Science with VUV and Soft x-ray Synchrotron Light Sources

M. Altarelli

1. Introduction
2. Photoemission Spectroscopy and Microscopy
3. Examples: Superconductors, Catalysts, Magnetic Materials
4. Structural Information from Spectroscopy. Examples:Fullerene Surfaces, Porphyrins on Surfaces
5. Perspectives: Ultraviolet Inelastic Scattering

Third-generation Synchrotron Light Sources

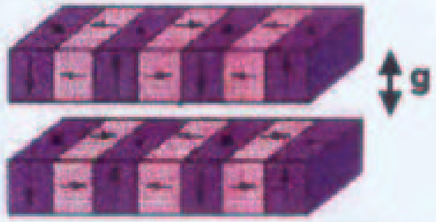
- Small source size and divergence --> microfocus

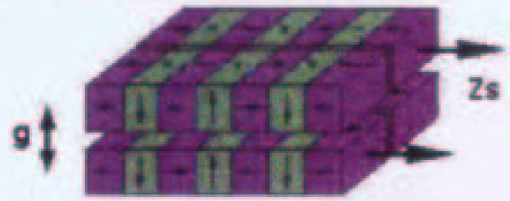
- High brilliance

- Tunable Polarization from special ID's

ELETTRA Insertion Devices Status (March 2002)

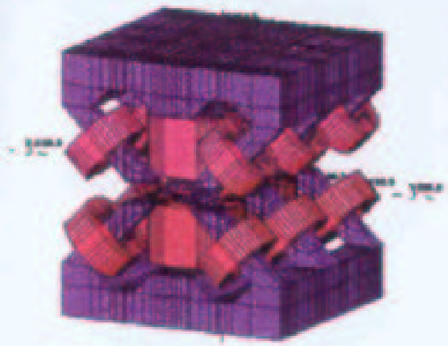
ID	type	section	Period (mm)	Nper	gap (mm)	status
EU10.0	PM/Elliptical	1	100	20+20	19.0	operating
U5.6	PM/Linear	2	56	3 x 27	19.5	operating
U12.5	PM/Linear	3	125	3 x 12	32.0	operating
EEW	EM/Elliptical	4	212	16	18.0	operating
W14.0	HYB/Linear	5	140	3 x 9.5	22.0	operating
U12.5	PM/Linear	6	125	3 x 12	29.0	operating
U8.0	PM/Linear	7	80	19	26.0	operating
EU4.8	PM/Elliptical	8	48	44	19.0	operating
EU7.7	PM/Elliptical	8	77	28	19.0	operating
EU6.0	PM/Elliptical	9	60	36	19.0	operating
EU12.5	PM/Elliptical/QP	9	125	17	18.6	operating
FEU	PM/Figure-8	10	140	16+16	19.0	construction
SCW	SC/Linear	11	64	24.5	10.7	construction

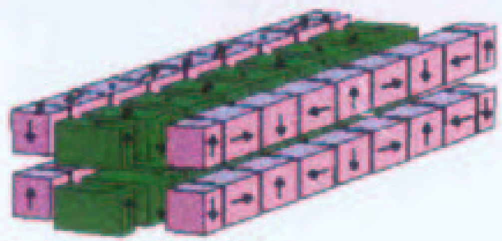




20 ID segments installed

PM = Permanent Magnet
HYB = Hybrid
EM = Electromagnetic
SCW = Superconducting
QP = Quasi-Periodic



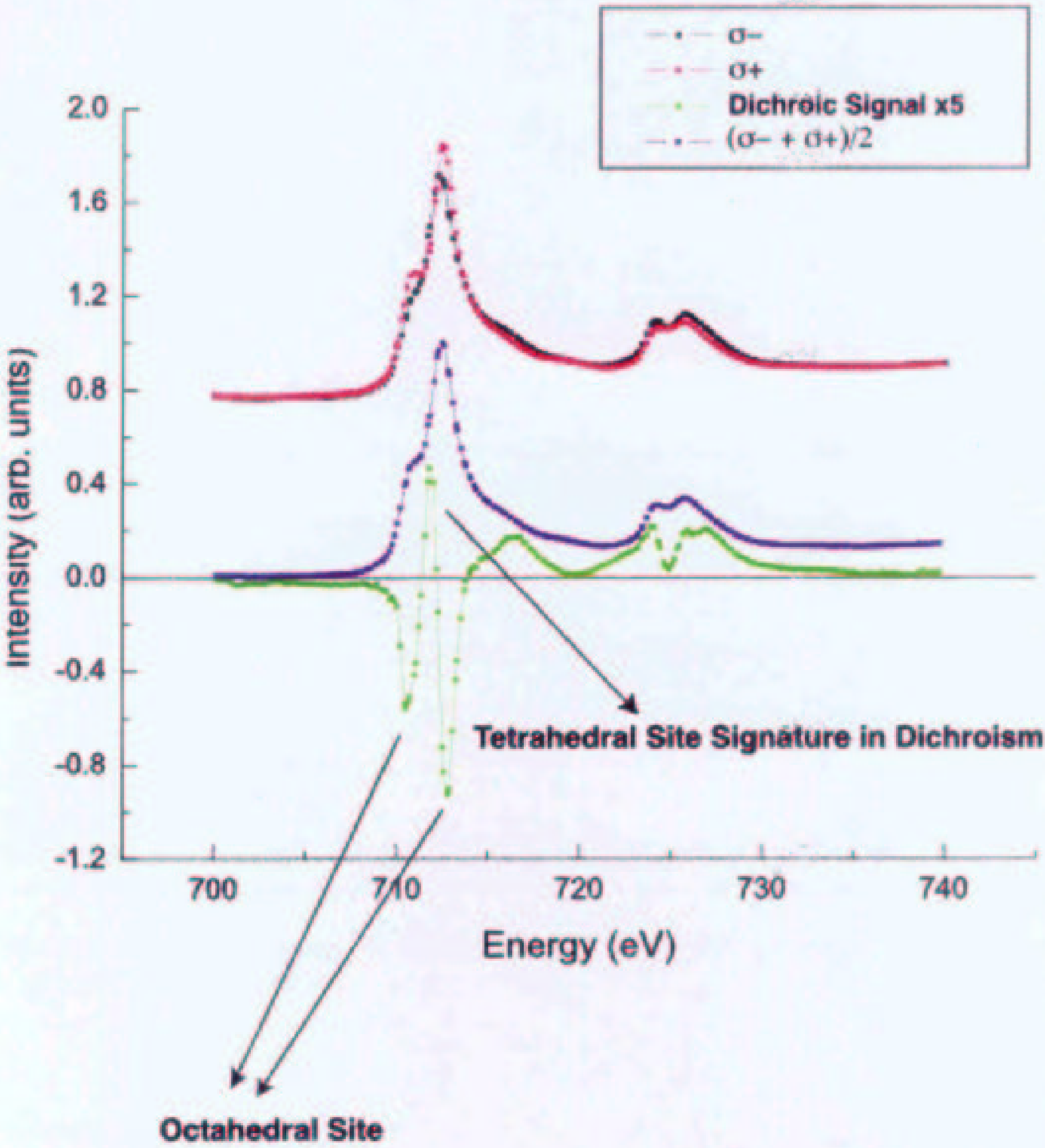


Elettra-INFM BACH Beamline: Studies of Ferromagnetic and Paramagnetic Systems

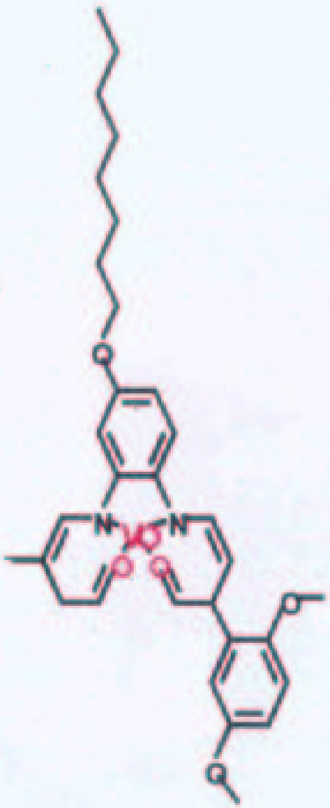
Collaboration with CNRS for low-T, high B cryostat

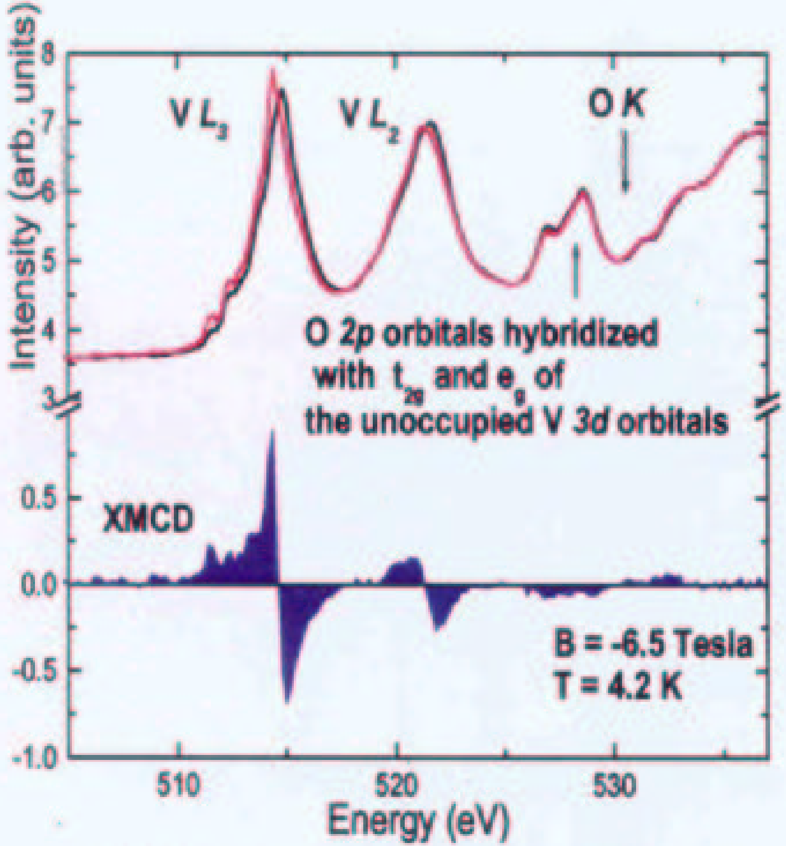
(Ph. Sainctavit, J.P. Kappler, G Krill, C. Cartier et al.)

