Soft X-ray Absorption and Resonant Scattering at ALBA synchrotron

BOREAS - BL29
Beamline Of REsonant Absortion and Scattering

P. Gargiani – ALBA workshop 13 November 2014

Outline

- BL scientific case
- Basic overview of the technique
- BOREAS endstations overview
- Example results/applications

BOREAS beamline

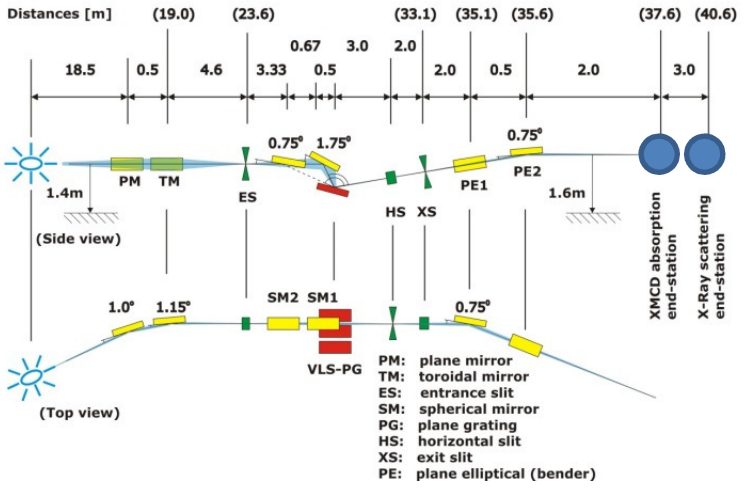
Scientific case

> Apple II undulator (full polarization control) + VLS grating mono → 80-**4500** eV energy range

> **2 endstations** : XAS/XLD/XMCD cryomagnet & RXS chamber **+ 2 T magnet**

> HECTOR: Cryomagnet up to 6 T (2 T in ***sphere* mode**) with sample preparation chamber

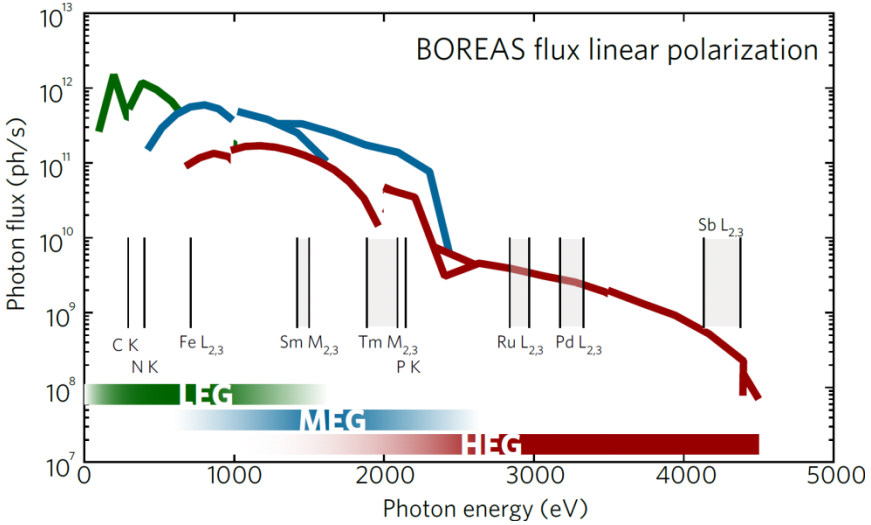
> MARES: Resonant soft X-ray scattering chamber with in-vacuum detectors sample prep. chamber and in-situ deposition possibility (metal/organic evap) (endstation under commissioning)



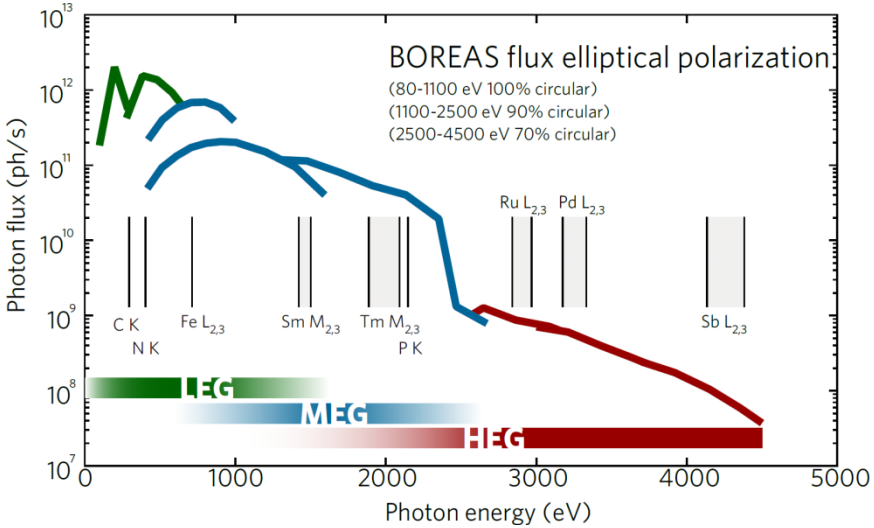
BL highlight:

- **Extended soft X-ray energy range**
- **High flux/High resolving power** (3 gratings x 2 mirror combinations)
- Variable spot size with KB mirror system
- **State-of-art XAS/XMCD/XRS endstation equipment**

