ComIXS on Bach:

a compact soft x-ray spectrometer operating at Elettra

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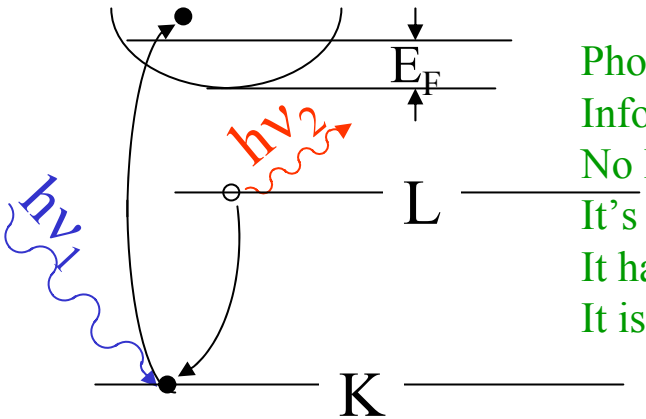
Carl Zeiss

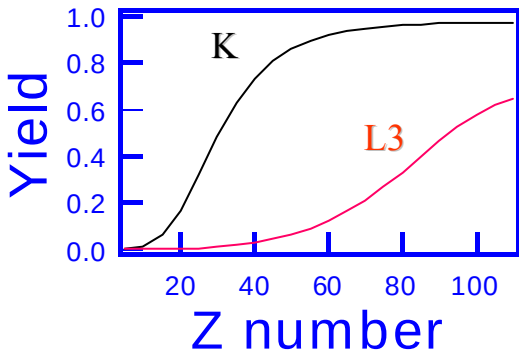
Eighth International Conference
on Synchrotron Radiation Instrumentation
August 25-29 2003 Yerba Buena Arts Center, San Francisco

SXES, RIXS and Low Count Rate



Photon in Photon out technique. (2nd order optical process)
Information on the electronic structure of insulator, semiconductors
No Magnetic or Electric field influenced
It's bulk sensitive and probe structure of buried interfaces
It has elemental, chemical and orbital symmetry sensitivity
It is no sensitive to the surface contamination

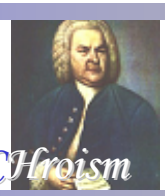
Fluorescence yield typically very low
Photons emitted on a very large solid angle
Necessity to energetically separate the emitted photons
Necessity to have monochromatized high bright source



Did You attend the presentation of M. Zangrando on Monday?

BACH

Beamline for Advanced diCHroism



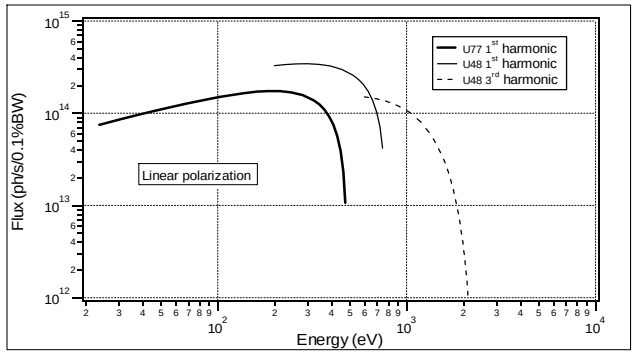
ComIS

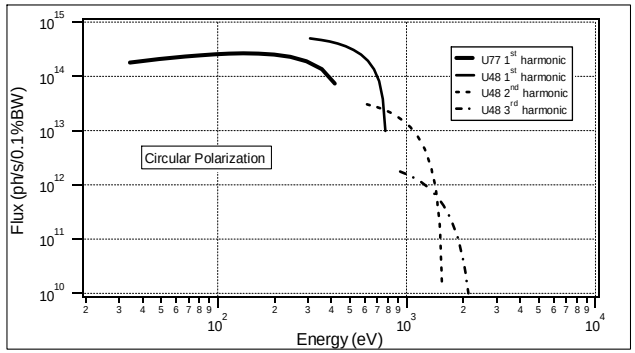
Insertion Devices

2 Taperable

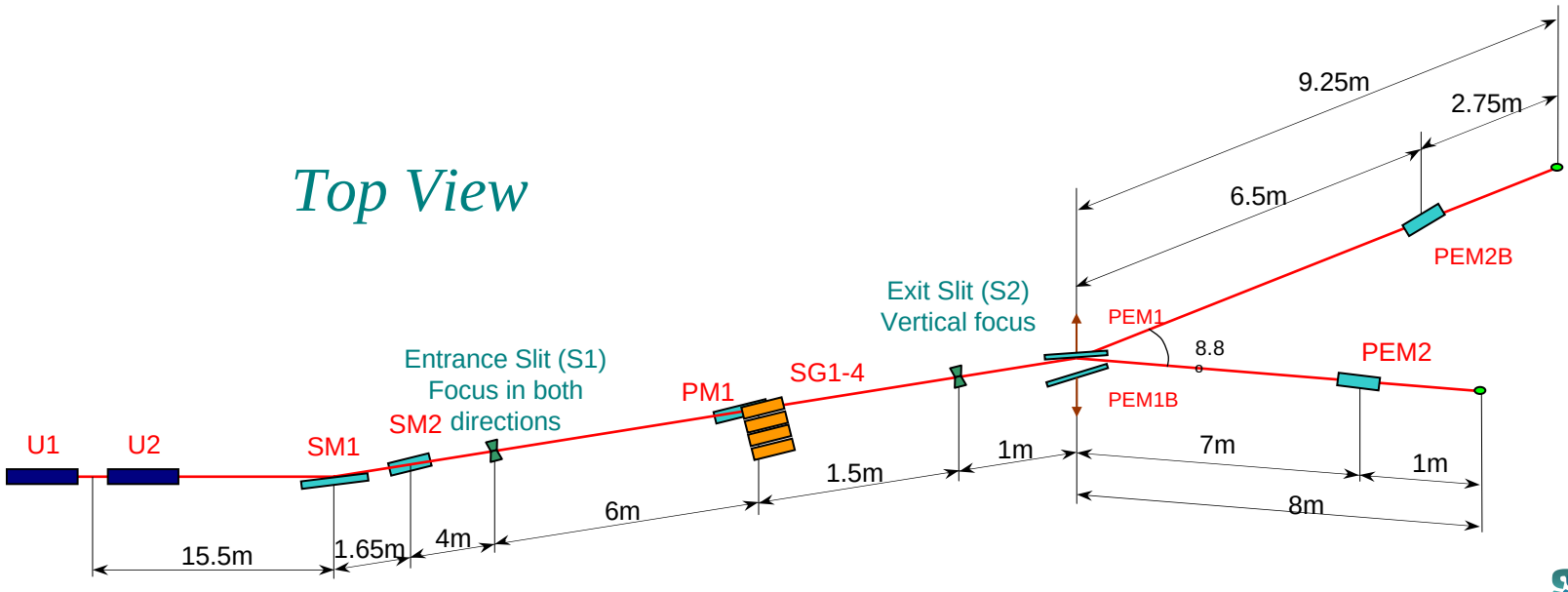
Helical Undulators:

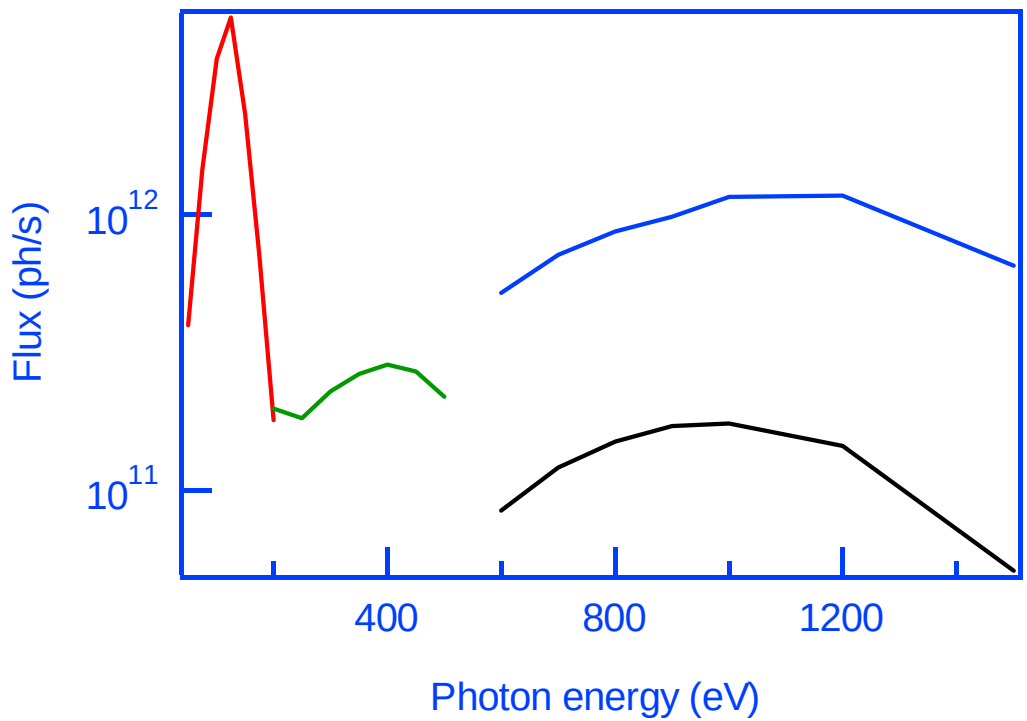
Period: 77 and 48 mm





Top View





On a spot of
300X12 μm FWHM

Spectrometer requirements

High angular acceptance & high efficiency

Good energy resolving power (>2000)

Compact and mechanically simple

Large photon energy range (20-1200eV)

To collect as much photons as possible

Spectrometer requirements

High angular acceptance & high efficiency

Good energy resolving power (>2000)

Compact and mechanically simple

Large photon energy range (20-1200eV)

To distinguish the chemical state of the atoms.