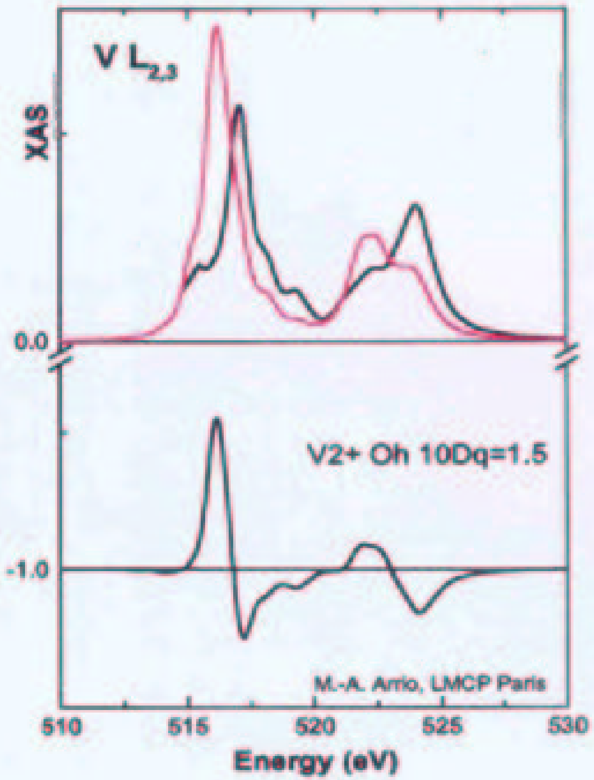
XMCD on γ-Fe_2O_3 (nanoparticles 8 nm)
Undulator phase = 17.08, Gap = 25.94 mm
T = 5.1K
H = 2 Tesla



XMCD at the V-$L_{2,3}$ edges on V^{2+} complex

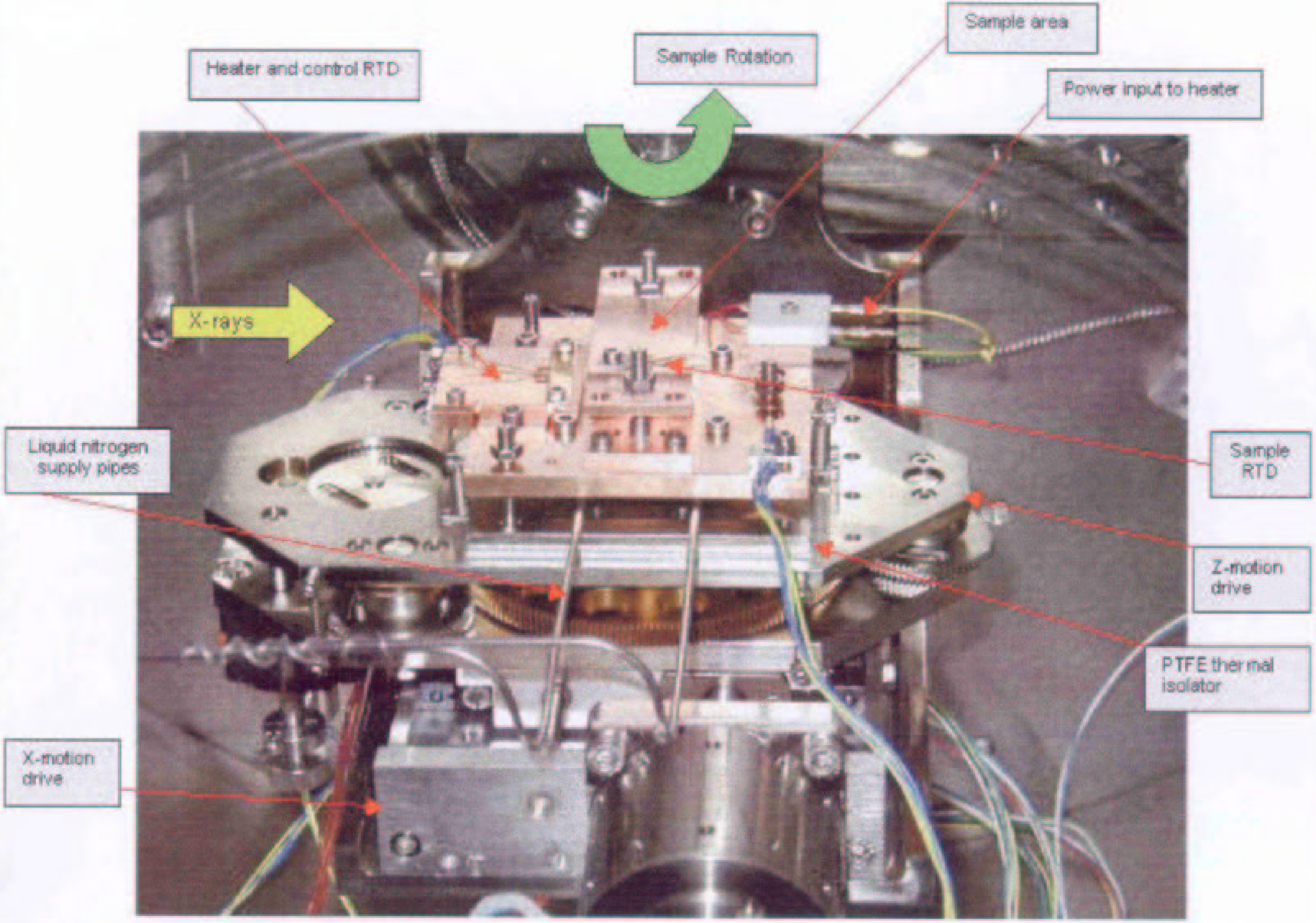




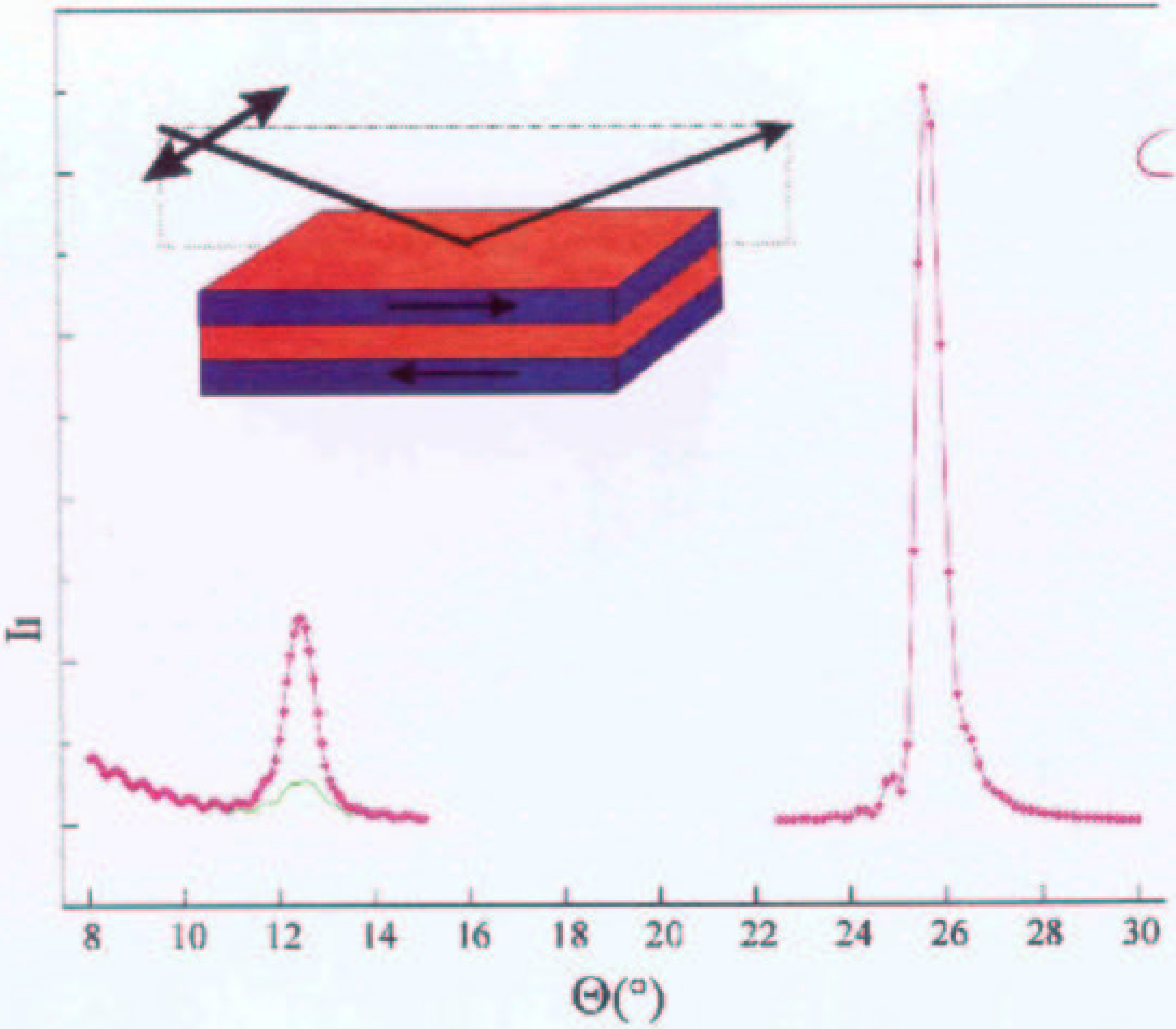


BACH Beamline: 19/03/02 15:51:58 origin file:.ORG J.L. Gallani, jpK, IPCMS

Vanadyl bis-enamino ketone derivate
Langmuir-Blodgett film on Si substrate


Heater and control RTD
Sample Rotation
Sample area
Power input to heater
X-rays
Liquid nitrogen supply pipes
Sample RTD
Z-motion drive
PTFE thermal isolator
X-motion drive