BL Energy range



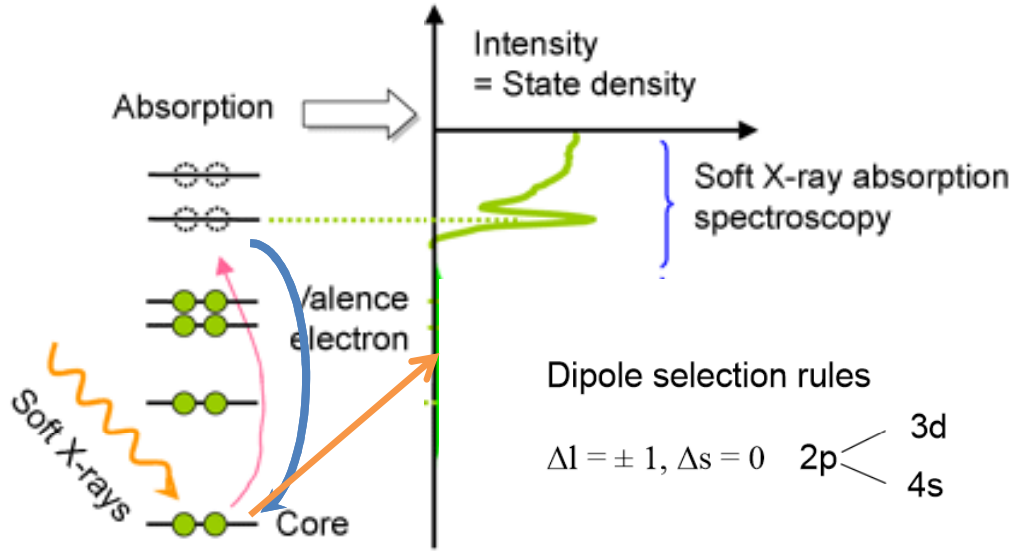
Linear polarization

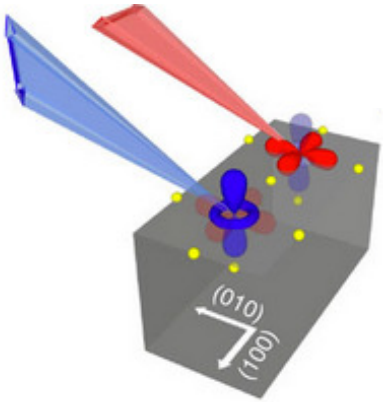


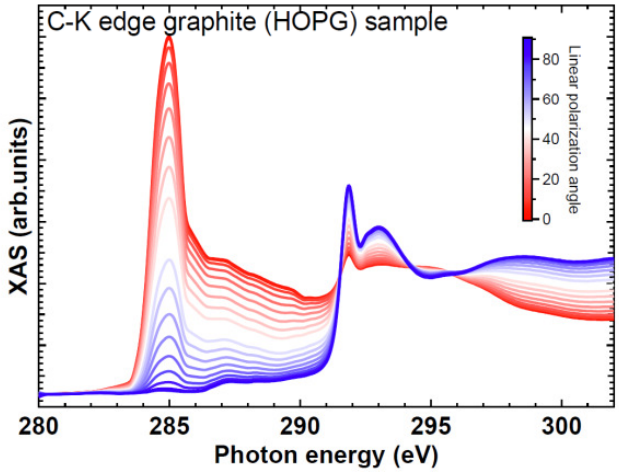
Circular & elliptical polarization

- High flux at optimum resolution (measured at 100mA ring current)
- Considerable flux in the high energy range (>1.5 keV)
- Typically 1st ID harmonic 100-1100 eV ; 3rdh : 1000-2500 eV approx. ; 3rd, 5th , … for E>2000 eV

X-ray absorption/scattering



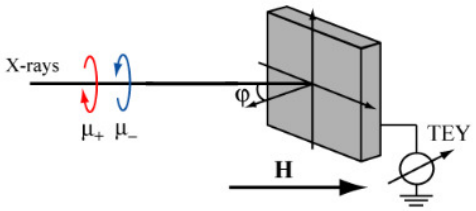




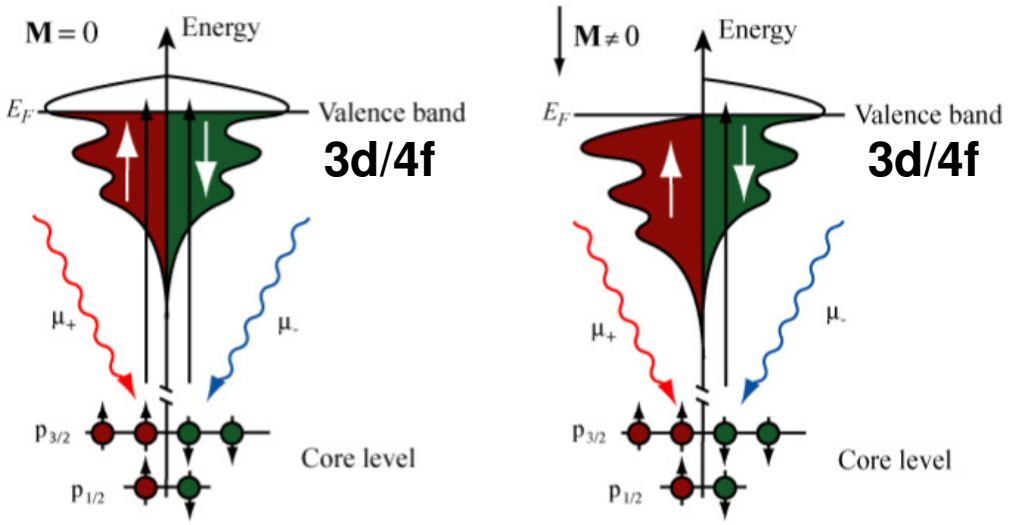
- XAS chemical sensitivity due to core-level absorption + dipole selection rules
- XAS orbital sensitivity due to light polarization direction
- XRS scattering enhancement in correspondence with intermediate excited state formation → resonant process