Compromise between high resolution requirement and high flux and semplicity

Spectrometer requirements

High angular acceptance & high efficiency

Good energy resolving power (>2000)

Compact and mechanically simple

Large photon energy range (20-1200eV)

To be mounted on different chambers (with the chance to rotate), and to be easy to be aligned and calibrated

Spectrometer requirements

High angular acceptance & high efficiency

Good energy resolving power (>2000)

Compact and mechanically simple

Large photon energy range (20-1200eV)

To study the K,L and M threshold on most common materials

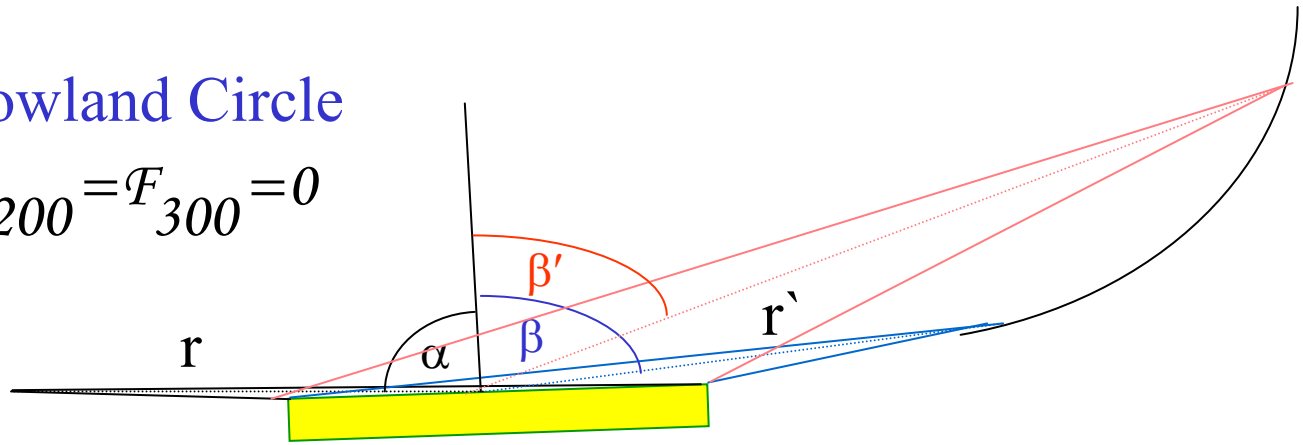
How to do it?

Nordgren, J., Bray, G., Cramm, S., Nyhlom, R., Rubensson, J.E., Wassadhal, N., Rev. Sci. Instrum. 60, 1690 (1989)

Calcott, T.A., Tsang, K.L., Zhang, C.H., Ederer, D.L., Arakawa, E.T., Rev. Sci. Instrum. 57, 2680 (1986)

Rowland Circle

$$\mathcal{F}_{200} = \mathcal{F}_{300} = 0$$



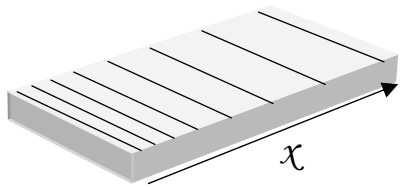
$$r = \mathcal{R}\cos\alpha \qquad r' = \mathcal{R}\cos\beta$$

VLS grating

Groove density D varies along the grating surface: $\mathcal{D}(x) = \mathcal{D}_0 + \mathcal{D}_1 x + \mathcal{D}_2 x^2 + \mathcal{D}_3 x^3 + \cdots$

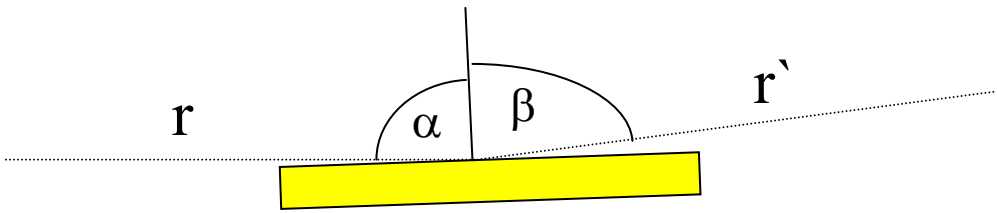
$$\mathcal{F}_{200} = \frac{1}{2}\left(-n\lambda\mathcal{D}_1 + \left(\cancel{\frac{\cos^2\alpha}{r} - \frac{\cos\alpha}{\mathcal{R}}} + \frac{\cos^2\beta}{r'} - \frac{\cos\beta}{\mathcal{R}}\right)\right)$$

$$\mathcal{F}_{300} = -\frac{1}{3}n\lambda\,\mathcal{D}_2 + \frac{1}{2}\left[\left(\cancel{\frac{\cos^2\alpha}{r} - \frac{\cos\alpha}{\mathcal{R}}}\right)\frac{\sin\alpha}{r} + \left(\frac{\cos^2\beta}{r'} - \frac{\cos\beta}{\mathcal{R}}\right)\frac{\sin\beta}{r'}\right]$$



If distance source-grating and angle of incidence are kept constant i.e. $\mathcal{R} = \frac{r}{\cos\alpha}$

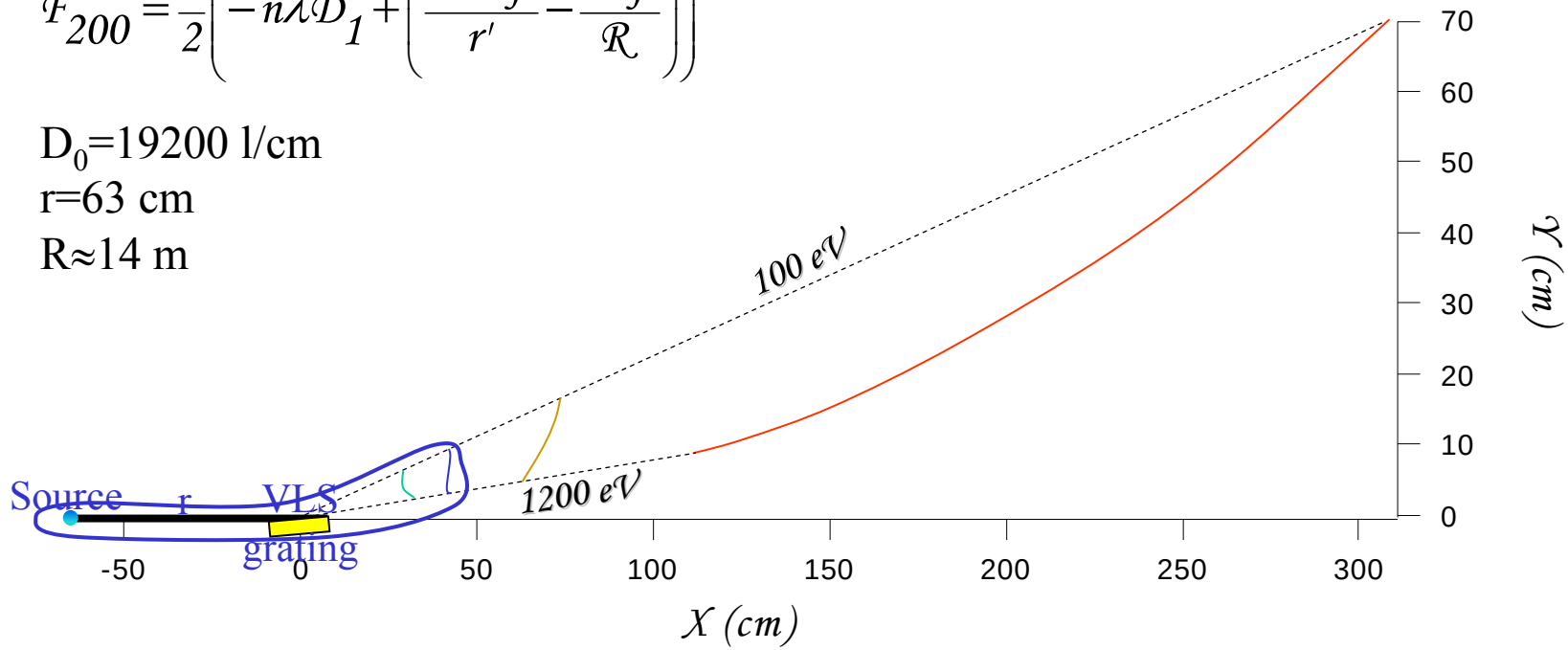
$$\mathcal{F}_{200} = \frac{1}{2}\left(-n\lambda\mathcal{D}_1 + \left(\frac{\cos^2\beta}{r'} - \frac{\cos\beta}{\mathcal{R}}\right)\right) = 0 \Longrightarrow r' = f\left(\beta(\lambda), \mathcal{D}_1\right)$$



Effect of $\mathcal{D}_1$

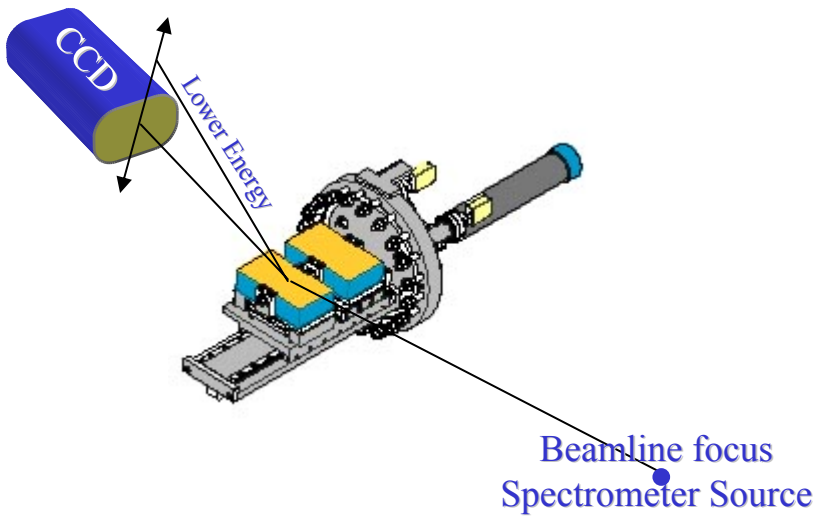
$$\mathcal{F}_{200} = \frac{1}{2}\left(-n\lambda\mathcal{D}_1 + \left(\frac{\cos^2\beta}{r'} - \frac{\cos\beta}{\mathcal{R}}\right)\right)$$