H. Dürr et al., $[Co(10Å)\,Cu(10Å)]_{50}$



Co L_3 edge

M. Sacchi et al.

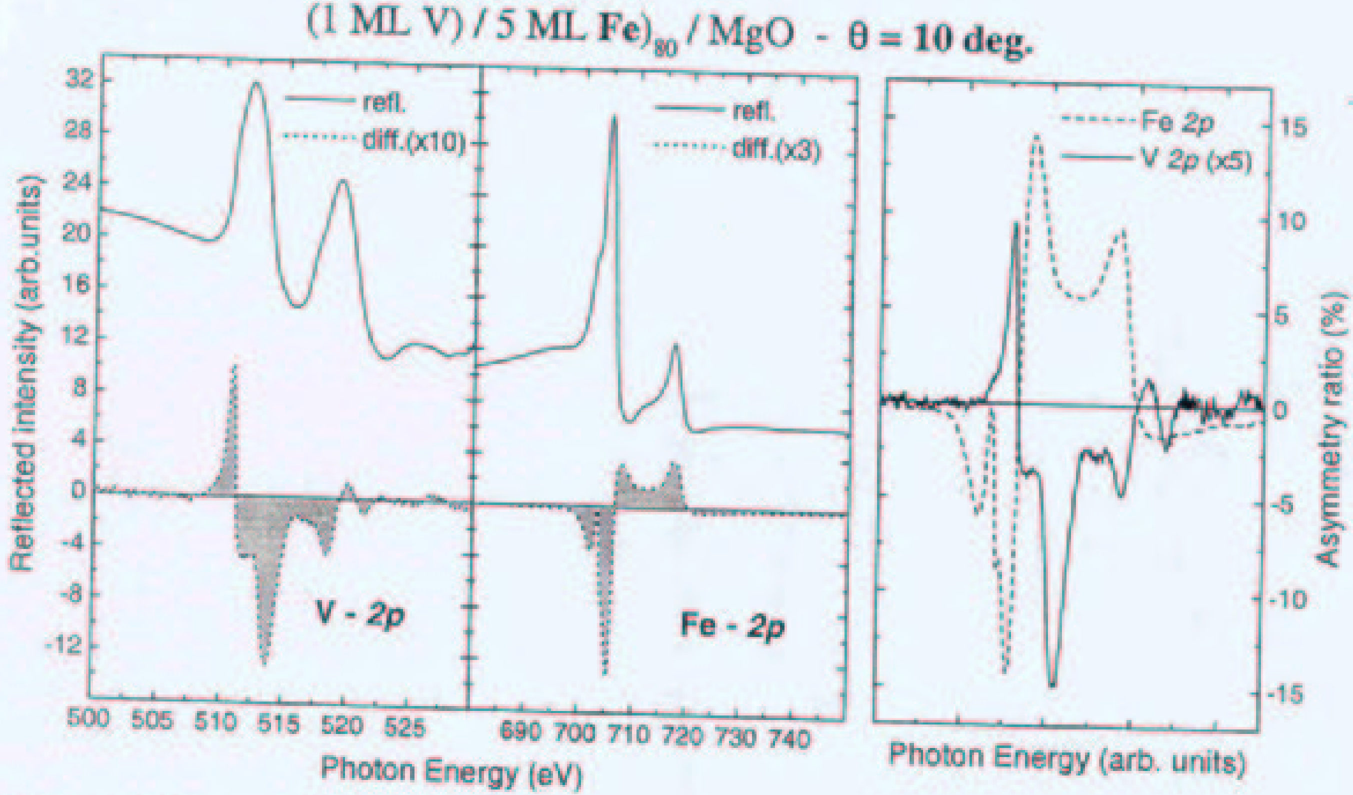


Fig. 7. Reflectivity spectra across the V and Fe 2p resonances at a scattering angle of 20° (elliptically polarized light). The sample is a (1 ML V/5 ML Fe)$_{80}$ superlattice, magnetized along a [100] direction in the sample surface and in the scattering plane. Full lines are magnetization-averaged curves, and dashed lines are difference curves. The right panel shows the corresponding asymmetry curves, on an arbitrary energy scale that matches the spin-orbit splitting of the 2p core hole for V and Fe.

Photoemission Spectroscopy

Valence Band Photoemission:

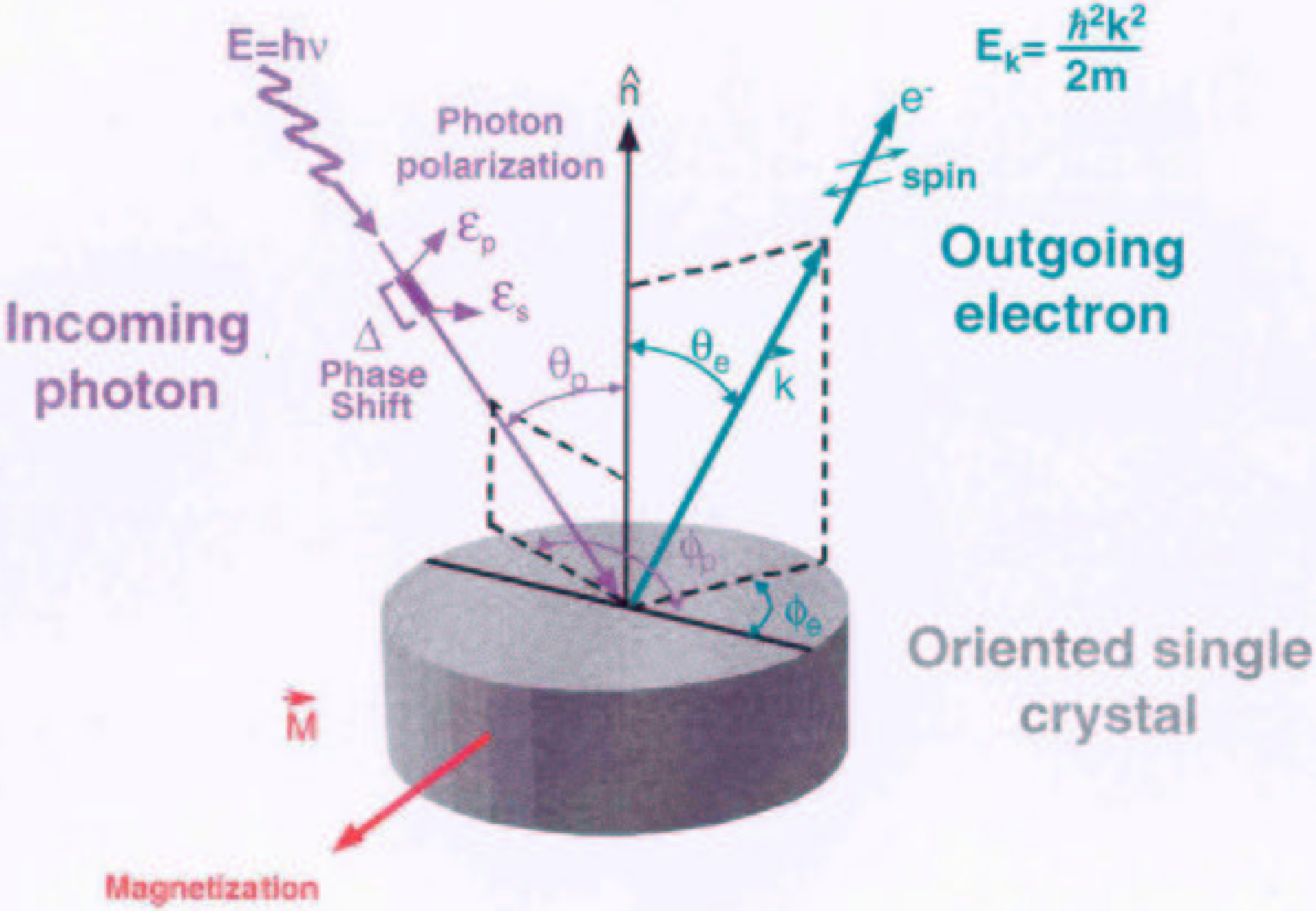
Angle-integrated --> Density of states

Angle-resolved --> Electronic band structure

Core Level Photoemission:

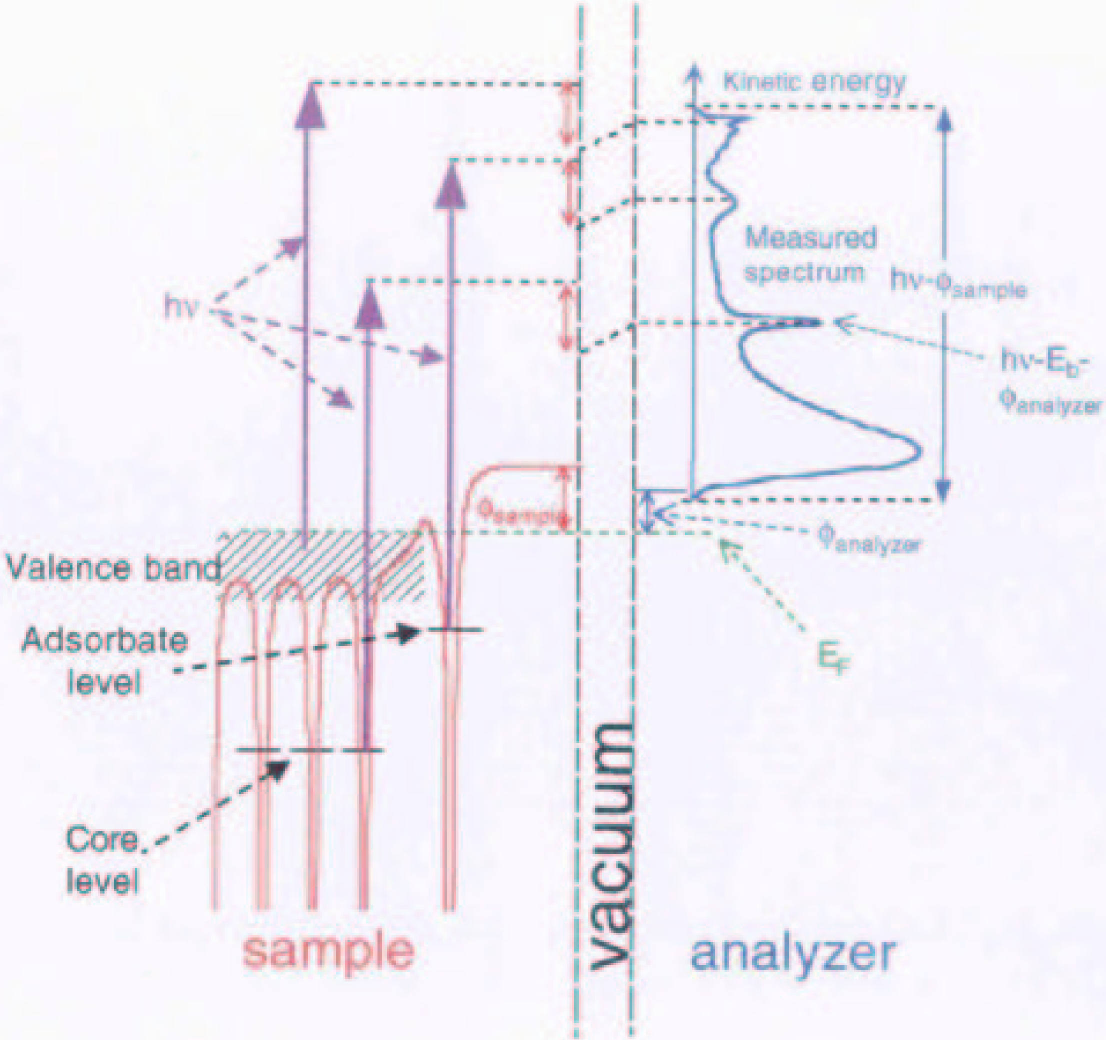
Element and oxidation state sensitive

The photoemission experiment

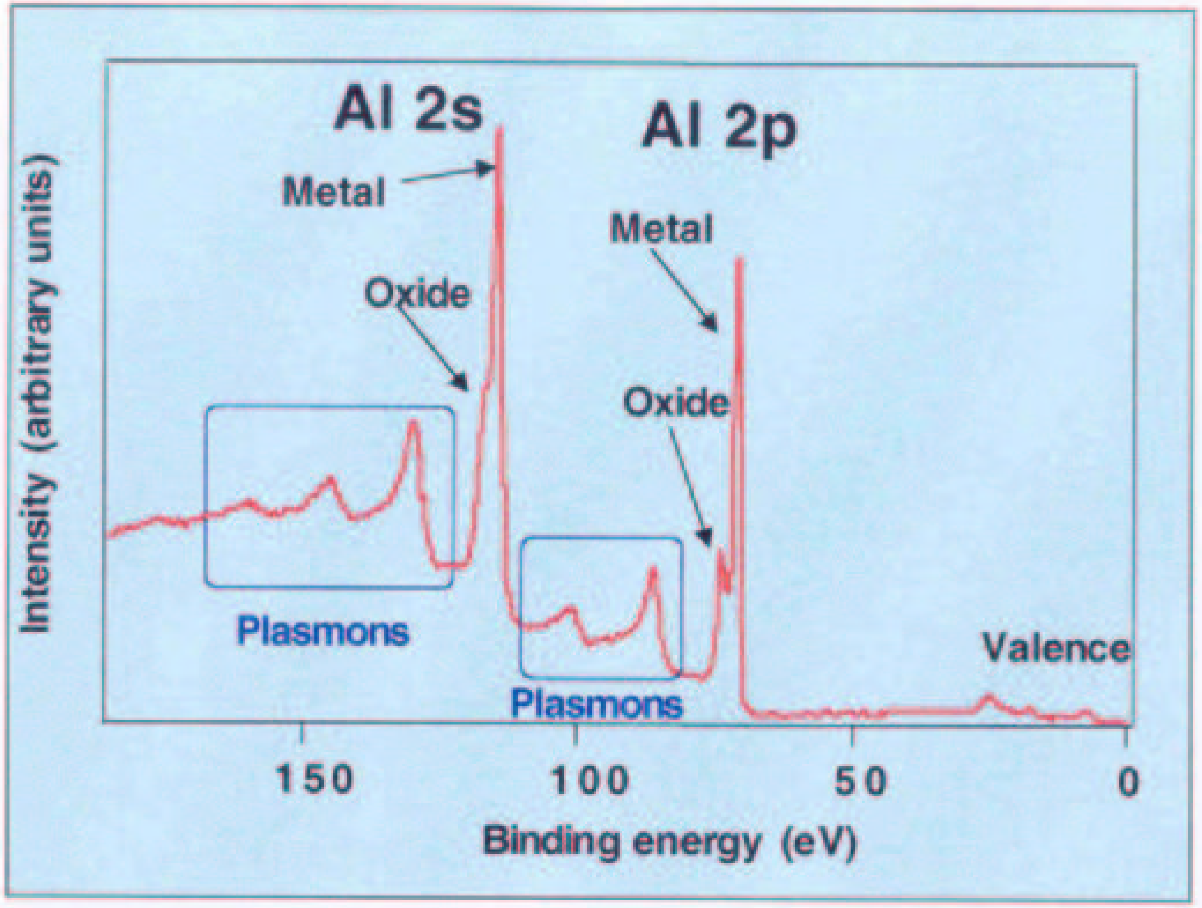


The electron must overcome the sample work function ϕ_{sample} in order to reach the vacuum; afterwards its energy is changed by the difference in work function between the analyzer and the sample. So:

$$E_k^{mea} = h\nu - E_b - \phi_{analyzer}$$



Energy of core level peaks.



$$E_k = h\nu - E_b + E_a + E_r$$

Koopman (initial state) binding energy

Intraatomic relaxation

Extraatomic relaxation

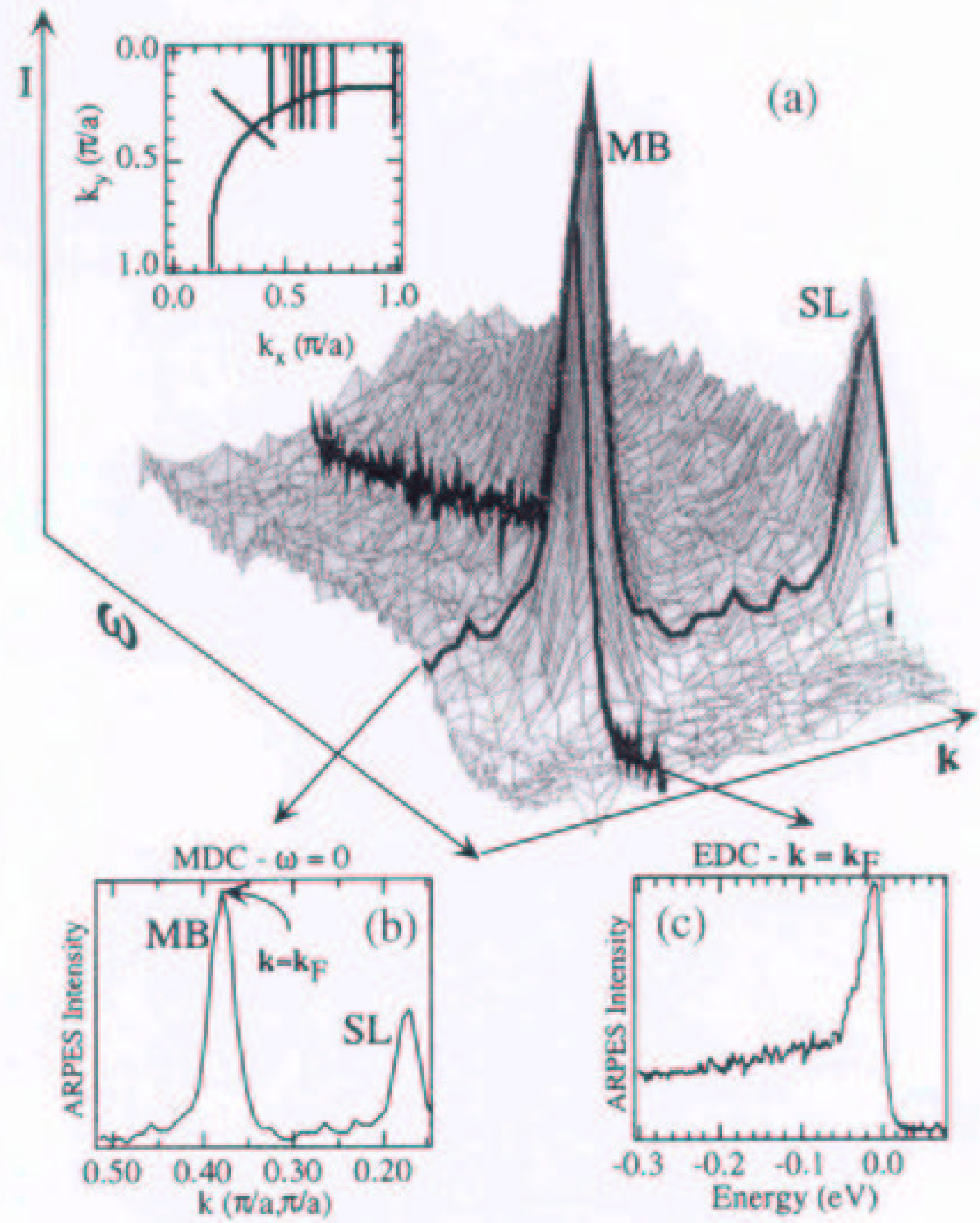


FIG. 1. (a) The ARPES intensity as a function of **k** and ω at $h\nu$ = 22 eV and T = 40 K. MB is the main band and SL a superlattice image. (b) A constant ω cut (MDC) from (a). (c) A constant **k** cut (EDC) from (a). The diagonal line in the zone inset shows the location of the **k** cut; the curved line is the Fermi surface.

Ding et al.

Phys. Rev. Lett. 76, 1533(9

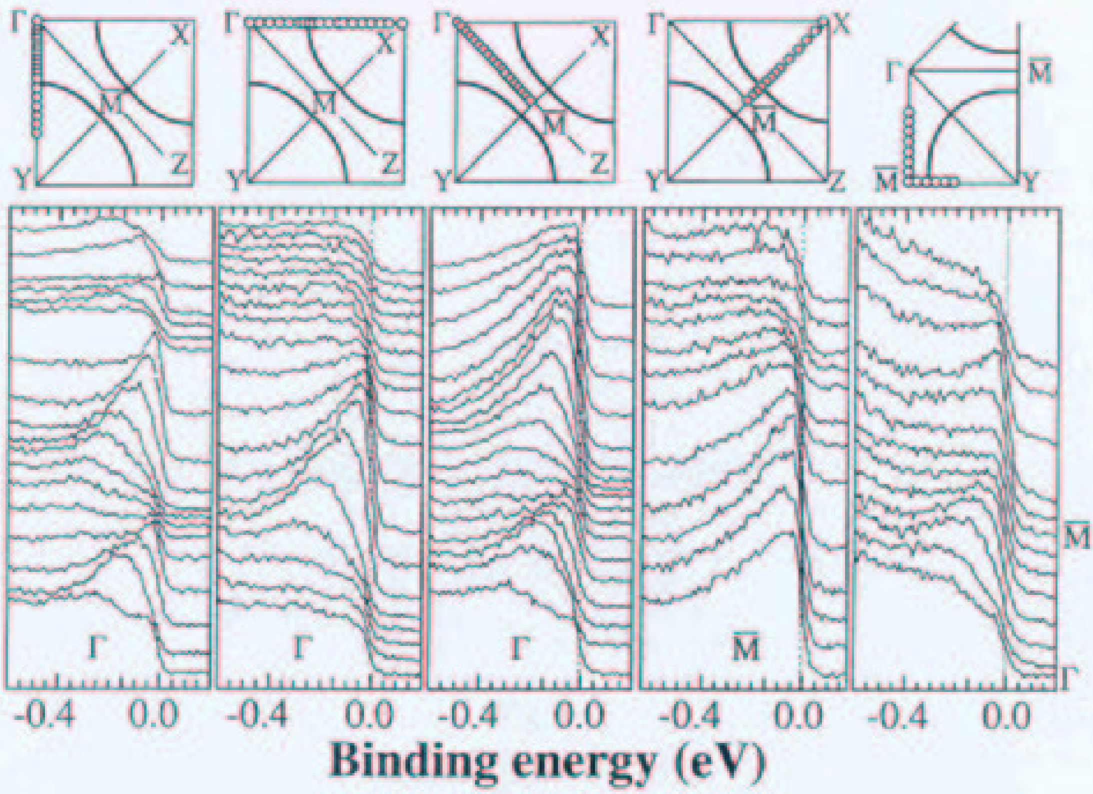
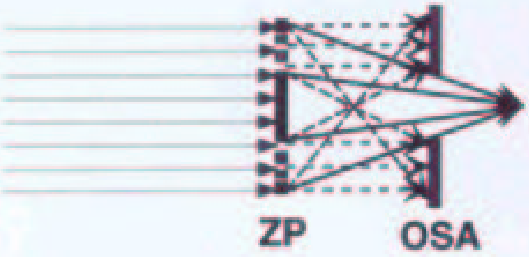


FIG. 1. Normal state (T = 95 K) EDC's of Bi2212 along various symmetry lines at values of the momenta shown as open circles in the upper insets. The photon polarization **A** is horizontal in each panel.