X-ray magnetic circular dichroism

Circular dichroism

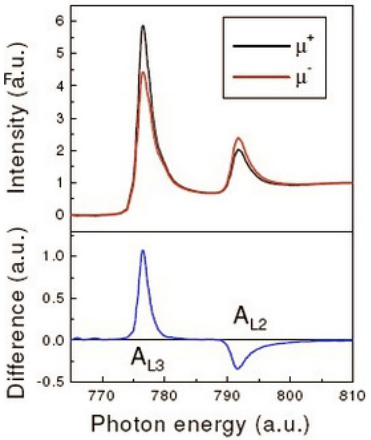


Transition sensible to final state spin



Dipole selection rules

3d

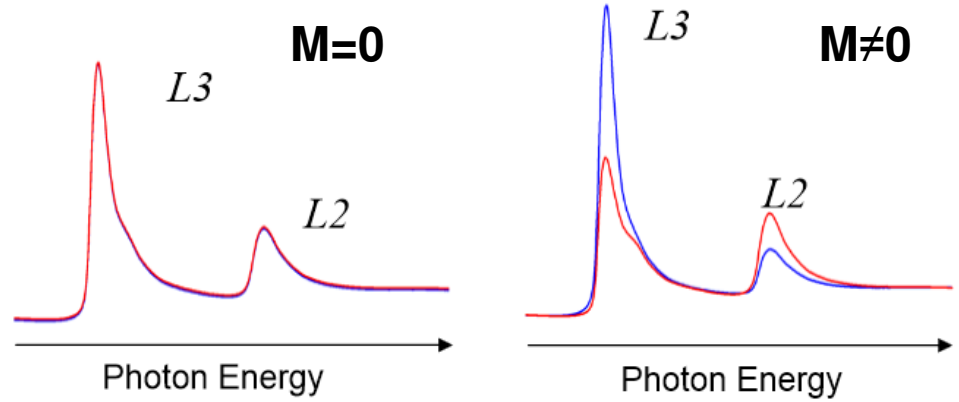


Sum rules

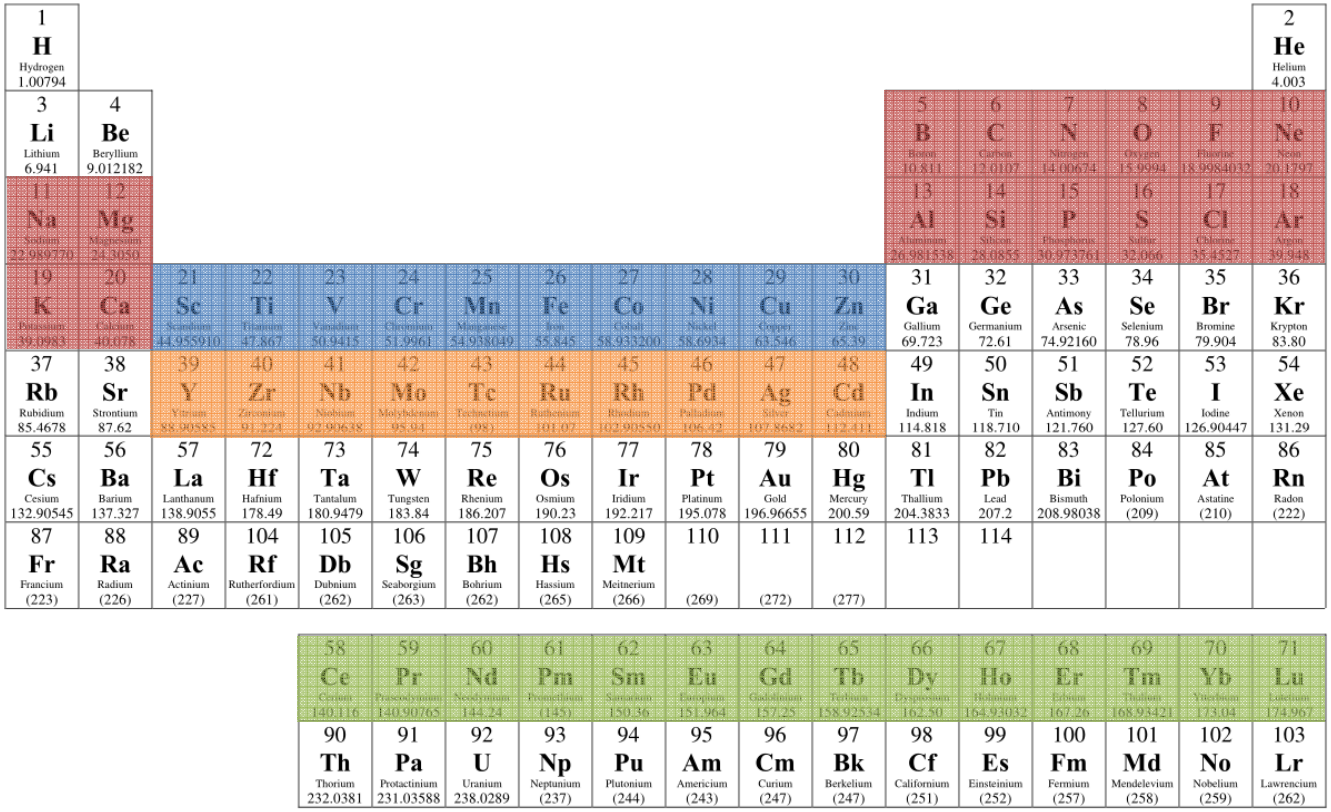
$$m_s/\mu_B \sim \frac{A_{L3} - 2A_{L2}}{A_{iso}}$$

