Towards photon polarisation analysis in soft X-ray inelastic scattering

A. Tagliaferri[1], E. Annese[1], L. Braicovich[1], N.B. Brookes[2], M. Fiore-Donati[1], G. Ghiringhelli[1], G. van der Laan[4]

[1] INFM, Dipartimento di Fisica, Politecnico di Milano, piazza Leonardo da Vinci 32, 20133 Milano, Italy
[2] ESRF – European Synchrotron Radiation Facility, BP 220, 38043 Grenoble, France
[3] INFM-OGG, c/o ESRF, BP 220, F-38043 GRENOBLE CEDEX, France
[4] Daresbury Laboratory, Warrington WA4 4AD, United Kingdom

POLARISATION DEPENDENT SOFT X-RAY SPECTROSCOPY — ESRF DRAGON BEAM LINE

I.N.F.M.

Overview

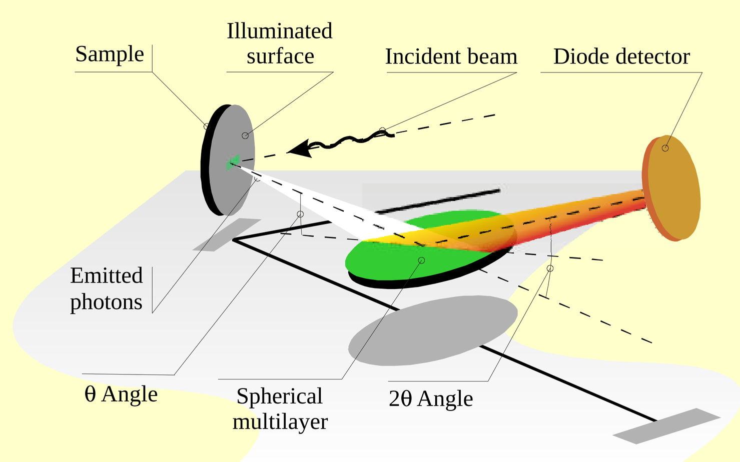
- In the hard X-ray energy range (E > 3 keV), the polarization analysis of magnetic X-ray scattering has been intensively exploited in the last years to investigate the spin and orbital magnetic structures of solids [1].
- The branching ratio between the X-ray scattering channel and the Auger emission is close to 10^{-2} for soft X-rays, to be compared with some 0.3 in hard X-rays. This property is responsible for the signal intensity limitations in soft X-rays. Thus up to now the routine investigation of the polarization properties of soft X-ray magnetic scattering where very difficult.
- Soft X-xay have the advantage of higher circular and linear magnetic dichroism cross section with respect to hard X-rays and in perspective higher sensitivity to magnetic properties. These have been recently exploited for structural magnetic investigations, without polarization analysis [2].
- I the recent years, Partial Photon Yield (PPY) spectroscopy has been demonstrated a powerful tools to investigate the element specific **local** magnetic properties of condensed matter and the scattering angular dependence [3, 4]. This has been done by using an element specific filter to discriminate the energy of different photon scattering channels.
- **We show that a proper choice of the scattering layout allows to join the energy and polarization selectivity of MultyLayer (ML) devices to obtain a more versatile PPY detector and a linear polarization analyzer.**
- **Results from a test case experiment on Co are presented, that demonstrate the feasibility of the polarization analysis in the most demanding case: the investigation of local magnetic properties.**