D_0=19200 l/cm
r=63 cm
R≈14 m

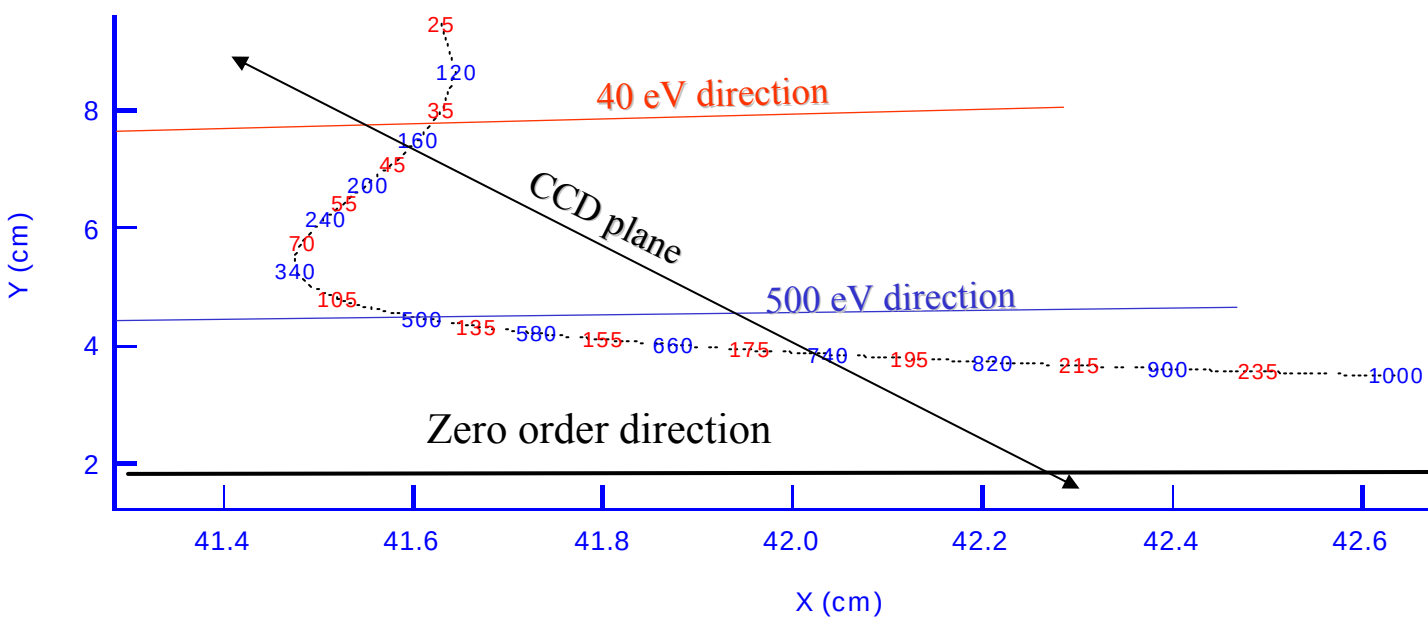


D_1=0 **D_1=400 l/cm²** **D_1=800 l/cm²** **D_1=1200 l/cm²**

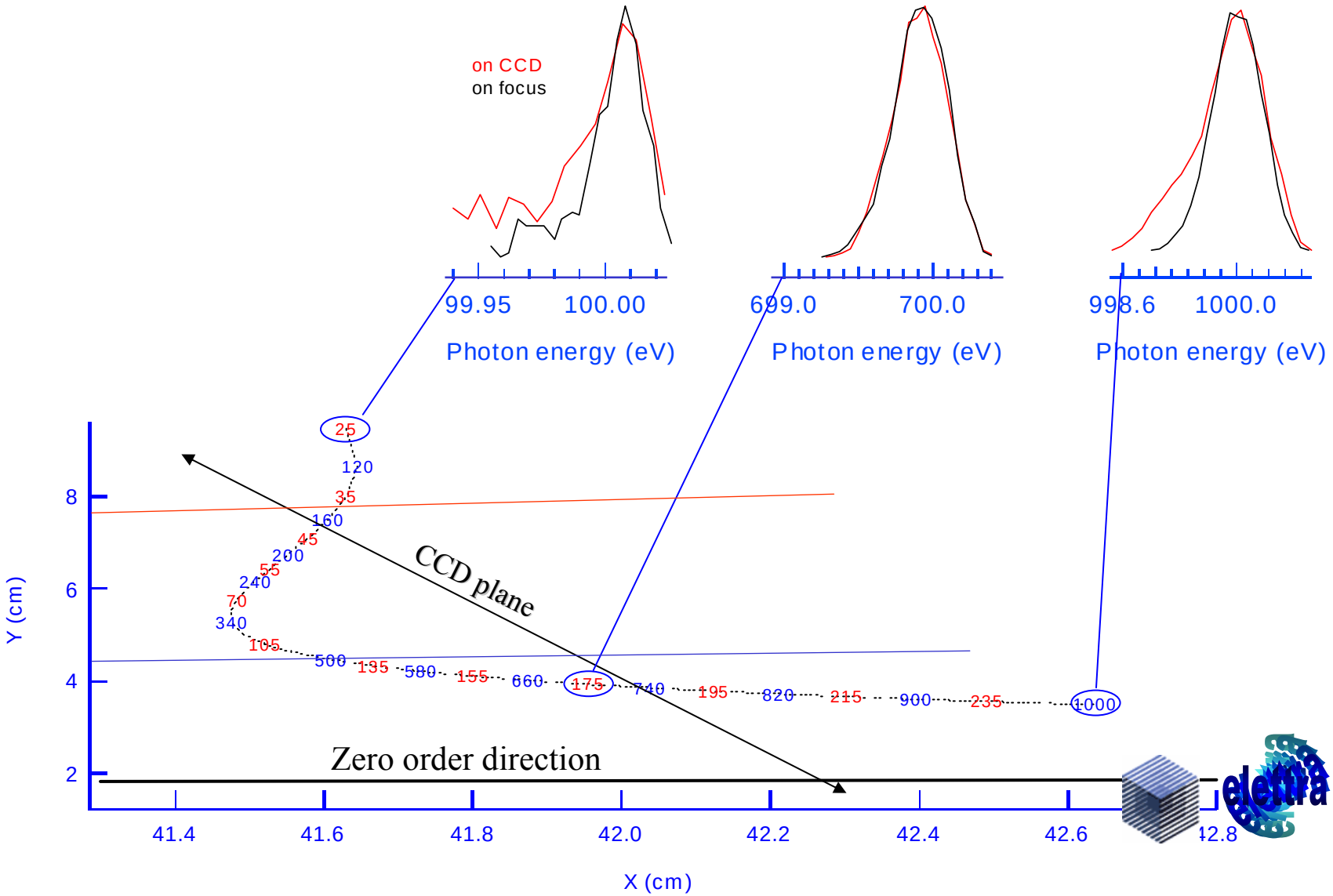
ComIXS layout



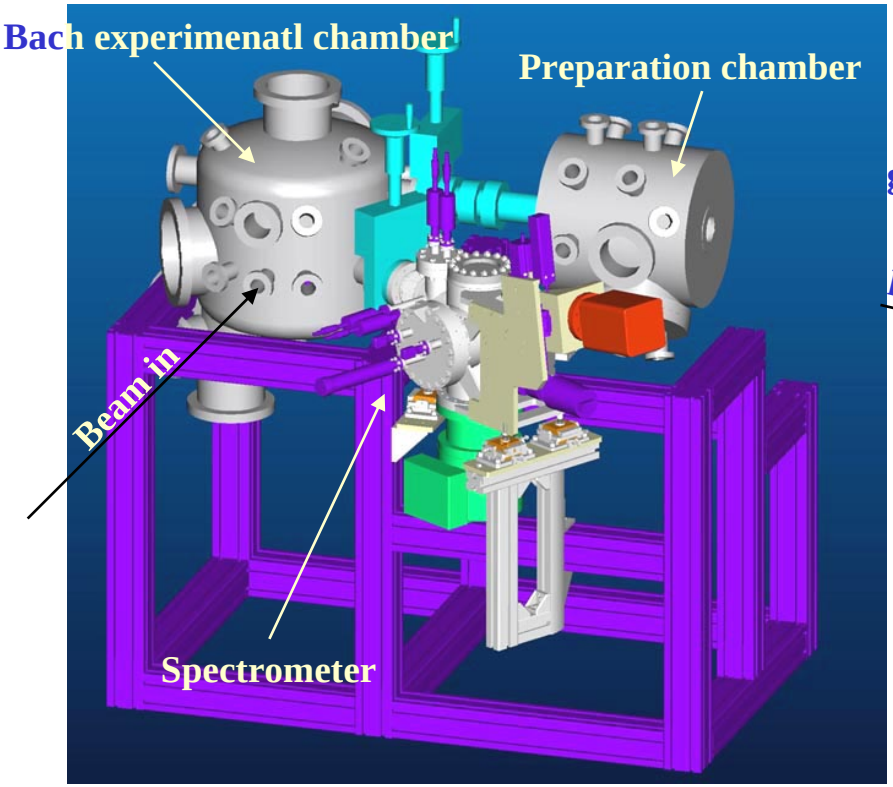
Distance sample grating (cm)	63	
Distance grating CCD (cm)	variable ≈ 42	
Angle of incidence(deg)	87.48	
radius of curvature (cm)	1432.7	
	LEG	HEG
Energy range (eV)	**25-200**	**100-1200**
D_0 (l/cm)	**4800**	**19200**
D_1 (l/cm^2)	**200**	**800**
D_2 (l/cm^3)	**7.5**	**30**