$$m_l/\mu_B \sim \frac{A_{L3} + A_{L2}}{A_{iso}}$$

Absorption spectra



Accessible absorption edges



400 – 1000 eV

L2,3 edge 2p->3d

900 – 1600 eV

M 4,5 edge 3d->4f

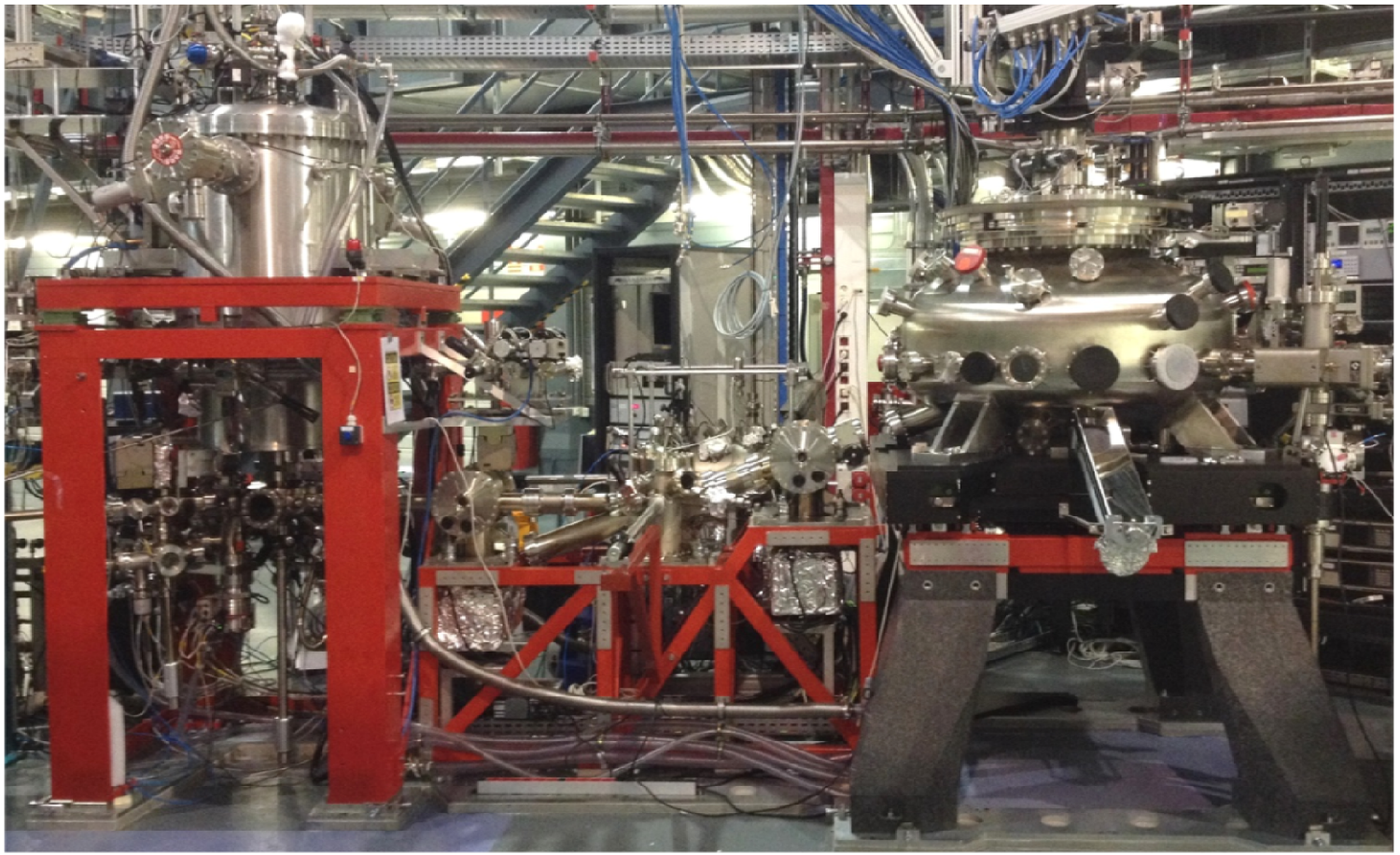
2300 – 3500 eV

L2,3 edge 2p->4d

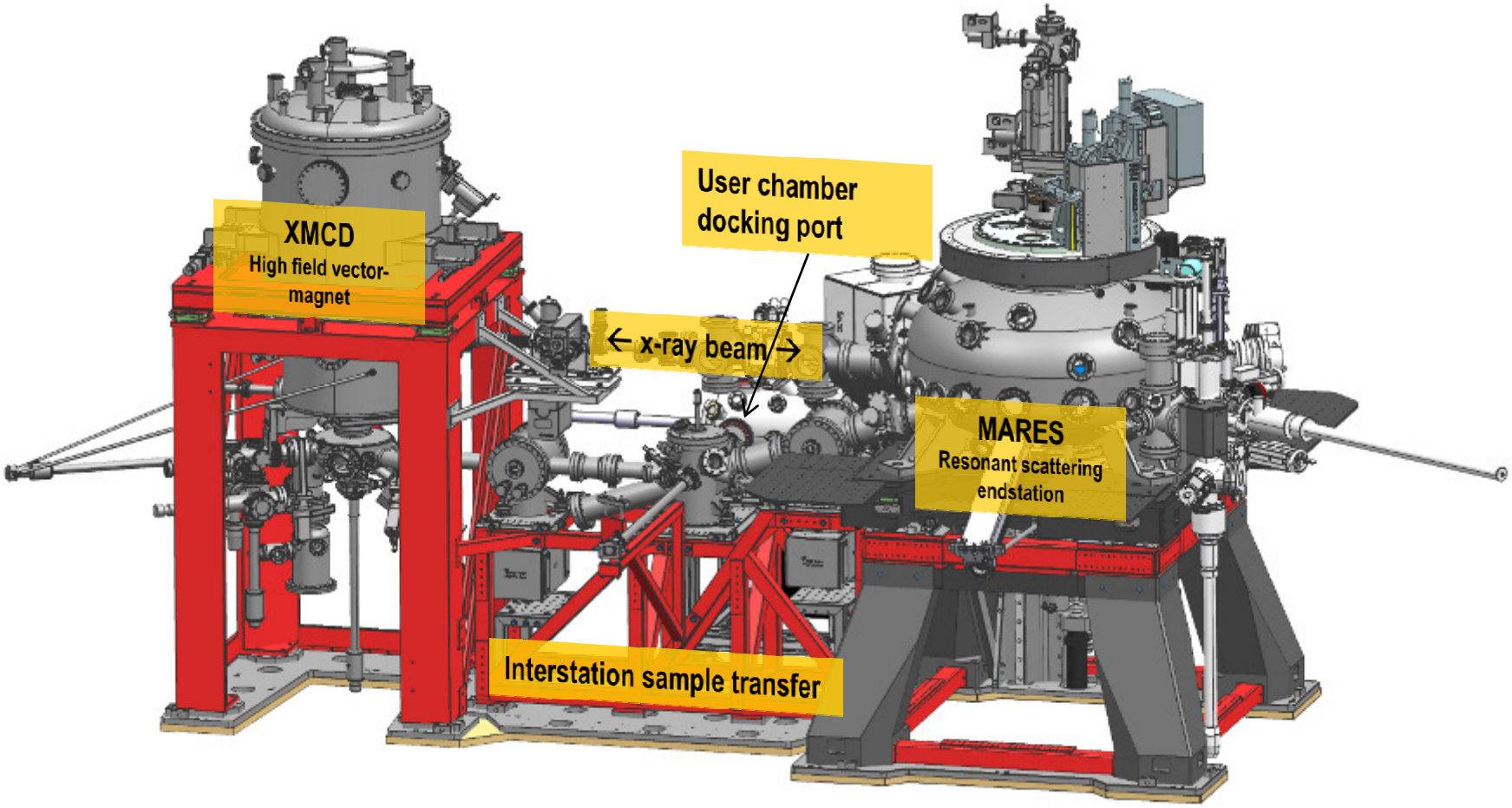
180 – 4000 eV

K edge 1s->p/vac.