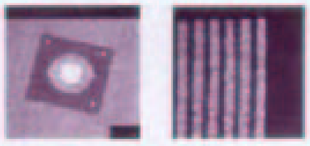
$Bi_2Sr_2CaCu_2O_8$

Photon focusing elements

1. Transmission diffractive elements:

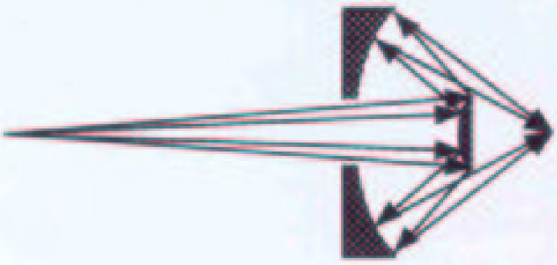


Fresnel zone plates



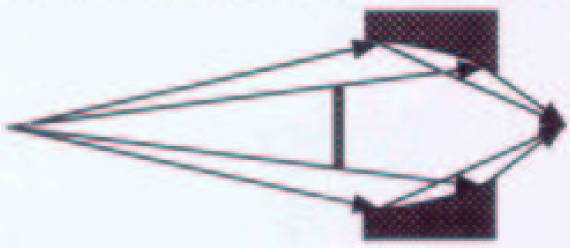
2. Reflective elements - mirrors:

NORMAL INCIDENCE SPHERICAL MIRRORS



Schwarzschield objectives

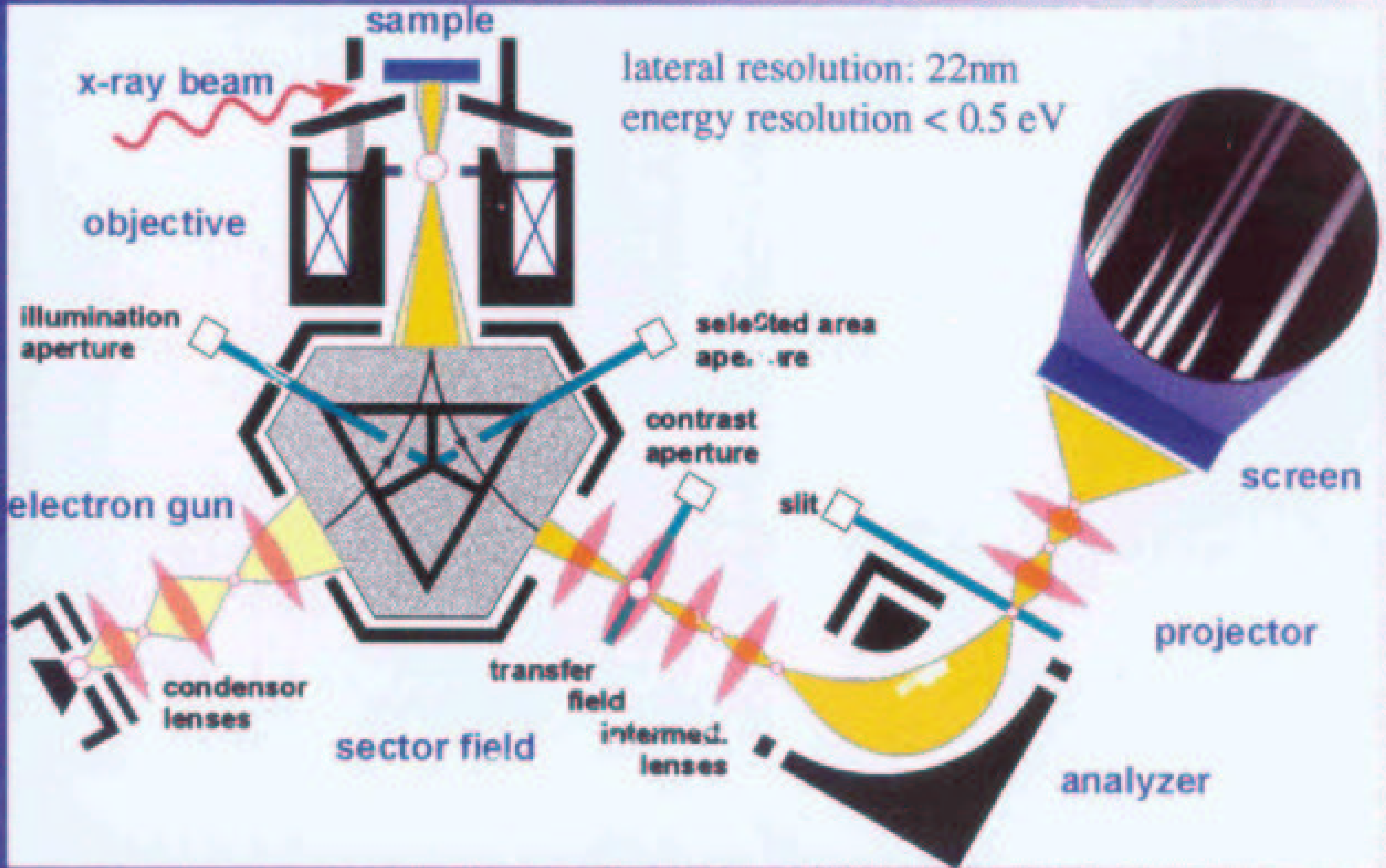
GRAZING INCIDENCE BENDABLE MIRRORS



Ellipsoidal mirror

Kirkpatrick-Baez arrangement

The SPELEEM at ELETTRA

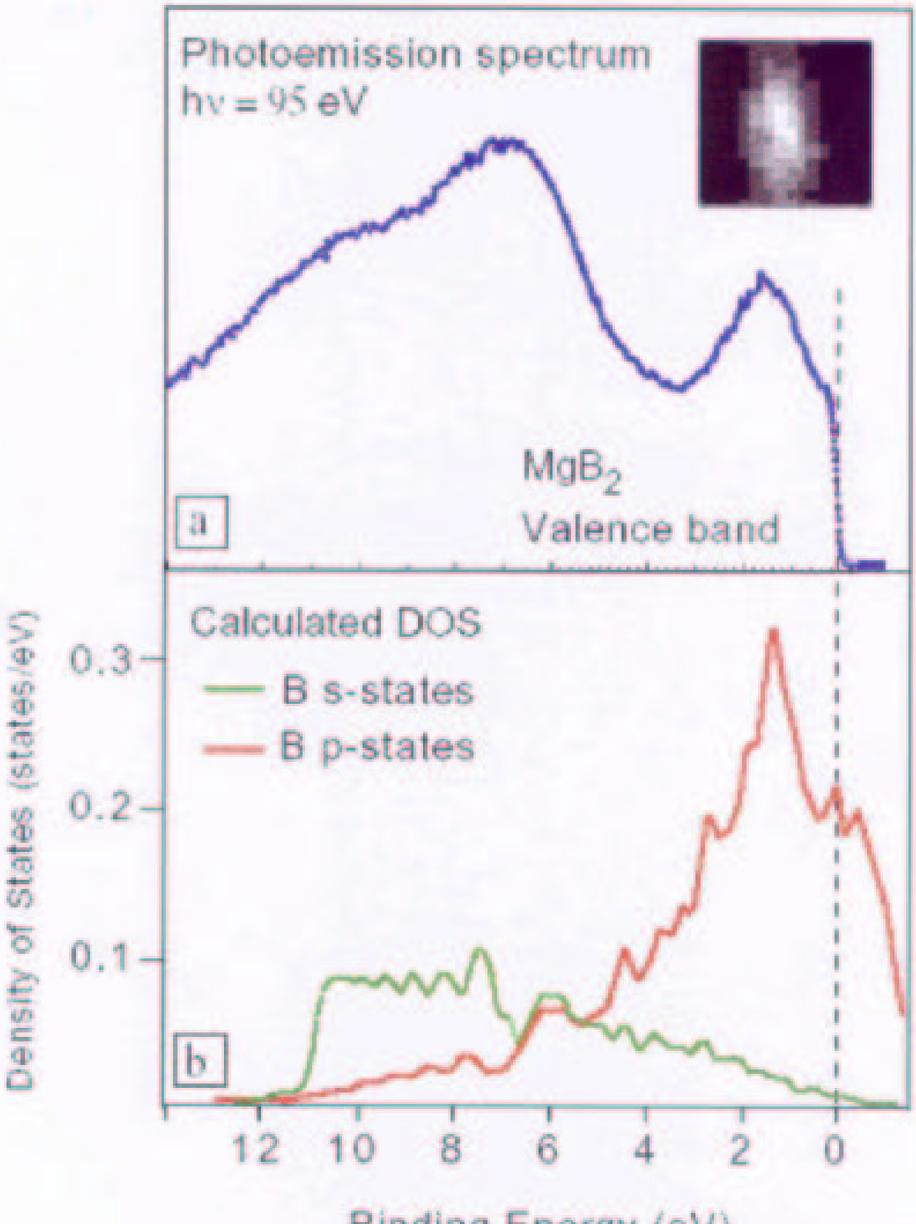


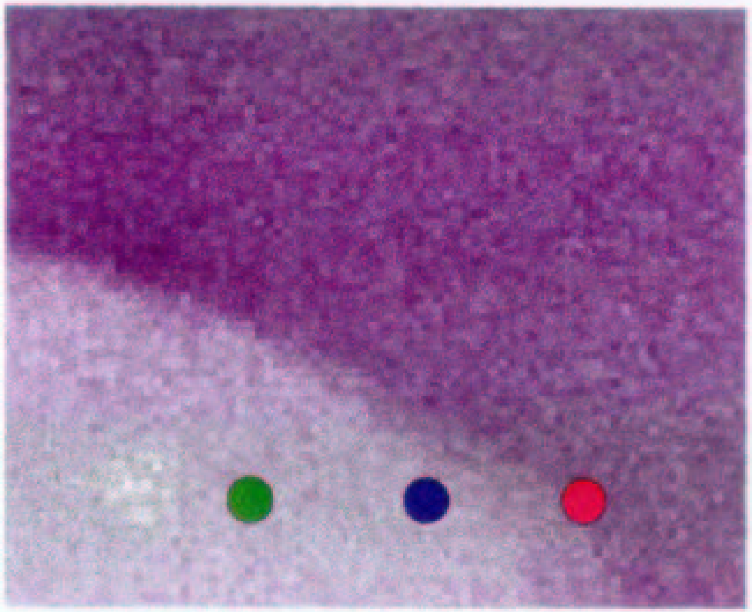
L. H. Veneklasen: Ultramicroscopy 36 (1991) 76.

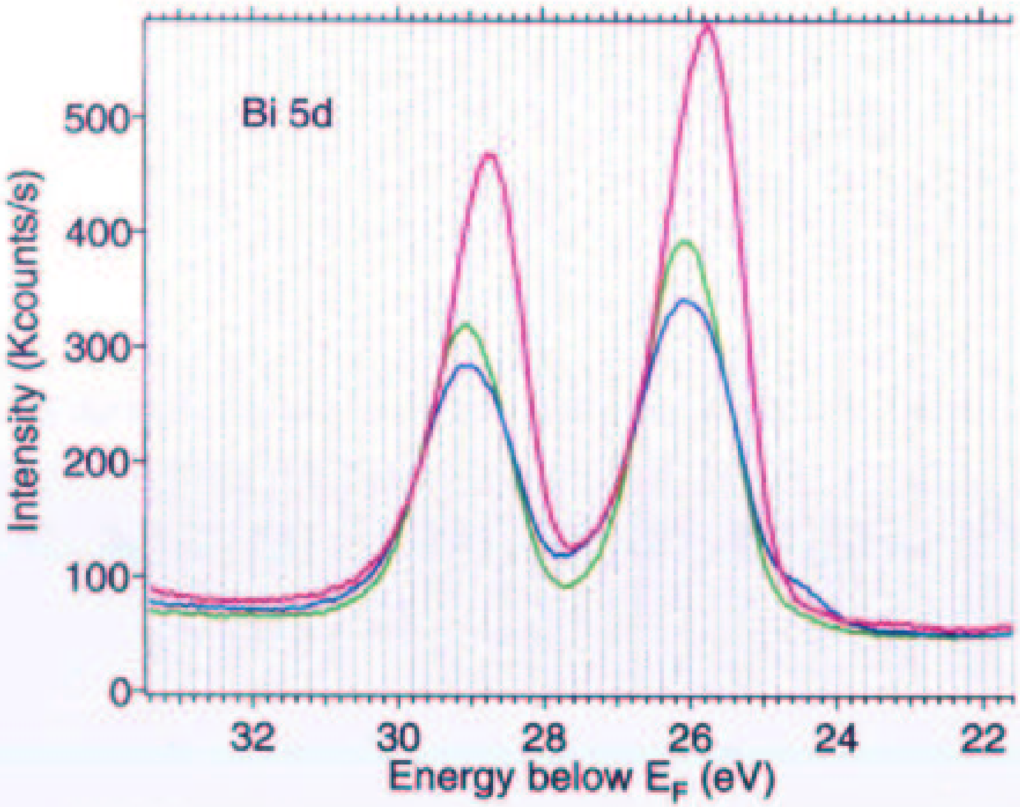
Elettra Spectromicroscopy Beamline: Applications to Superconductors