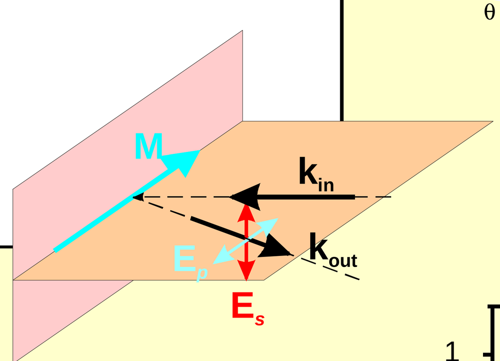
Test experiment on Co metal

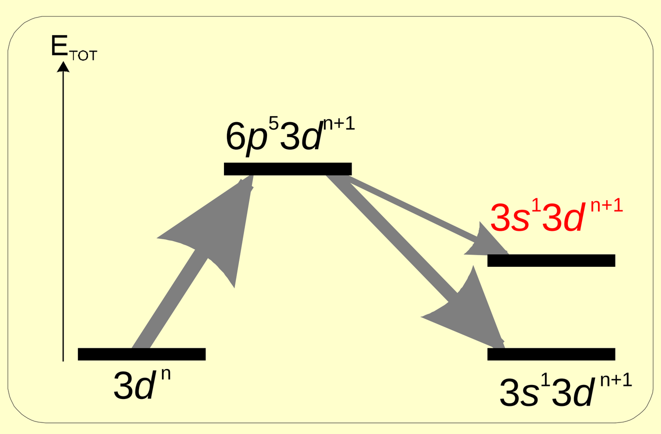
Experimental conditions

Id8 beamline
Excitation: ?E = 0.7 eV
100% Circular polarization
Normal incidence
Magnetization in the scattering plane, perpendicular to the exciting beam.
Emission at 45º