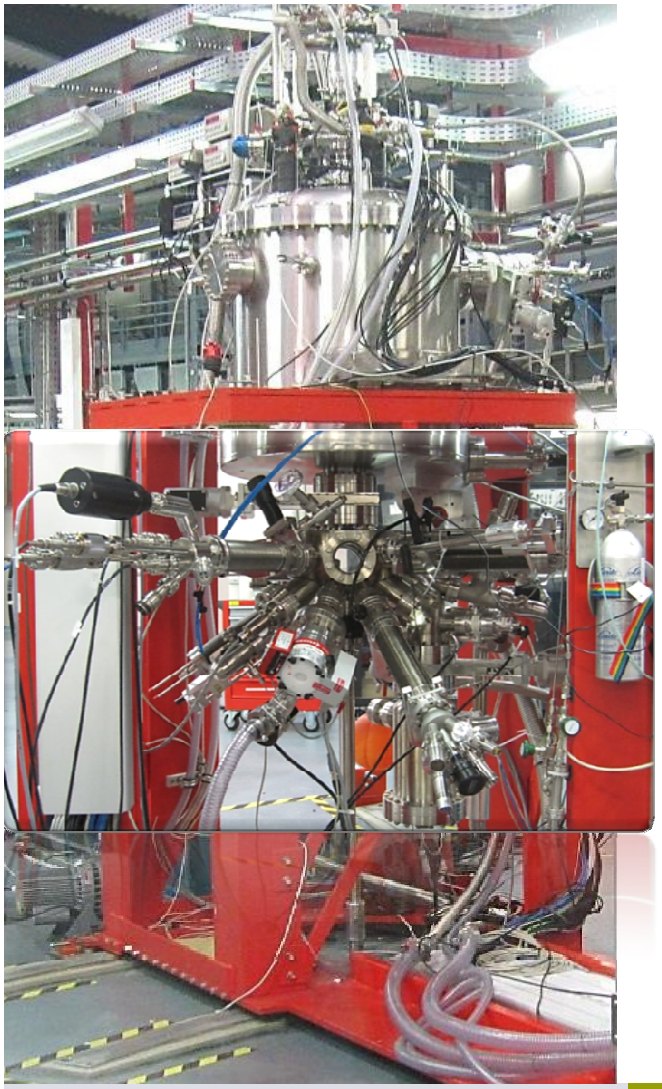
The endstations



The endstations



HECTOR – Vectorial superconducting magnet



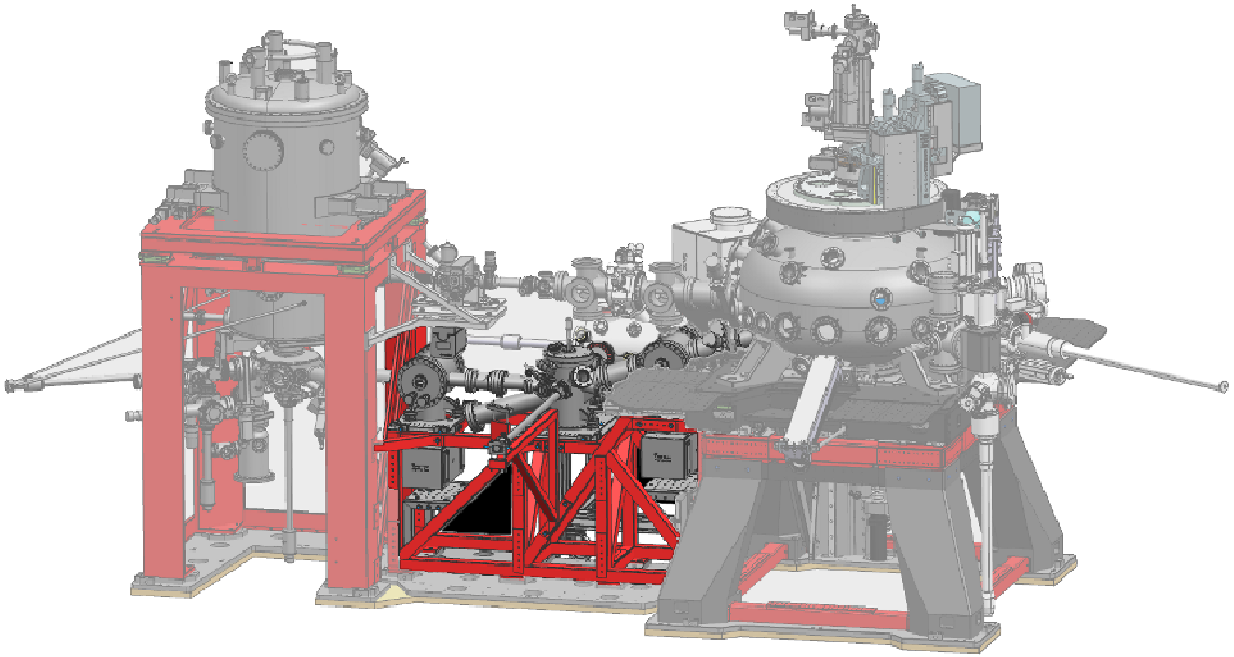
HECTOR – High magnetic field XMCD endstation:

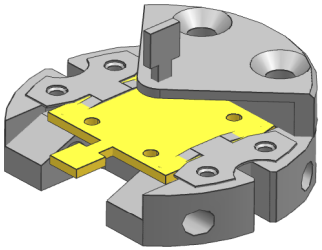
- Up to 6 Tesla along beam
- 2 T sphere mode
- 2-370 K variable sample temperature
- 4 electrical feedthrough available on sample holder
- Signal detection: total electron yield, fluorescence yield and transmission

HECTOR – UHV preparation chamber:

- Fully equipped surface science prep. Chamber: sputtering/annealing, metal/organic evap, mini LEED/AES, quartz balance and fast exchange user equipment
- Cleaver/scraper for single crystal/pellet
- Fast entry load-lock with up to 4 places + 4 places UHV buffer chamber