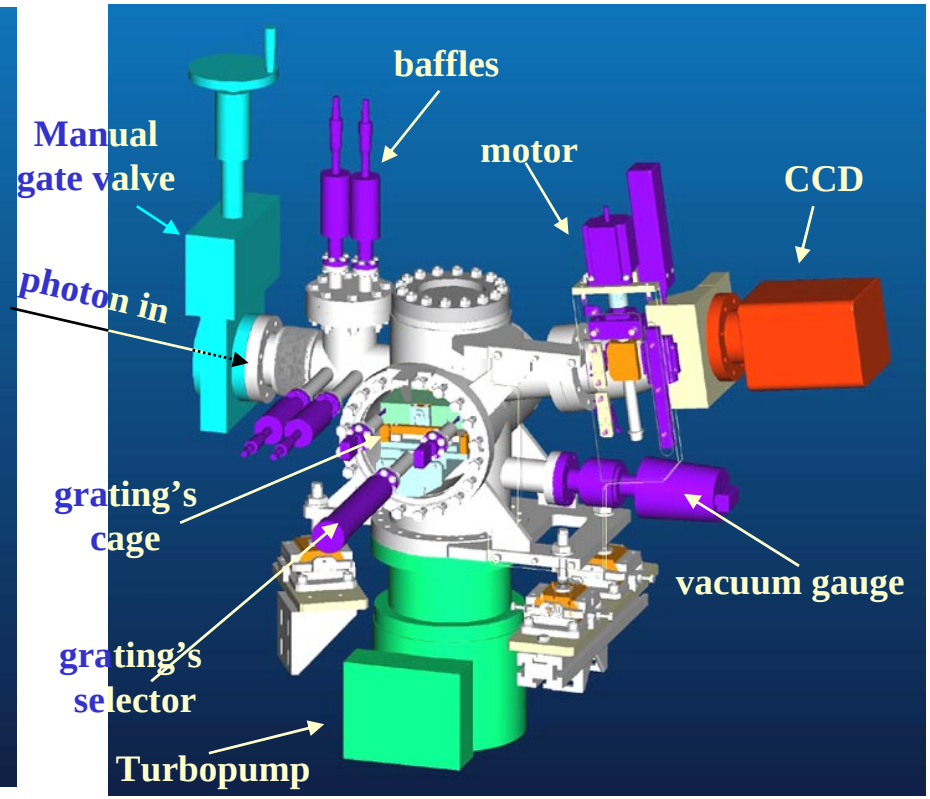


Spot enlargement



Mechanical Layout

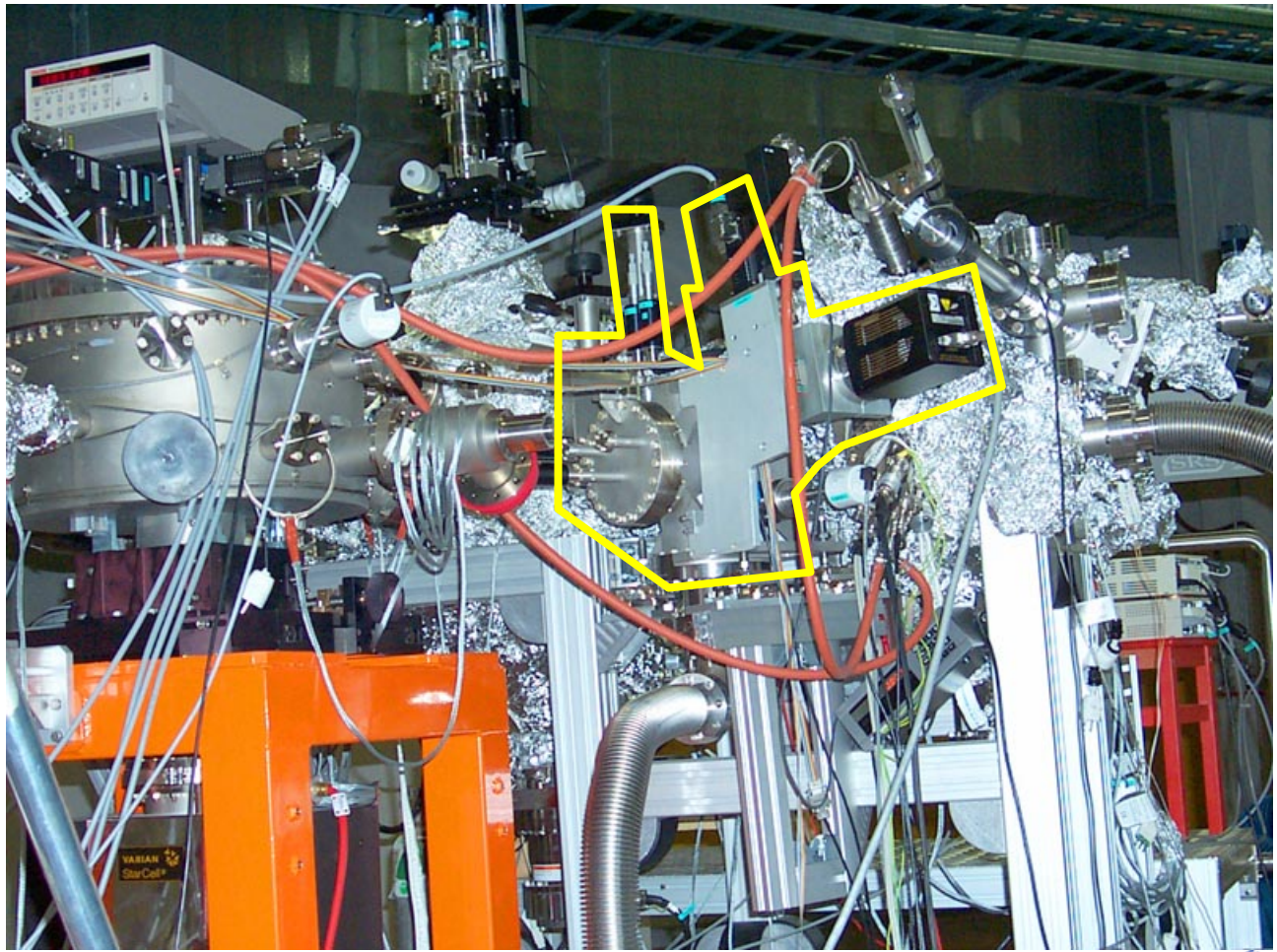




Mechanical parts produced by

STRUMENTI SCIENTIFICI CINEL®

ComIXS picture



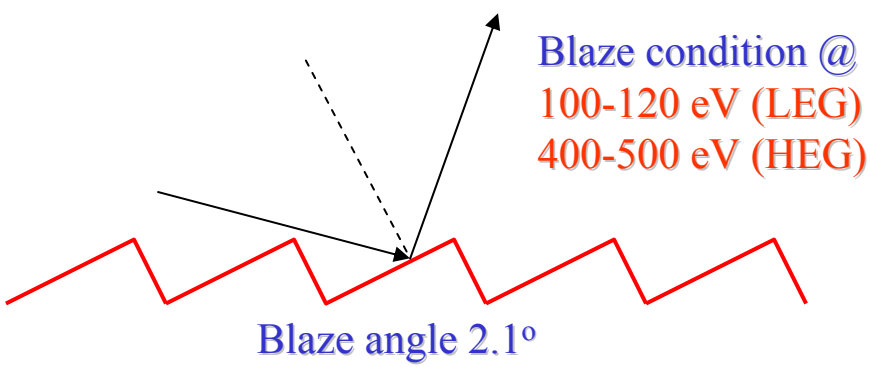
Gratings Production

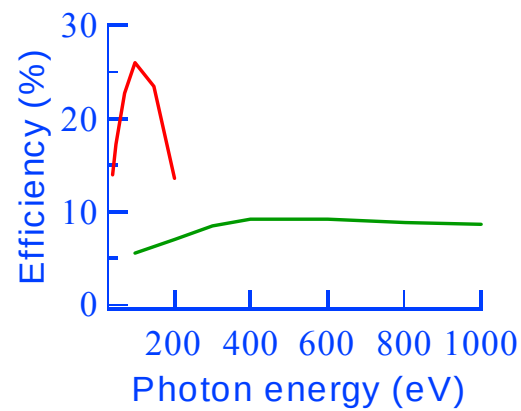
HE grating parameter: groove density = 19200 l/cm