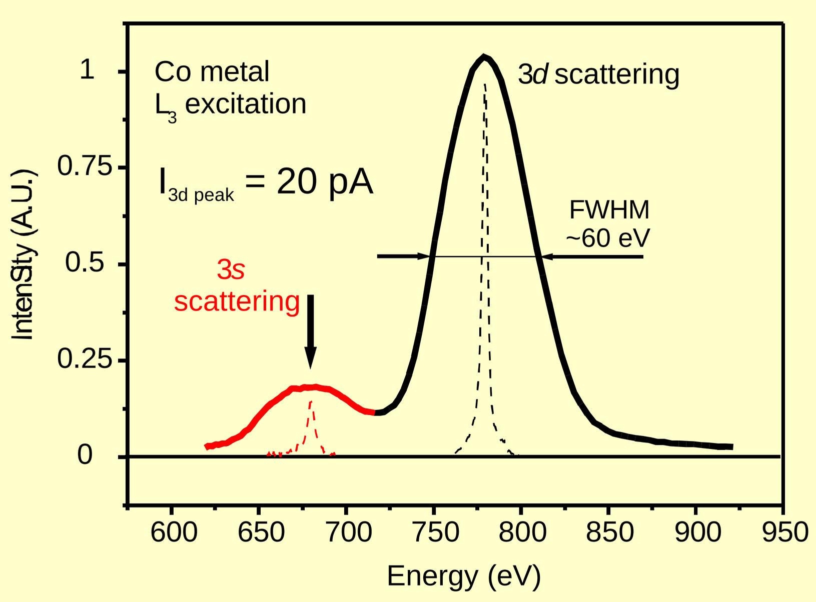
Sample
Co metal polycrystal



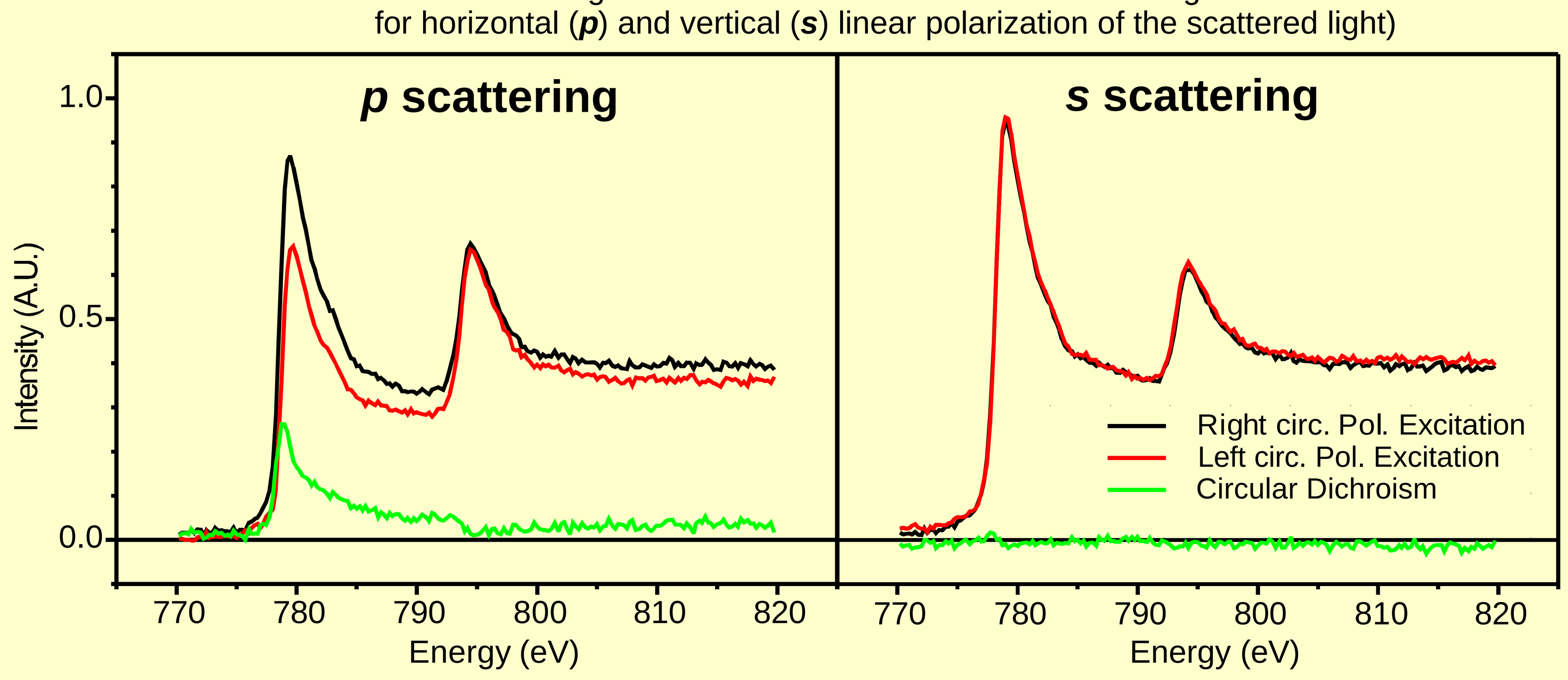




3d and 3s final hole scattering spectra measured by the ML analyser



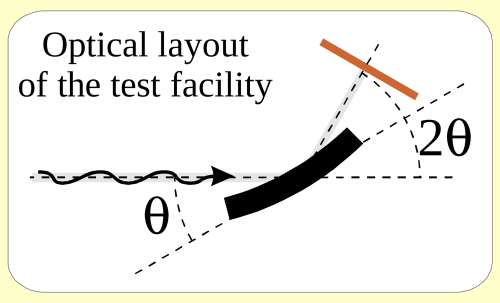
Co metal
Magnetic circular dichroism of the scattered light for horizontal (*p*) and vertical (*s*) linear polarization of the scattered light)



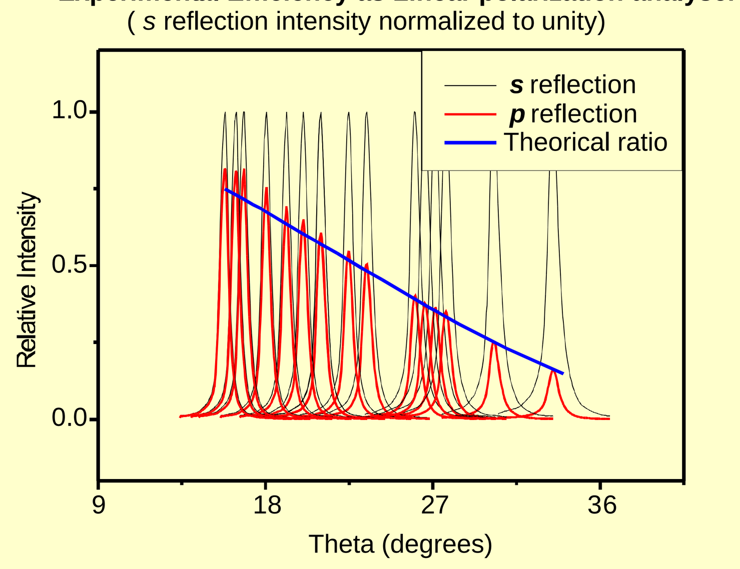
ML characterization

ML specifications:

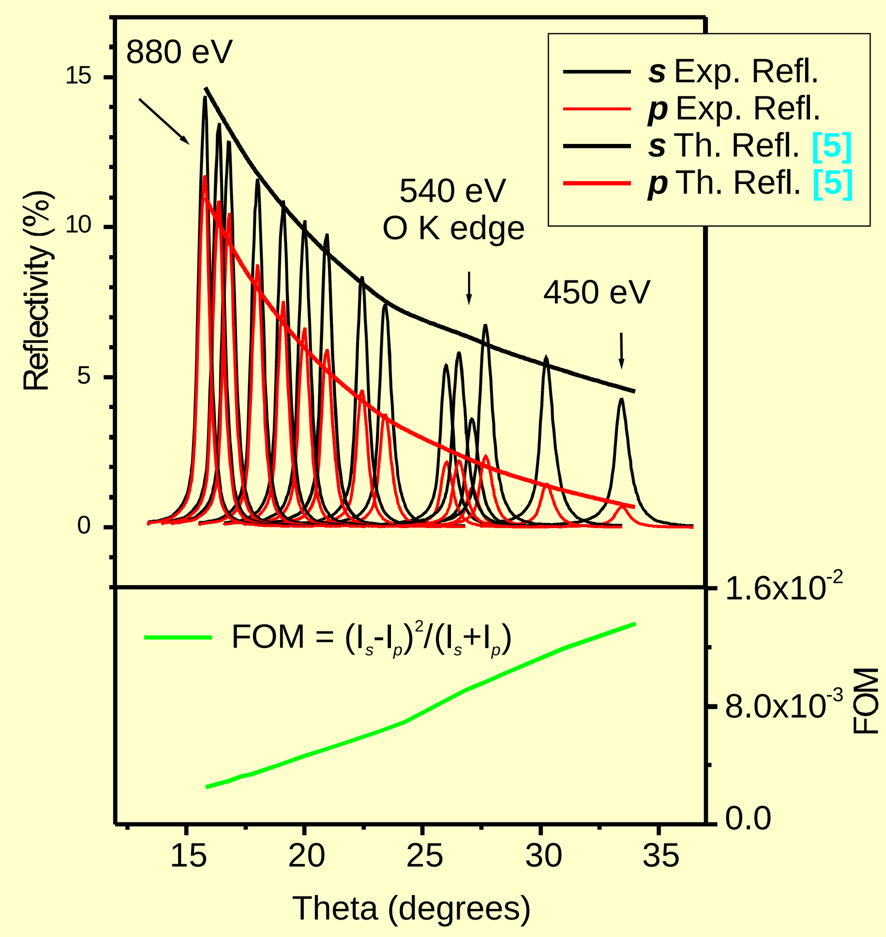
Si-W	
Period	2.5±0.1 nm,
Radius of Curv.	250 mm



Experimental Efficiency as Linear polarization analyser
(*s* reflection intensity normalized to unity)