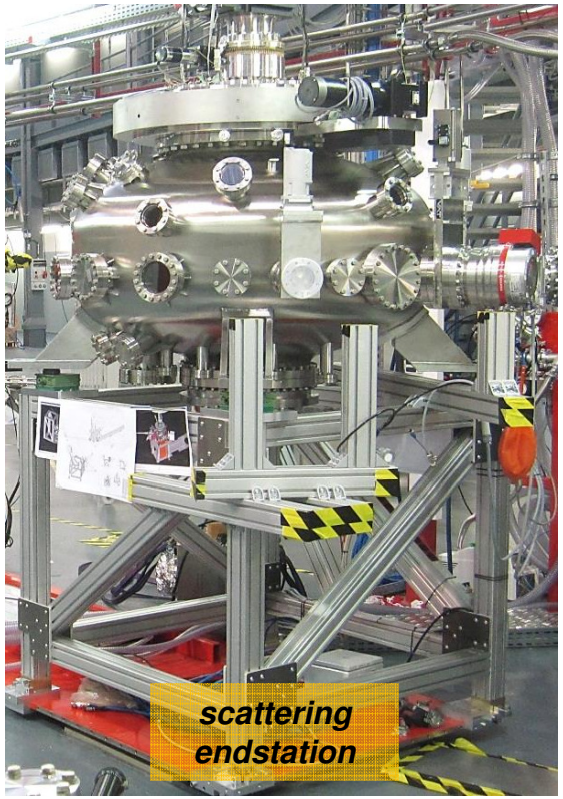
Interstation sample transfer





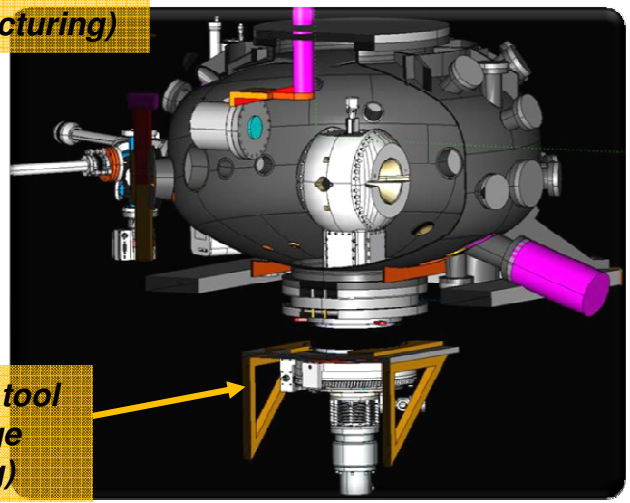
- UHV sample transfer between the two enstation
- Docking port for user-brought chamber/system
- Docking port for smalle UHV “suitcase”
- All compatible with “standard” omicron/specs like sample plates

MARES – soft x-ray diffractometer



> Final assembly late 2014
> Open to users starting from feb. 2015
> Availability : reflectometry exps. without applied magnetic field

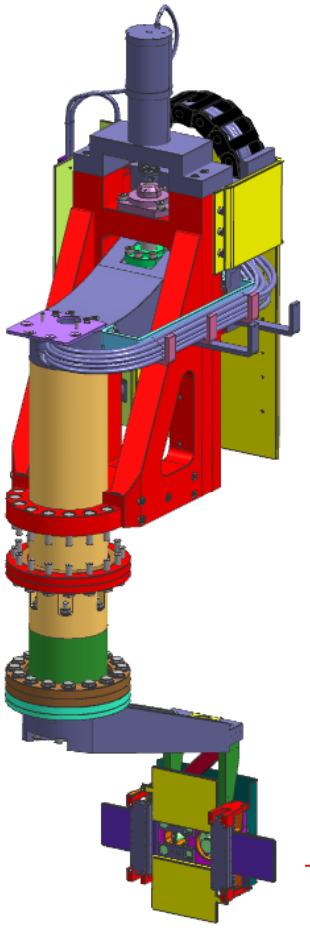
Two in-vacuum detector arms (IH-designed, manufacturing)

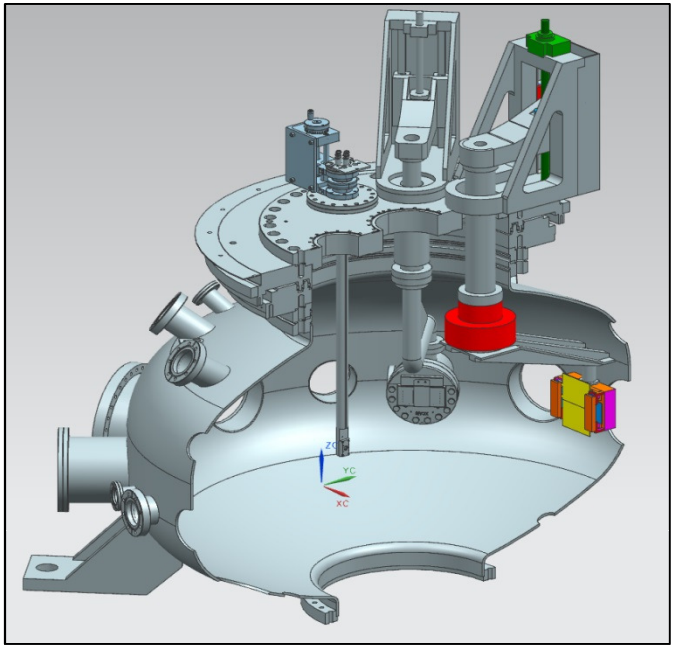


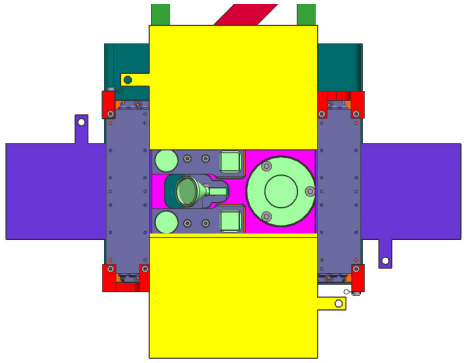
2 T magnet in/out tool with rotary stage (manufacturing)