g.d. variation = 800 l/cm^2 → 16000 < gd < 24000 l/cm

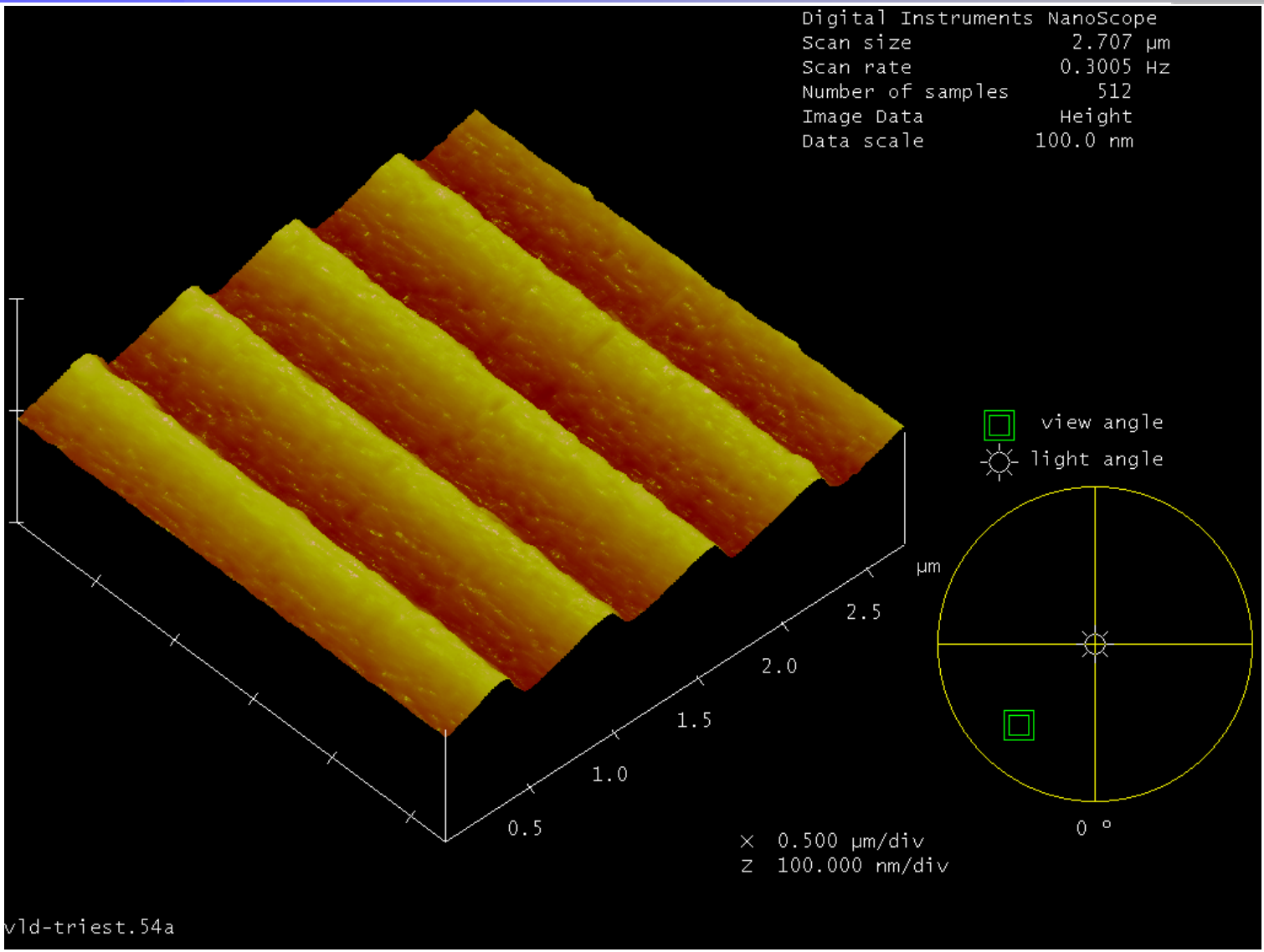
g.d. 3rd order = 30 l/cm^3

Mechanically ruled (CARL ZEISS Grating Ruling Engine GTM6) with blazed profile:
To have higher efficiency and to have the chance to use higher diffraction orders