A. Goldoni et al., electronic structure of single-crystal MgB_2

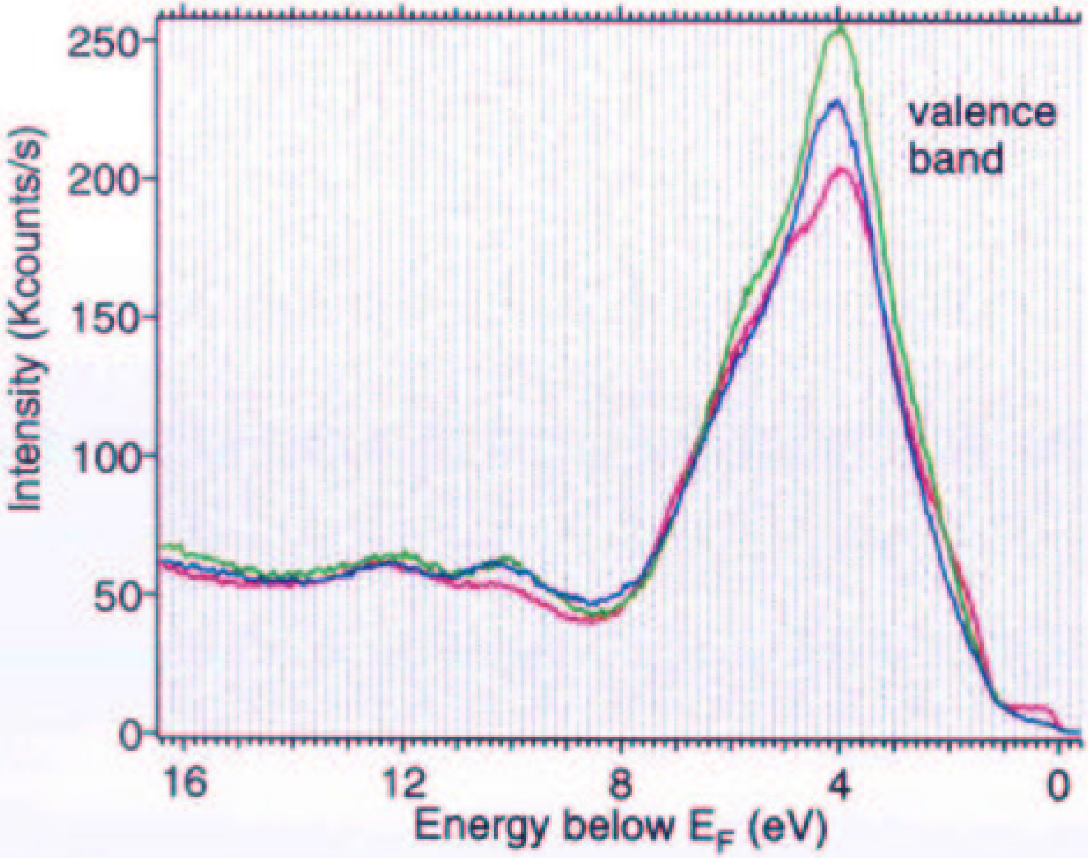
M. Bertolo et al., inhomogeneous electronic properties of BSSCO surfaces


Photoemission spectrum
hν = 95 eV
MgB_2
Valence band
a
Calculated DOS
B s-states
B p-states
b
0.3
0.2
0.1
Density of States (states/eV)
12
10
8
6
4
2
0
Binding Energy (eV)





Bi 5d
Intensity (Kcounts/s)
500
400
300
200
100
0
32
30
28
26
24
22
Energy below E_F (eV)



valence
band
Intensity (Kcounts/s)
250
200
150
100
50
0
16
12
8
4
0
Energy below E_F (eV)

Elettra Spectromicroscopy Beamline: Application to Catalytic Systems

A. Böttcher (FHI, Berlin) et al., initial stages of oxidation of the Ru(0001) surface

Initial Stages of Oxidation of Ru(0001) single crystal: direct evidence of nucleation and growth mechanism of the oxide phase

A. Böttcher et al, FHI-Berlin, October 2000

Ru 3d images taken after different duration of the oxidation reaction at 400 C: P_{O2}= 1*10^{-3} mbar:

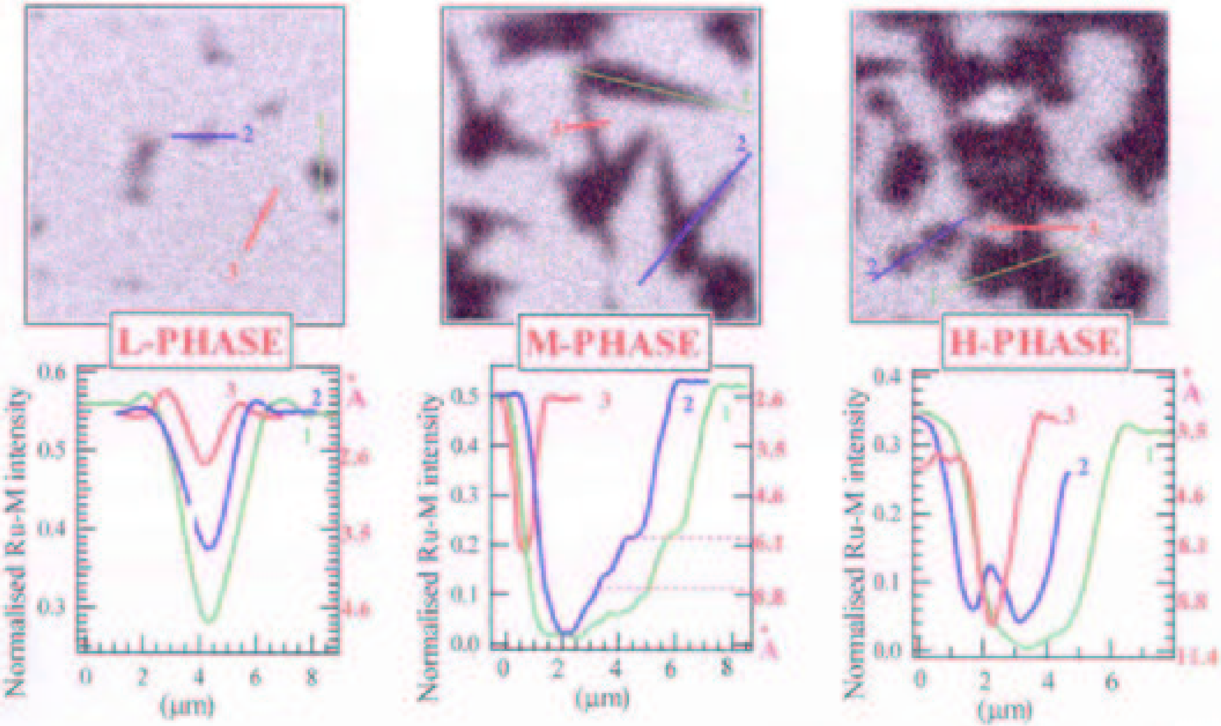
33 sec | 99 sec | 133 sec

64 µm

Temperature dependence of the spatial anisotropy of the oxide growth on Ru(0001)

A. Bottcher, H Conrad et al FHI-Berlin L. Gregoratti, M.Kiskinova et al Elettra

Maps of the Ru 3d signal from the underlying Ru substrate and the corresponding intensity profiles illustrating the inhomogeneity in the thickness of the 'oxide' phase



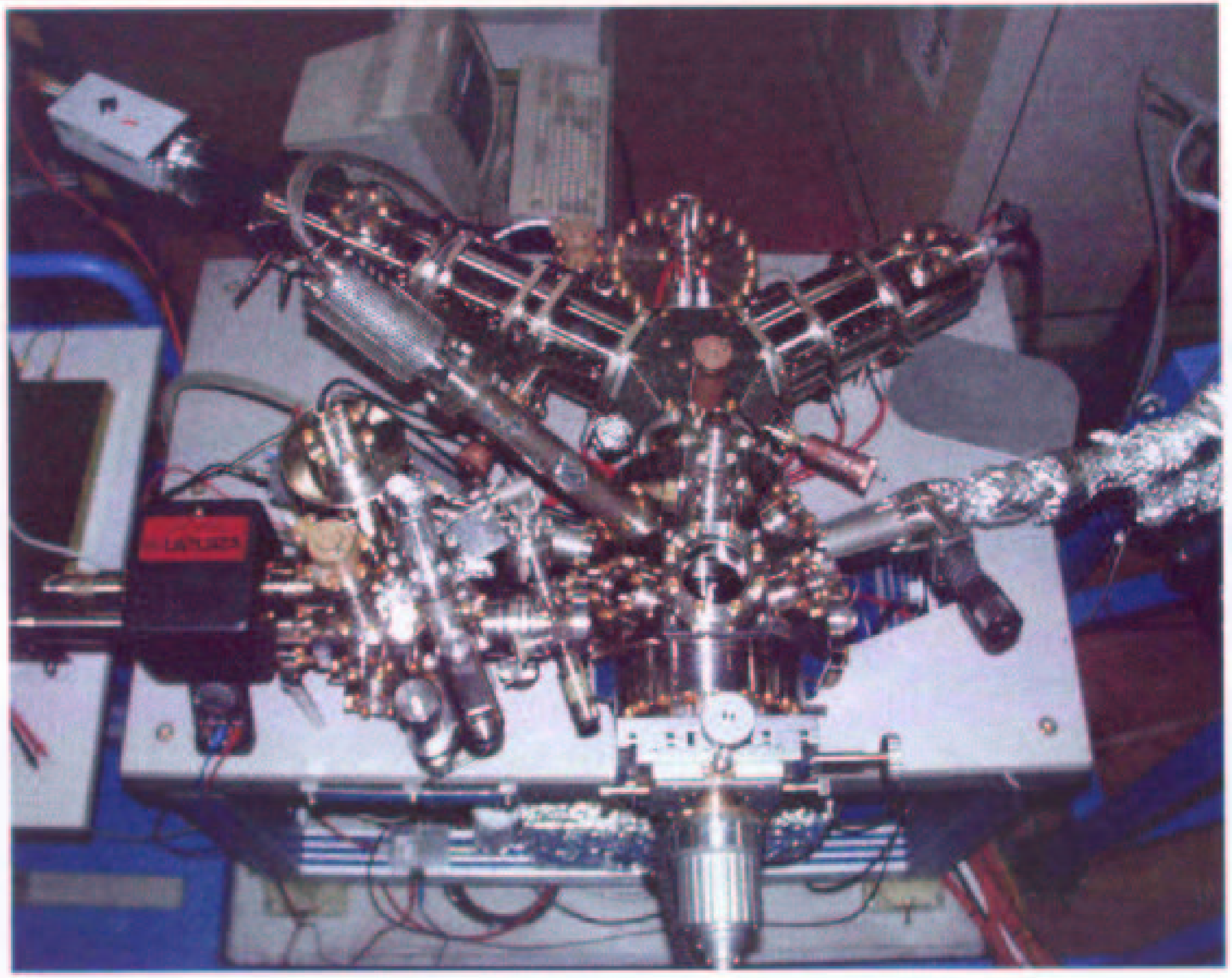
Oxidation conditions: 5×10^4 L, P=10^{-3} torr, T=625, 675, 775 K

The Nanospectroscopy SPELEEM at Elettra: Application to Magnetic Materials.