Comparison between Experiment and Theory

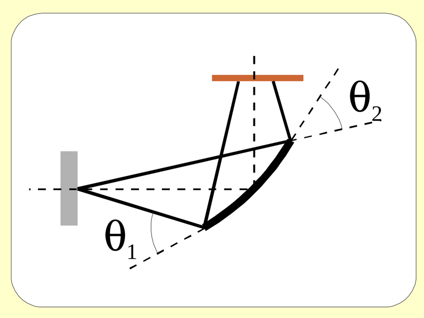


Optical design

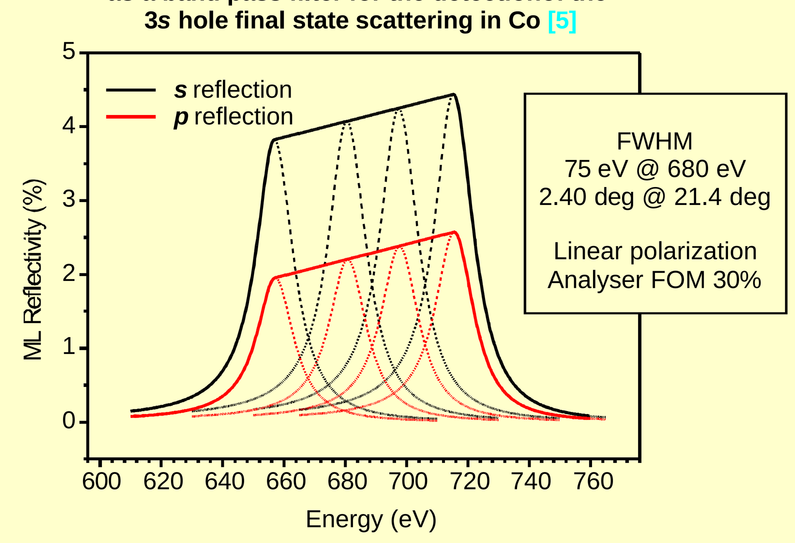
Optical design

Goals
1) Outgoing energy integration over a single scattering channel (Partial Photon Yield)
2) High FOM in the polarization analysis
3) Angular resolution ~10º

Constraints
1) Very LOW SIGNAL



Simulation of a spherical multilayer as a band pass filter for the detection of the 3s hole final state scattering in Co [5]



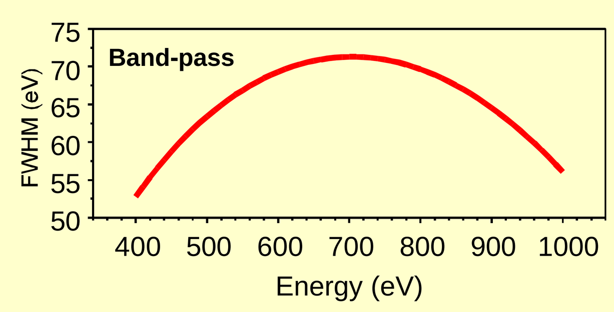
Nearly flat Bandpass

Reflectivity / FOM as linear polarization analizer $(I_s-I_p)^2/(I_s+I_p)$ → Incidence angle / ML period d_{ML}

FWHM → $\Delta\theta = \theta_1 - \theta_2$ / ML radius of curvature

Layout Specifications:

Entrance and exit arms	50 mm
Horizontal acceptance	0.2 rad
Vertical acceptance	0.125 rad (400 eV)
	0.050 rad (950 eV)



Conclusions

- **We demonstrate the possibility of a routine use of ML devices as tunable PPY detectors and polarization analysers in the soft X-ray range.**
- **The test experiment showed a 100% extrapolated linear polarization of the soft X-ray magnetic scattering of Co metal.**
- **The quality of the signal testifies the possible extension of the approach to less demanding application, namely the study of magnetic superstructures by soft X-ray magnetic diffraction.**

References

[1] D. Gibbs, *Physica B* **159**, 145 (1989).
[2] H.A. Dürr *et al.*, *Sicence* **284**, 2166 (1999); E. Dudzik *et al.*, *Phys. Rev. B* **62**, 5779 (2000).
[3] L. Braicovich, A. Tagliaferri, G. van_der_Laan, G. Ghiringhelli, N. B. Brookes, *Phys. Rev. Lett.* **90**, 117401 (2003).
[4] L. Braicovich, G. van der Laan, G. Ghiringhelli, A. Tagliaferri, N. B. Brookes, *Phys. Rev. B* **66**, 174435 (2002).
[5] The intrinsic reflectivity is calculated with the Fresnel equations using the online software at http:// www-cxro.lbl.gov.