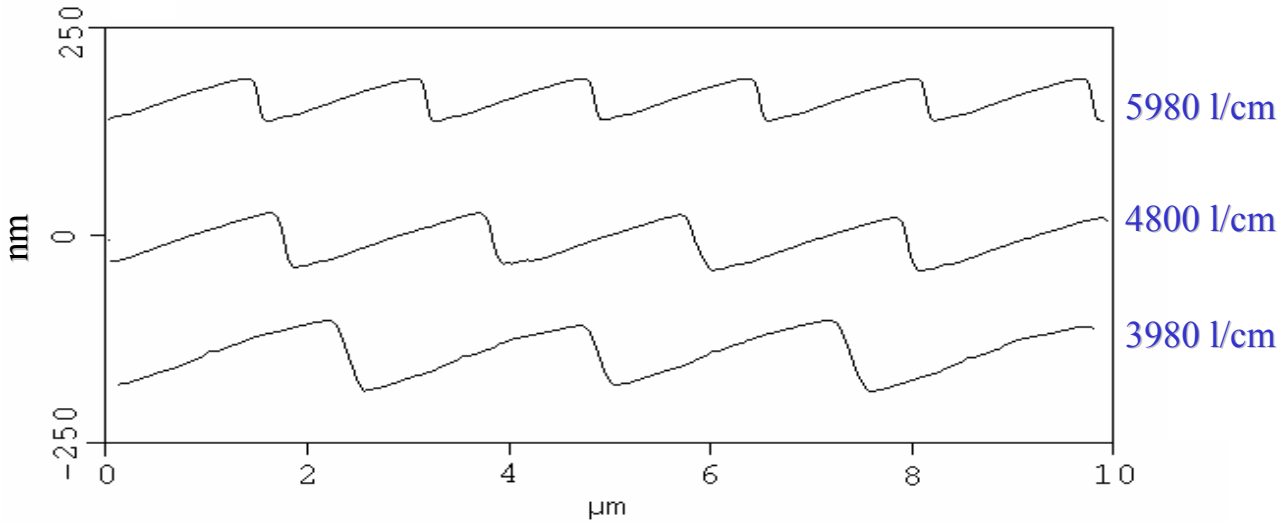


Gratings test

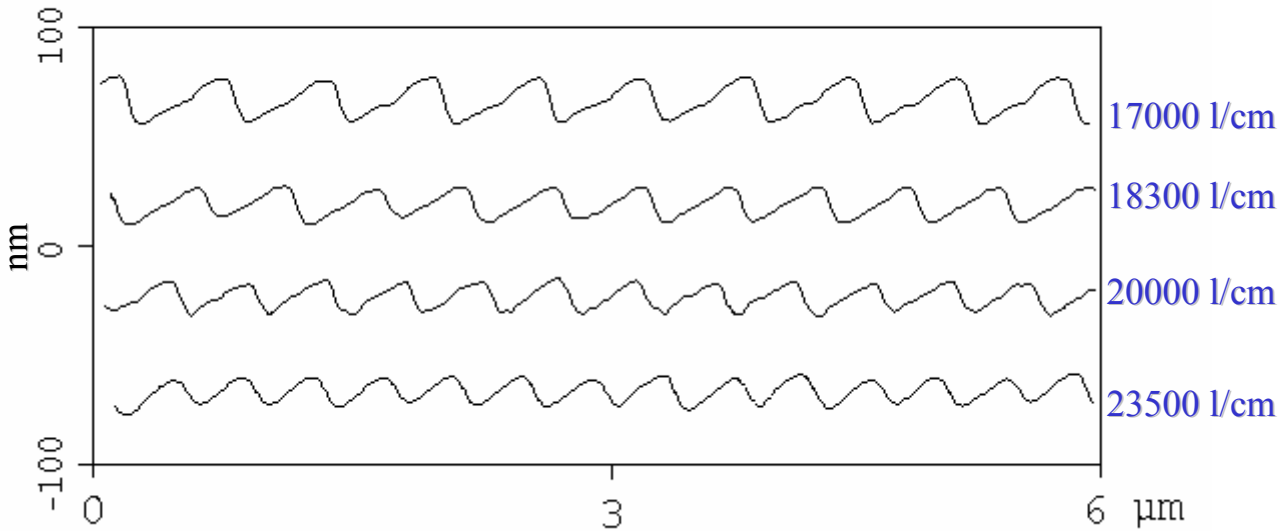


Grooves profile

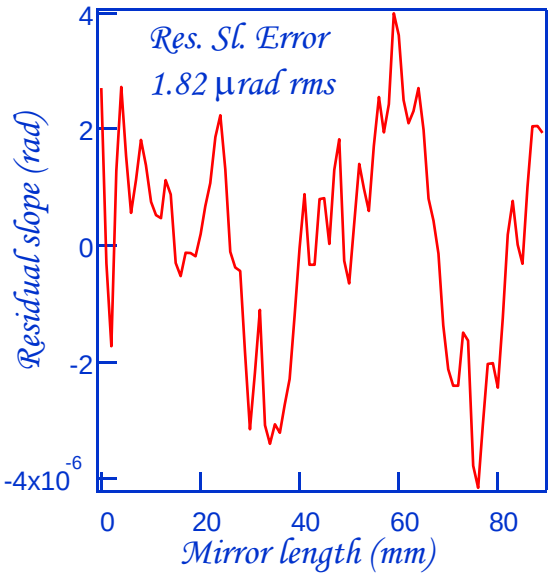
L.E.G

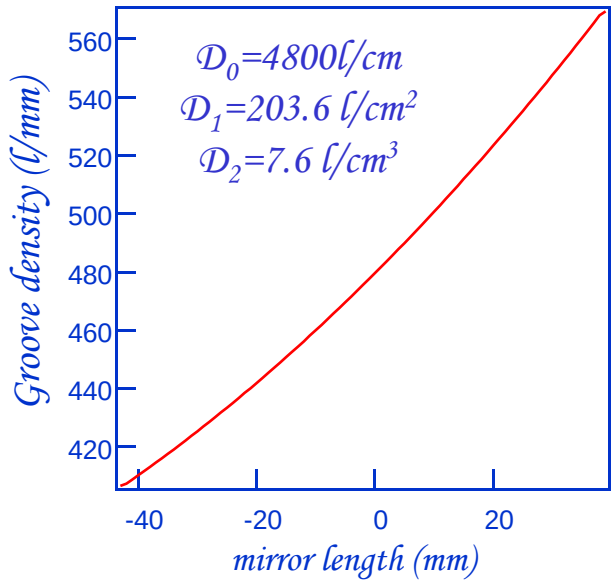


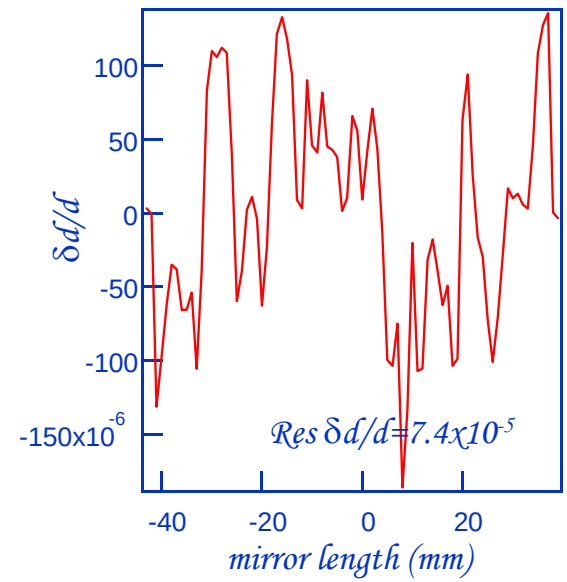
H.E.G

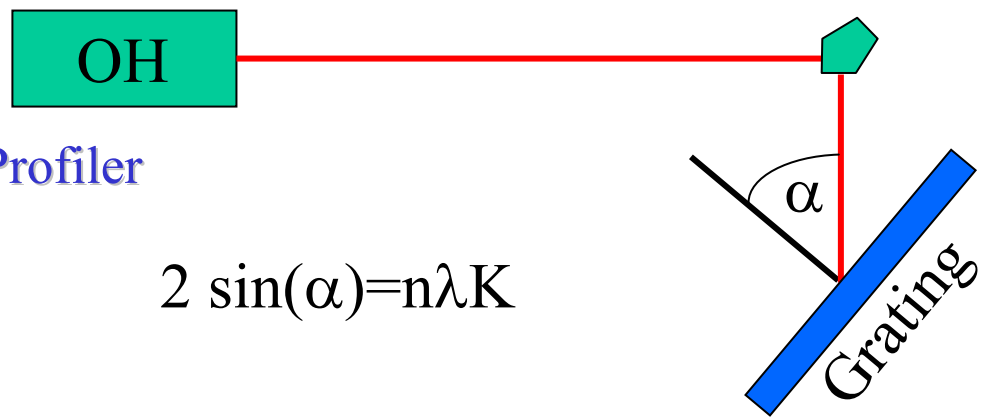


L.T.P. L.E.G. measurement





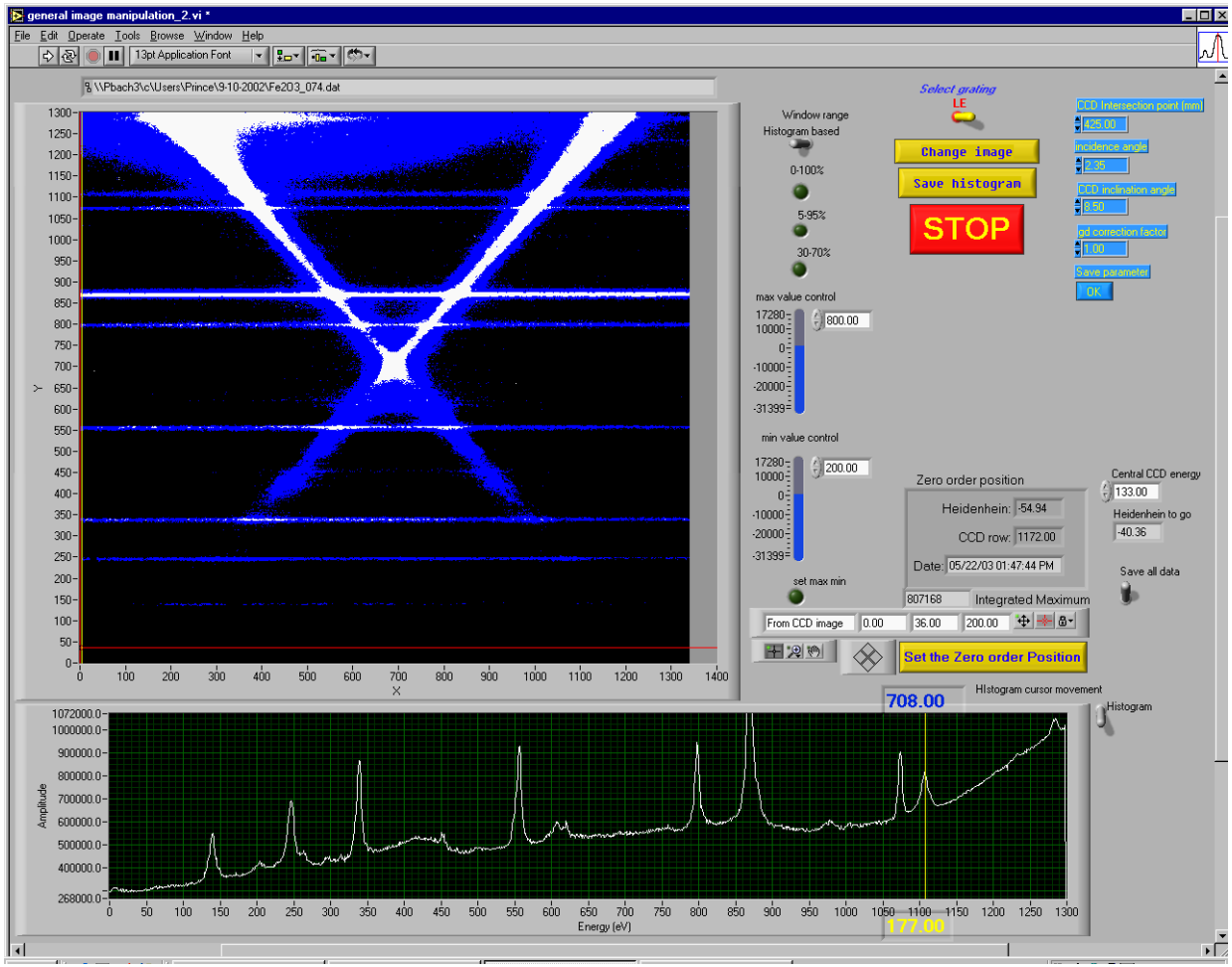


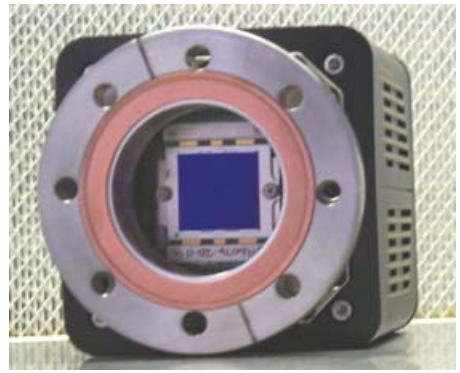


Long Trace Profiler

$$2\sin(\alpha)=n\lambda K$$

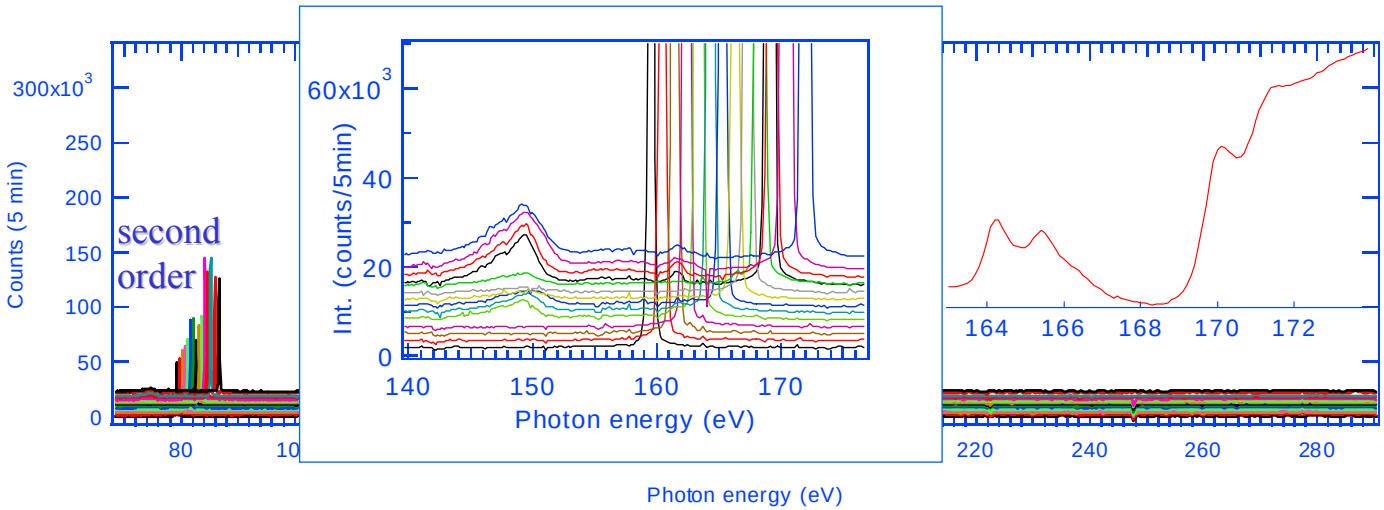
Detector



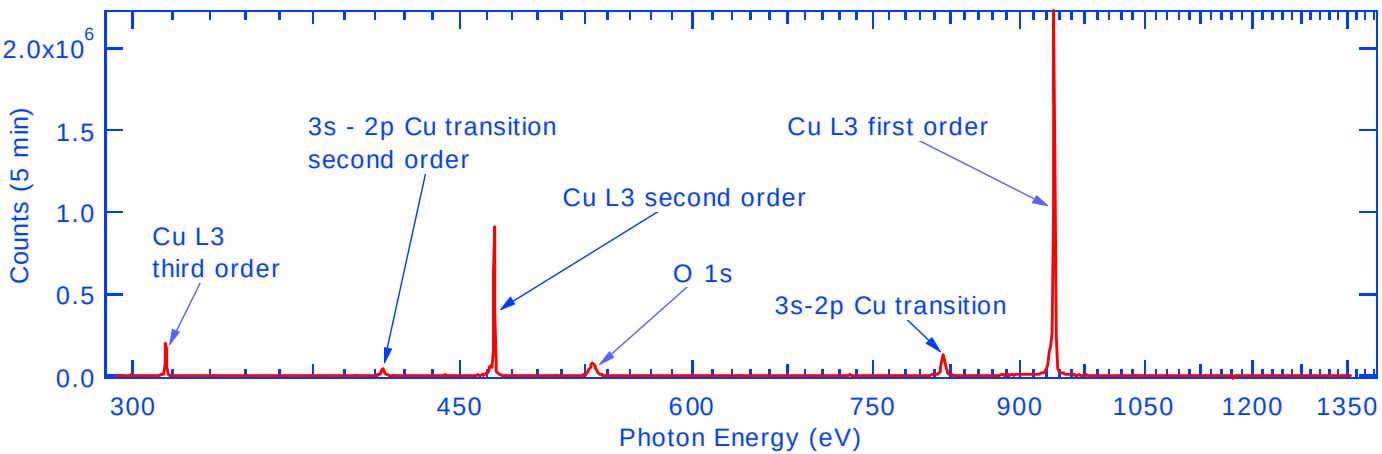


Princeton Instruments
SX TE 1300/CCD PB/1
Back Illuminated CCD (QE 0.5-0.9)
1340X1300 pixels
20X20 μm^2
26.8x26 mm^2 useful area
Peltier cooling (-50°)
In house UHV modified