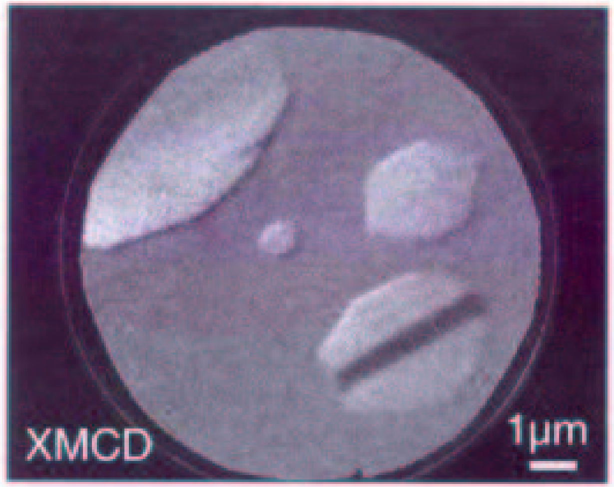
E.Bauer (Arizona State) et al., Imaging of MnAs

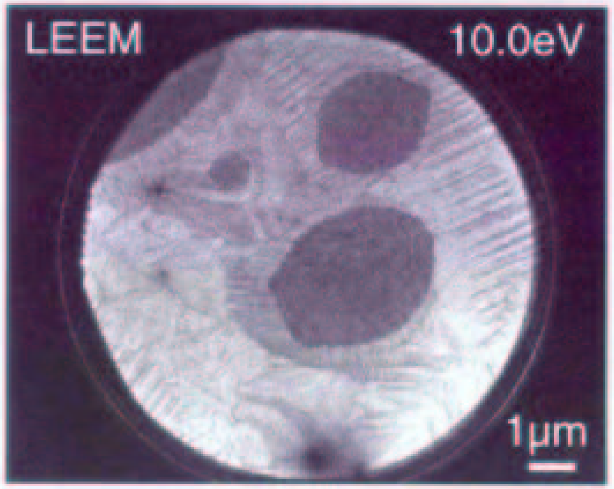
ferromagnetic domains on a GaAs substrate

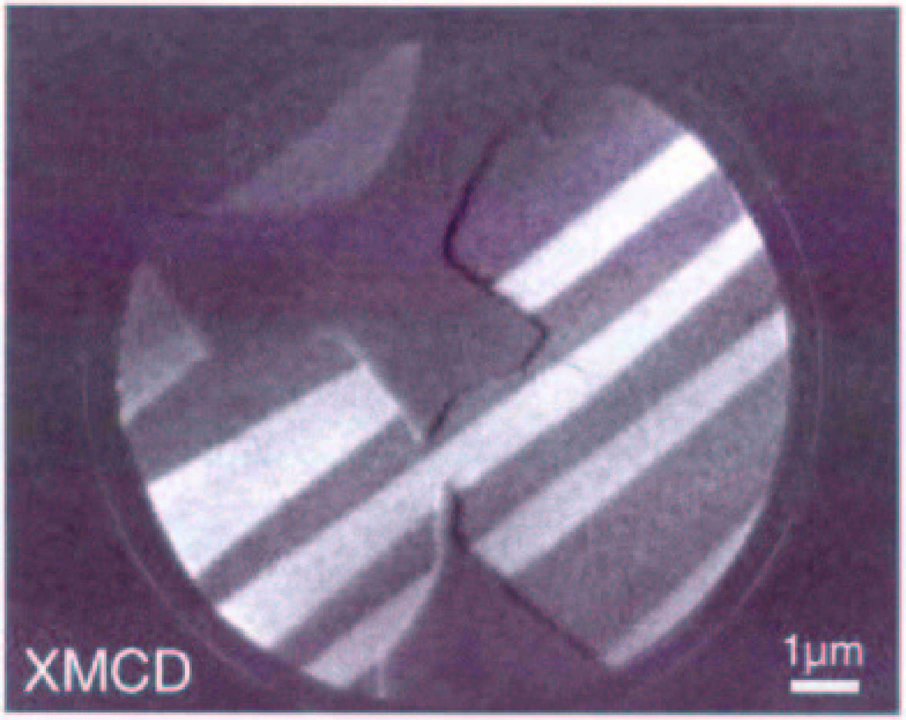
The SPELEEM at ELETTRA



Magnetic Contrast in Semiconductors







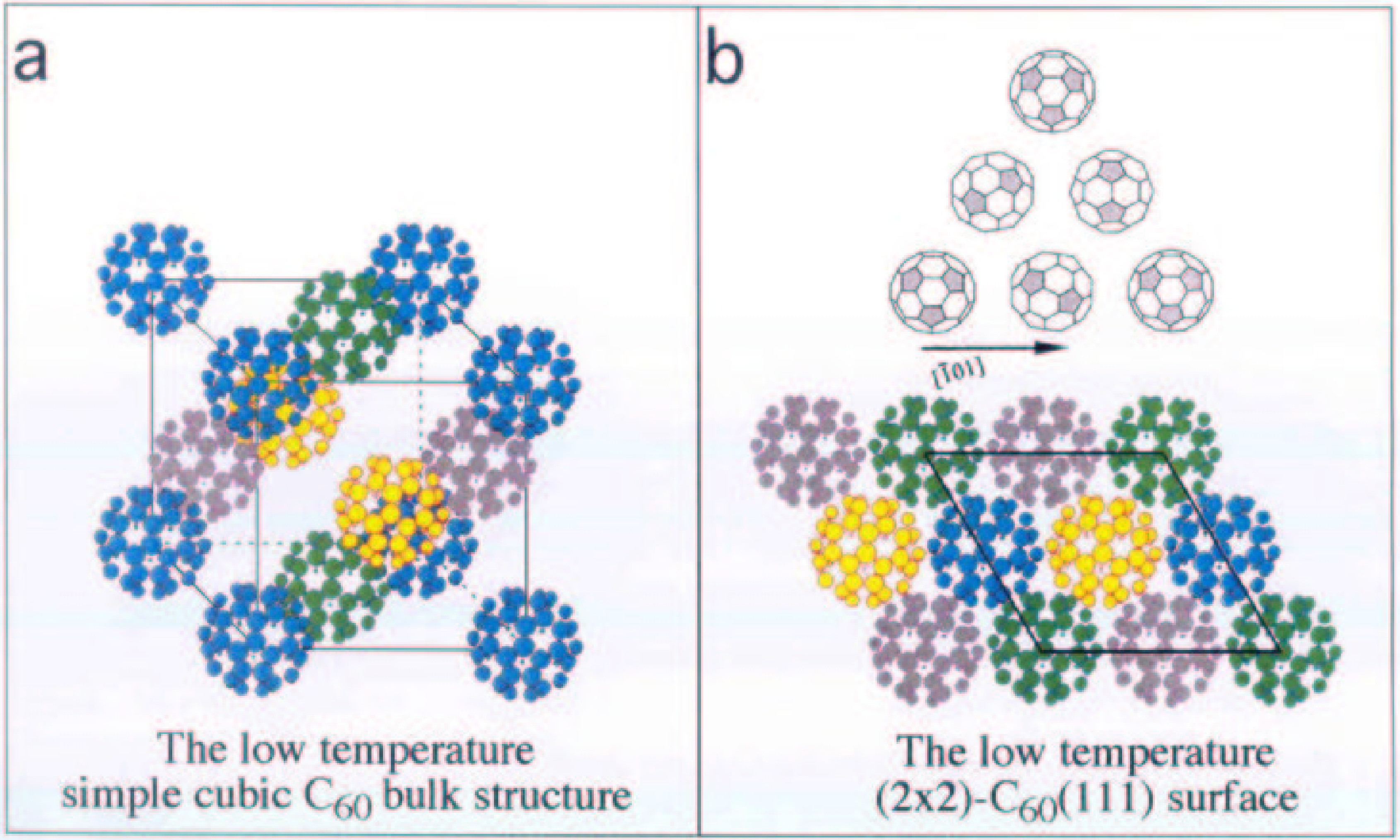
MnAs/GaAs(001)

E. Bauer, S. Cherifi, A. Locatelli, and S. Heun
Measured at the Nanospectroscopy Beamline
(Samples from K.H. Ploog et al., PDI Berlin)

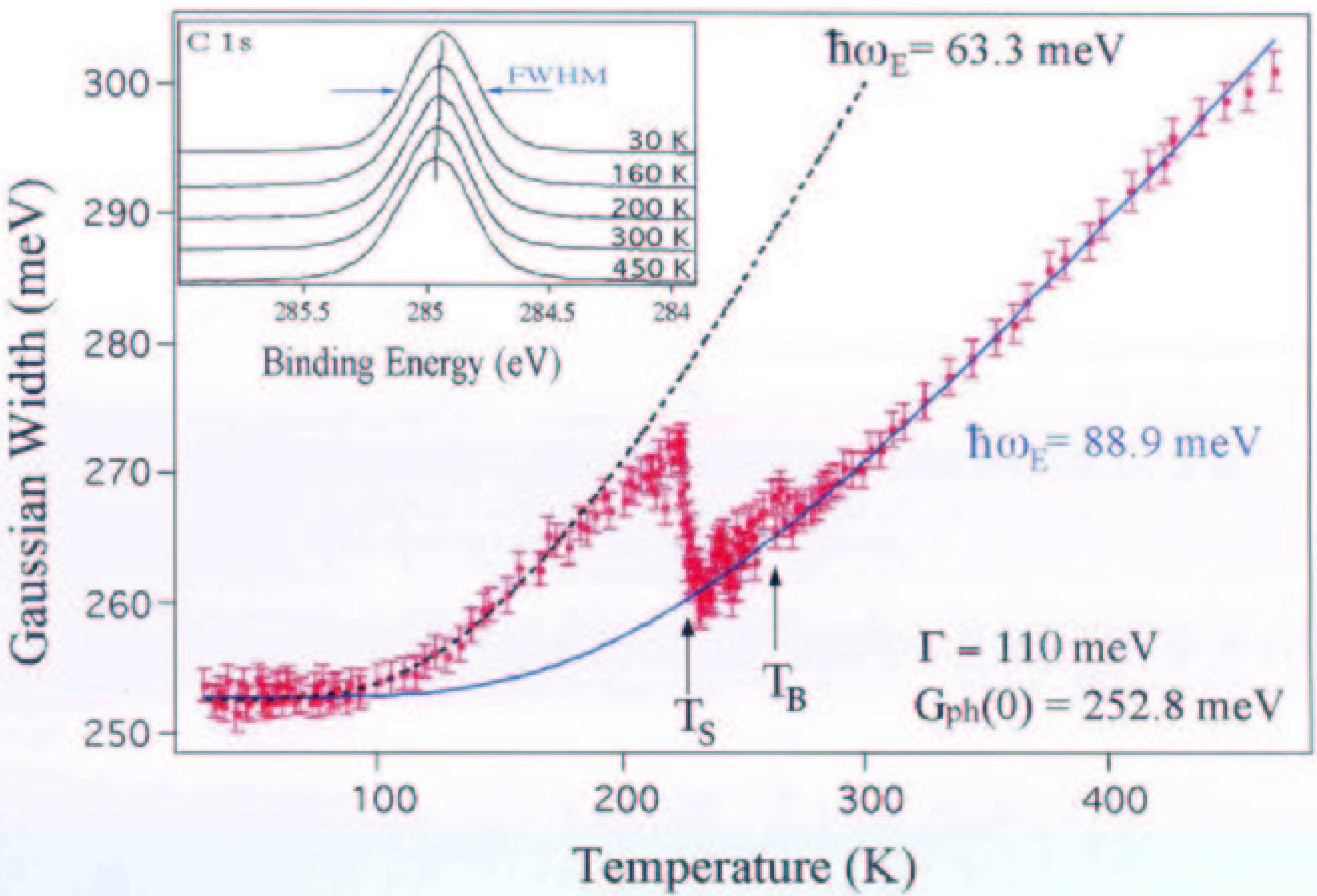
Elettra SuperESCA Beamline: Structural Information by Spectroscopic Experiments

