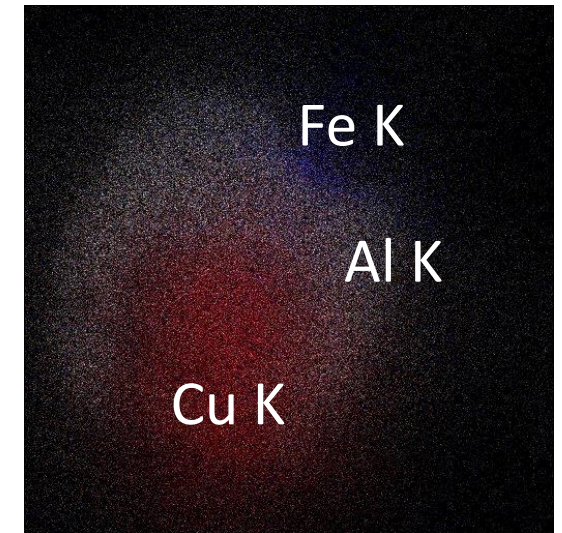
- Visible image
- Copper grid
 - Al sample holder
 - Iron screws



Emitted x-ray
 characteristic
 emissions



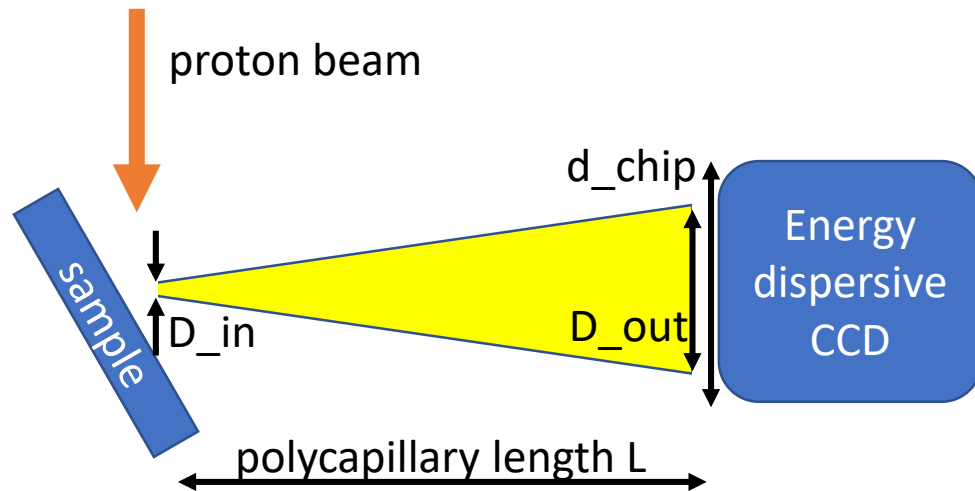
MPO



X-ray image
 Lot of scattered radiation
 Poor spatial resolution

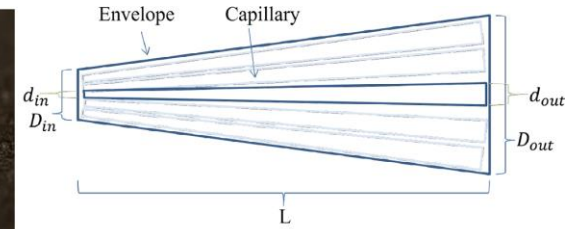
Spectral imaging

• Project with a conical polycapillary



Spatial resolution depends on

- Size of pixels
- Diameter of capillaries
- Magnification
- Aberrations, ...



Magnification	20–40
D_{in} [mm]	0.42 ± 0.02
D_{out} [mm]	6.56–0.2
d_{in} [μm]	0.5 ± 0.5
d_{out} [μm]	7 ± 0.5
L [mm]	$53.34 - 0.5 \pm 0.2$

We expect

- Spatial resolution $1 \mu\text{m}$
- Large field of view $1 \text{ mm} \times 1 \text{ mm}$
- Short acquisition time min to h
- Qualitative and quantitative mapping
- No scanning
- Study of geochemical markers of the environment obtained from biogenic carbonates (mollusc shells)

Conclusion

- X-ray energy dispersive CCD is a versatile instrument
spectroscopy – imaging
- PIXE-KOSSEL not only limited to periodic multilayers
analysis of stacks of nanometer thin films
- Imaging possible without scanning
short acquisition time
large number of count – quantitative maps
possibility to deploy this tools on electron microscopes



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