Energy window



Low Energy Grating
FeS2 Sample
Resonant Emission series of S 2p
Vertical polarization

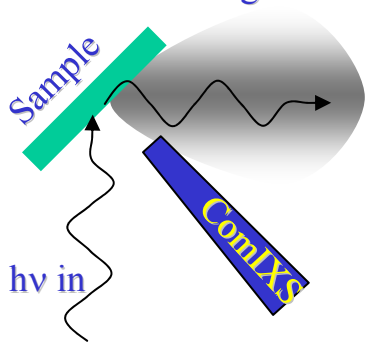


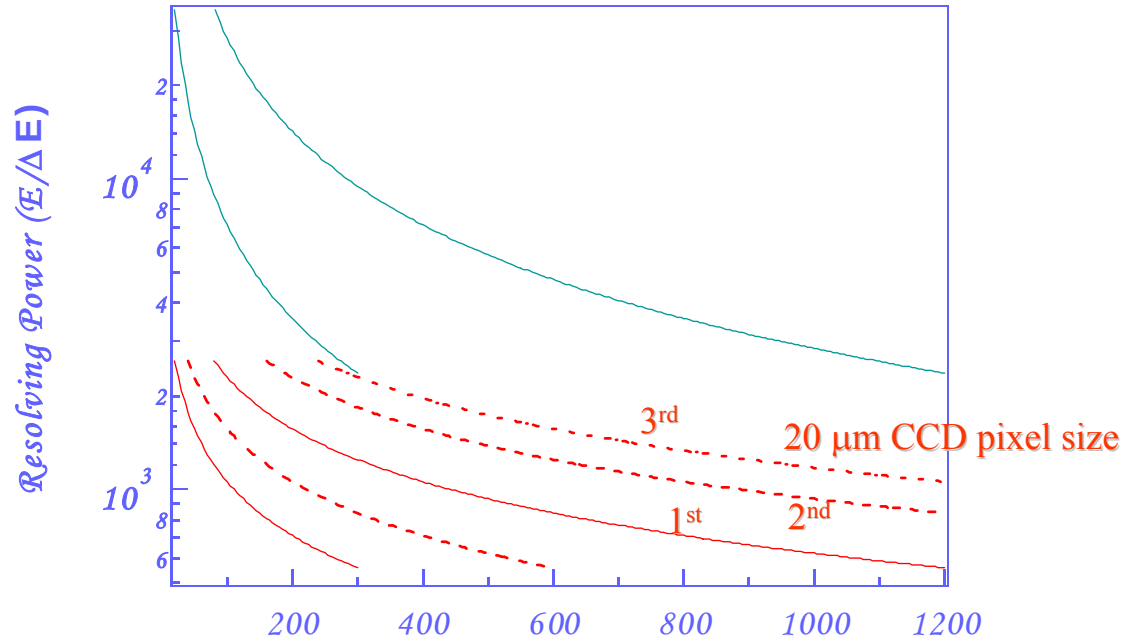
High energy grating
$CuSi_{0.1}Ge_{0.9}O3$
Vertical polarizations

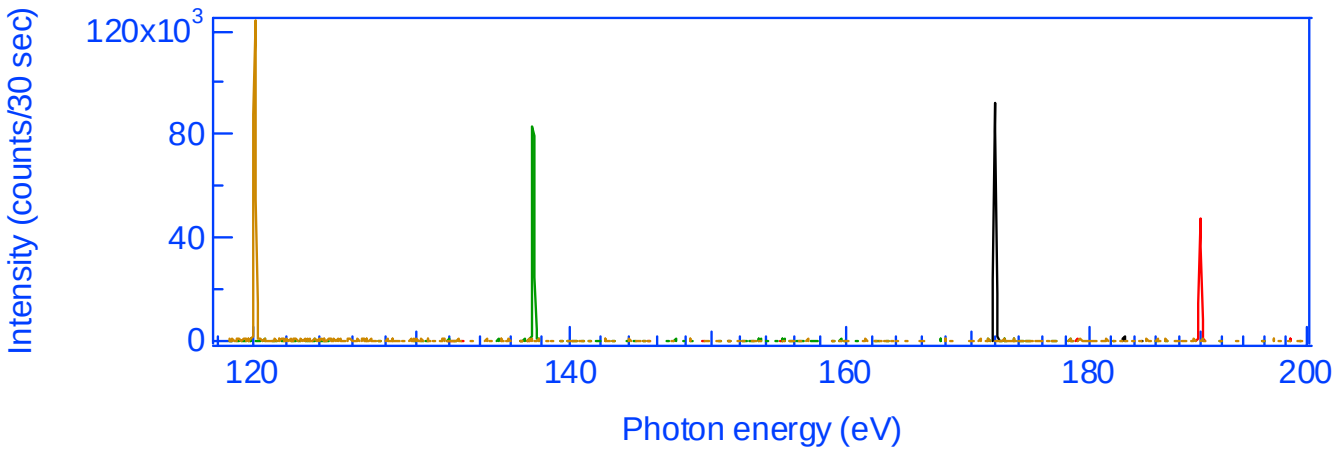
Energy resolution

No entrance slit 12 μm spot size

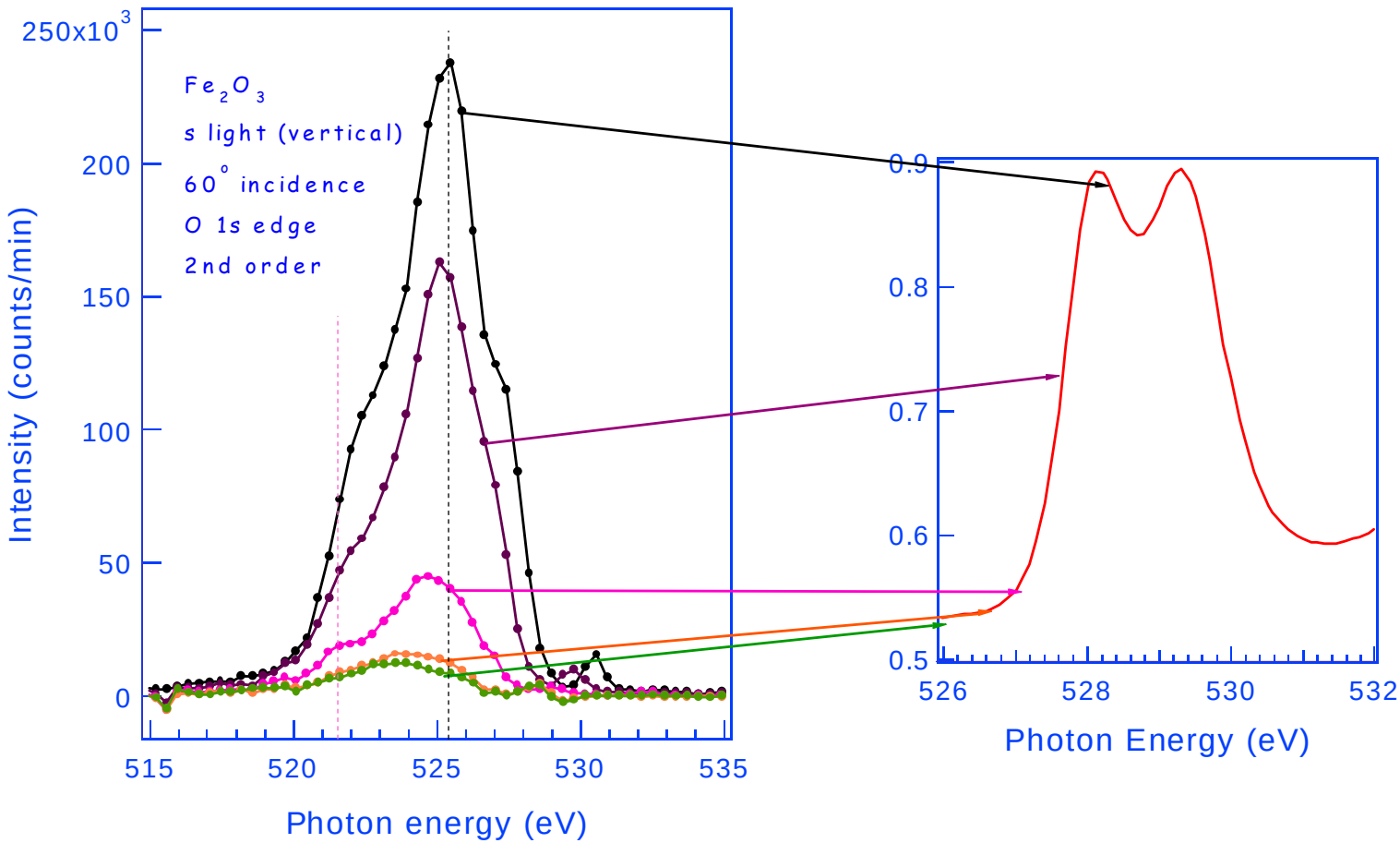
Diffuse peak
Light scattered by
surface micro roughness







Resonant measurement (Fe_2O_3)