A.Goldoni et al., Rotational order-disorder transitions in Fullerene surfaces

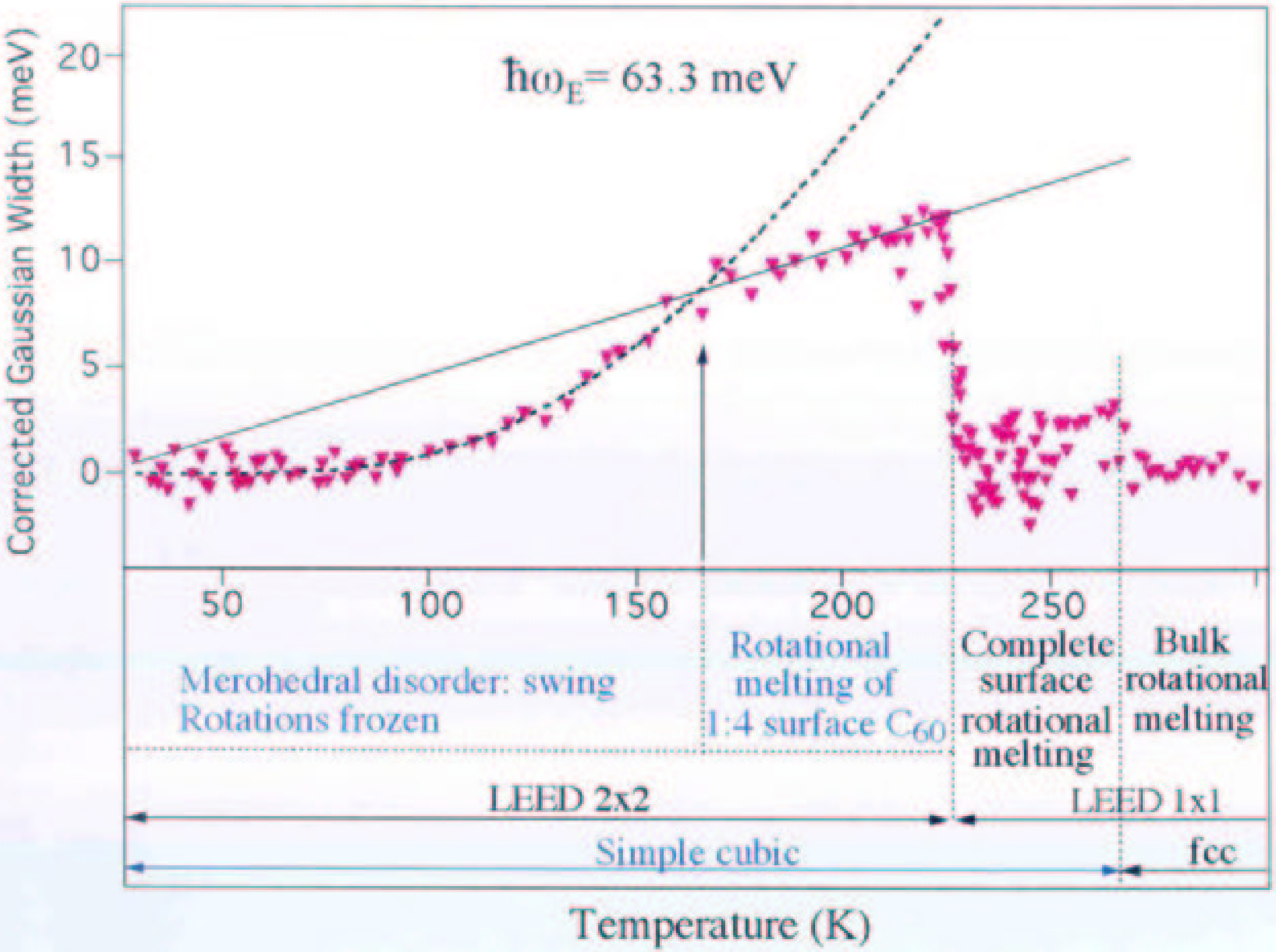
G. Polzonetti (U. Roma III) et al., Porphyrins and Porphyrin-Fullerene complexes on Cu(111)



A. Goldoni et al. Fig. 1



A. Goldoni et al Fig. 2



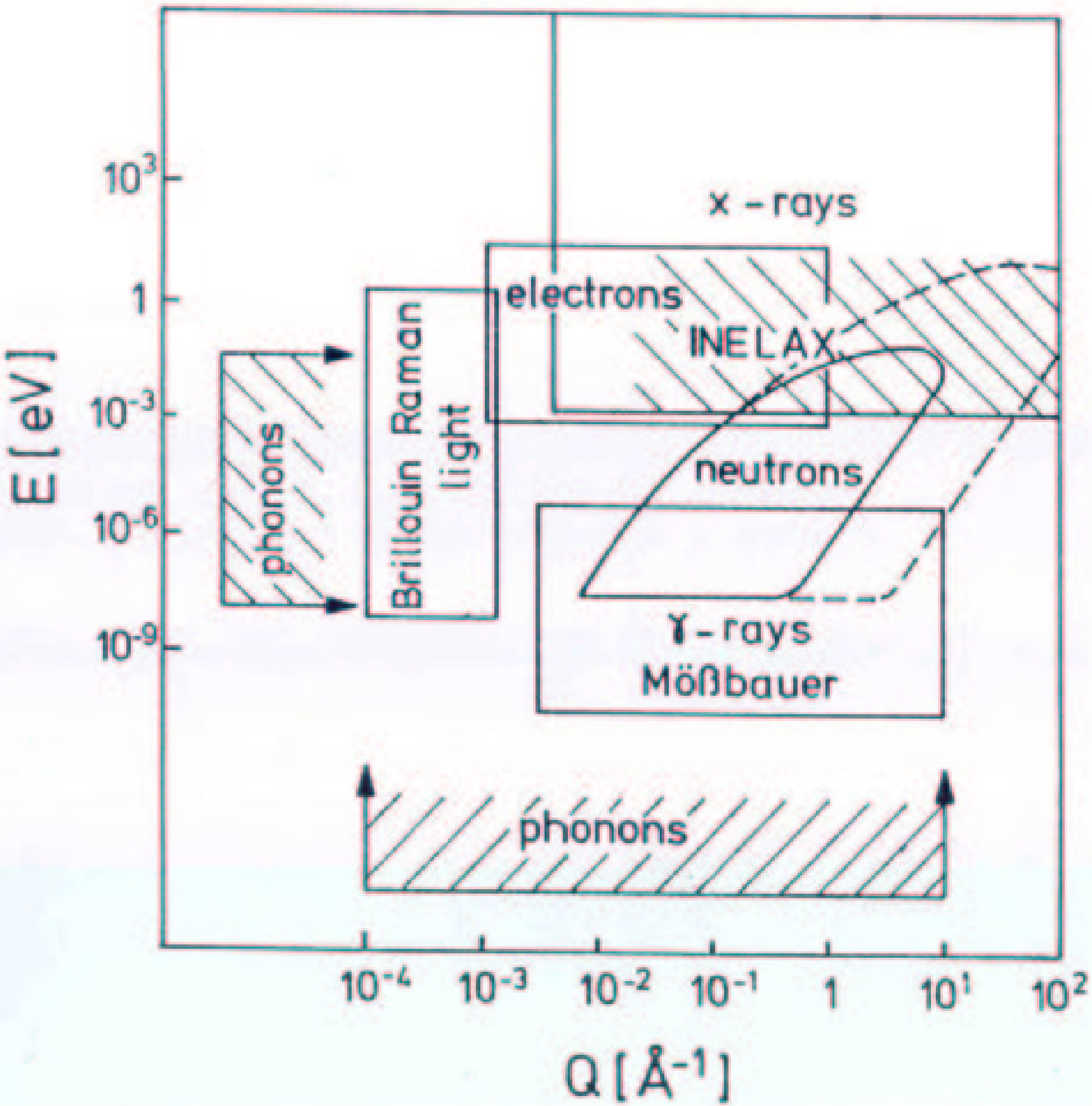
A. Goldoni et al Fig. 3

The Inelastic Ultraviolet Scattering Project

(C. Masciovecchio et al.)

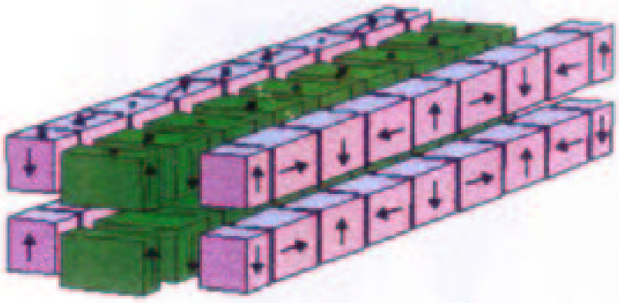
Inelastic Scattering of 5-11 eV photons with 10^{-5} to 10^{-6} energy resolution, and $2 \cdot 10^{-3}$ to $2.5\ 10^{-2}$ Å^{-1} momentum transfer

Collective dynamics of liquids, glasses and complex fluids in an unexplored region of the energy-momentum plane



E [eV]
10^3
1
10^-3
10^-6
10^-9
x - rays
electrons
INELAX
neutrons
Brillouin Raman
light
phonons
γ - rays
Mößbauer
phonons
10^-4
10^-3
10^-2
10^-1
1
10^1
10^2
Q [Å^-1]

Figure-8 undulator



Main parameters:

Tuning range	5-10 eV
Polarization	linear
Flux	> 10^{15} photons/s/0.1%bw
Period length	140 mm
Number of periods	32
Kx, Ky	3.4, 9.4
Total Power	2.5 kW
Pinhole Power	20 W

Status:

• magnetic blocks	received and within specifications
• block holders	received, mechanical tolerances OK
• variable gap support	will be assembled in house (delivery of main components in April 2002)
• auxiliary equipment	under procurements
• installation	summer 2002