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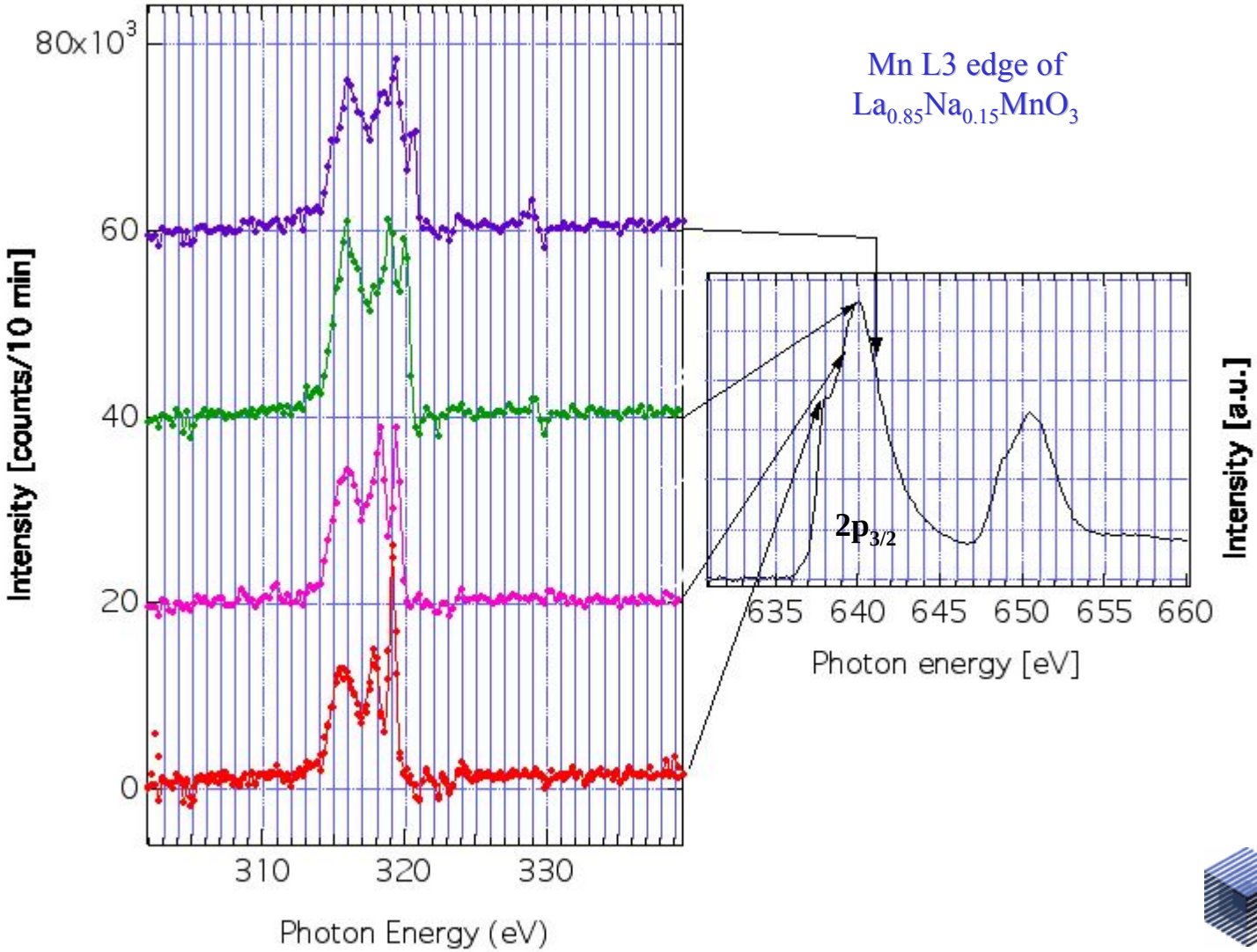
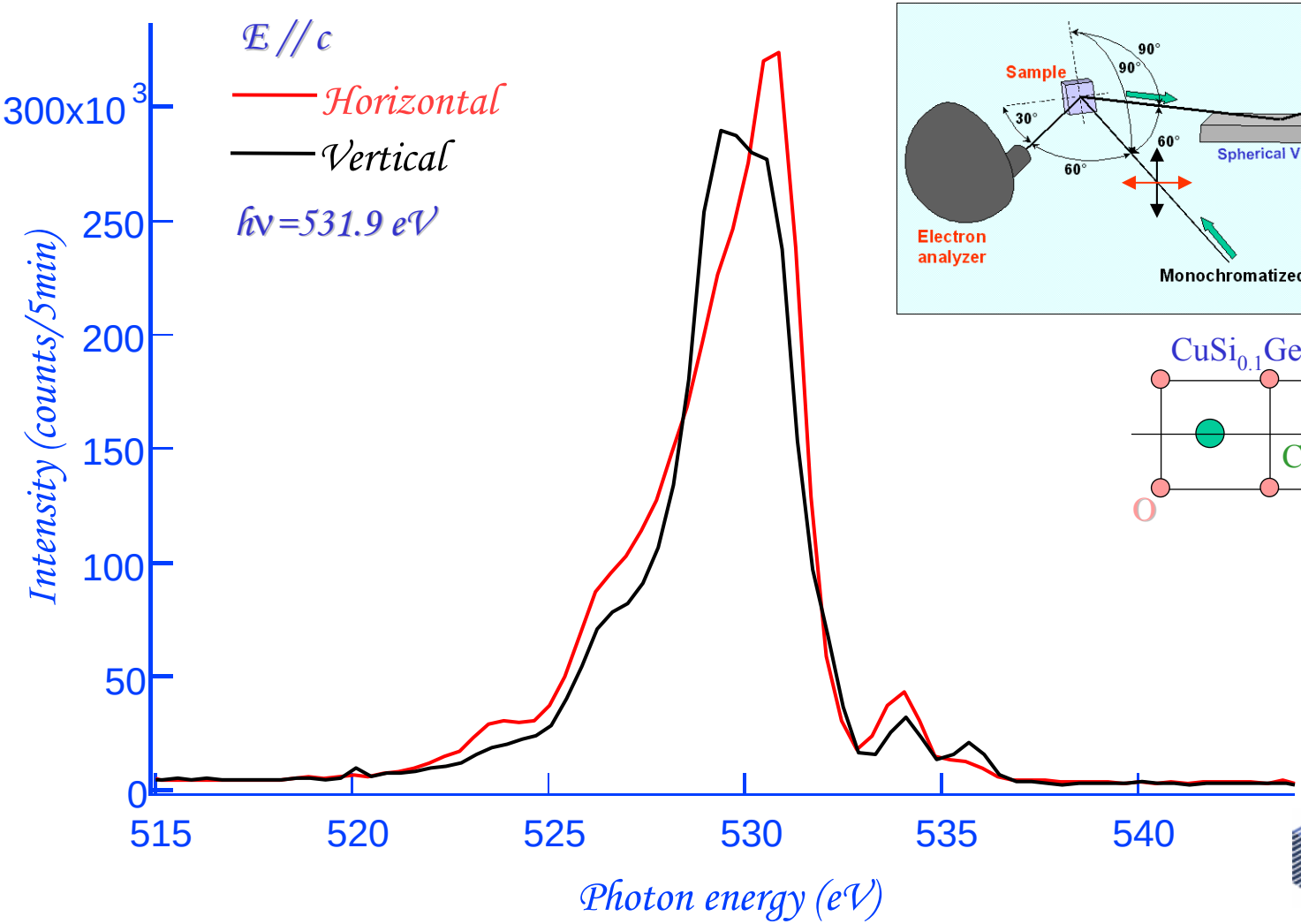
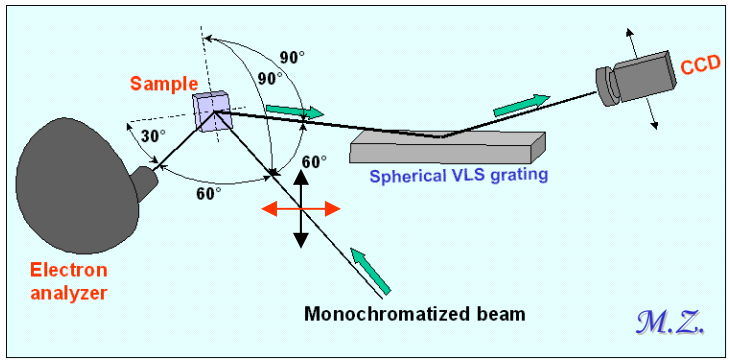
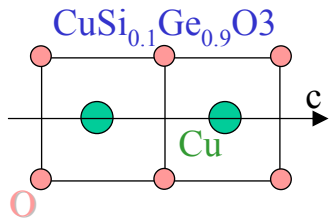


Polarization dependence







Summary

ComIXS (Compact Inelastic X-ray Spectrometer)

Actual status:

Good count-rate: ***Large angular acceptance (30X10 mrad^2); high efficiency blaze gratings; high sensitivity CCD; Very high bright source (Beamline BACH with small spot and full control of the light polarization).***

Resolving Power: ***CCD pixel size limited but higher diffraction orders will help us to have the desired resolution.***

Experiment performed: ***≈90% of the beam-time of the beamline Bach since May 2003 (after the 2nd grating installation) was dedicated to SXE experiments.***

Future development:

Improvement: ***New generation CCD (or other position sensitive detector) can improve considerably the spectrometer performance (resolution, noise, angular acceptance). We need it! (actually a 13 μm pixel size is commercially available)***

Software: ***A complete remote and automatic software (to be integrated in the Beamline control software made by M. Finazzi and M. Zangrando) is under development.***

<u>Users are welcome!</u> deadline for the proposal submission is August 31st

Summary

ComIXS (Compact Inelastic X-ray Spectrometer)

Actual status:

Resolving Power limited by CCD pixel size/Good count-rate/Large interest in SXES

Future development:

New generation CCD IS NEEDED!

<u>Users are welcome!</u> deadline is August 31st

ACKNOWLEDGMENT

Prof. T. A. Callcott

G. Sostero

M. Barnaba

M. Finazzi

MIPOT

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