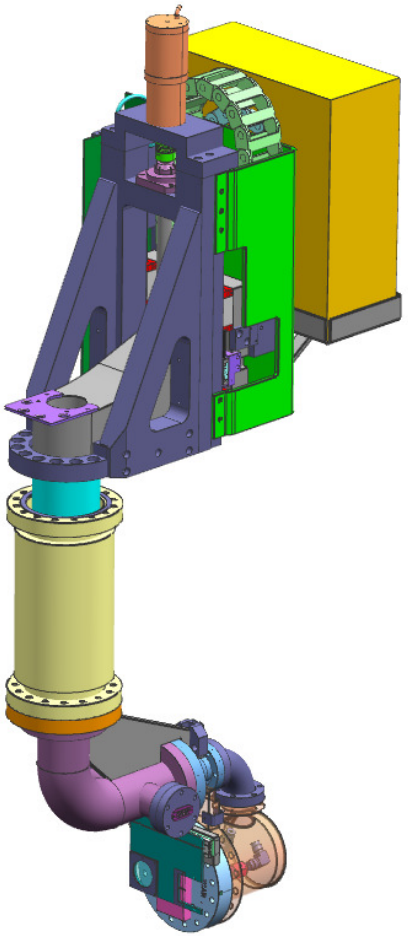
- Surf. science prep chamber (up to now sputtering/annealing stage gas line)
- In-situ deposition with metal/organic molecules evaporator (..with x-ray)
- Variable temperature 17-350 K, 6-DOF sample manipulator
- In-vacuum detector mounted on top rotary stage

MARES detectors









> Arm 1 – channeltron, microchannel plate, diodes, slits

> Arm 2 – XCAM CCD (SAT OK, june'14)

Example results

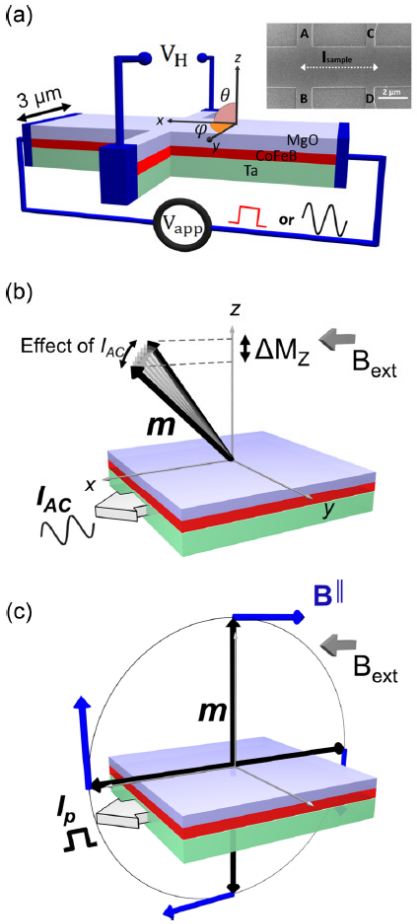


FIG. 2. (Color online) (a) Schematic of the sample and measurement geometry. Inset: Scanning electron micrograph image of a sample. (b) Small oscillations of the magnetization induced by an ac current. (c) Switching of the magnetization induced by the combined action of $B^{\parallel}$ and the external field.

PHYSICAL REVIEW B **89**, 214419 (2014)

Fieldlike and antidamping spin-orbit torques in as-grown and annealed Ta/CoFeB/MgO layers

Can Onur Avci,[1,2] Kevin Garello,[1,2] Corneliu Nistor,[1,2] Sylvie Godey,[2] Belén Ballesteros,[2] Aitor Mugarza,[2] Alessandro Barla,[3] Manuel Valvidares,[4] Eric Pellegrin,[4] Abhijit Ghosh,[1] Ioan Mihai Miron,[5] Olivier Boulle,[5] Stephane Auffret,[5] Gilles Gaudin,[5] and Pietro Gambardella[1,2]

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[4]*ALBA Synchrotron Light Source, E-08290 Cerdanyola del Vallès, Barcelona, Spain*
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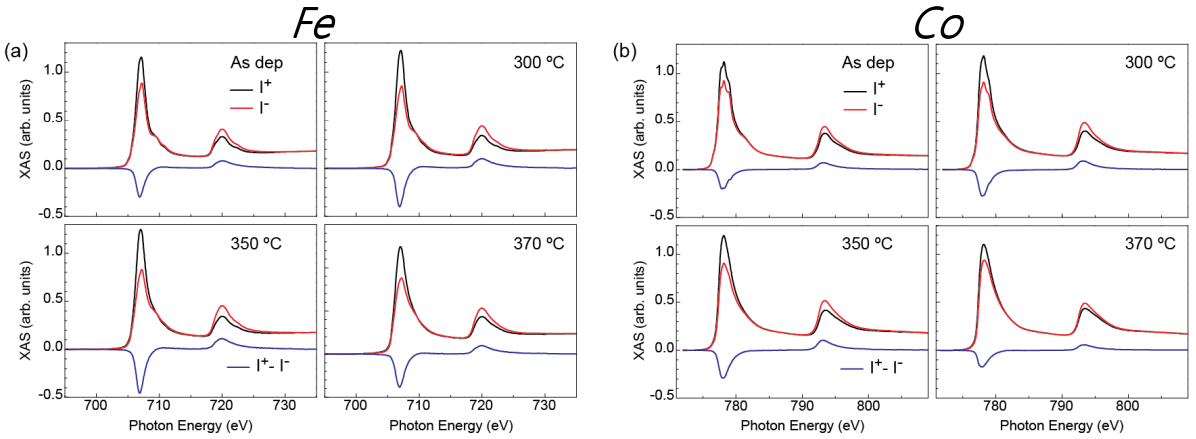
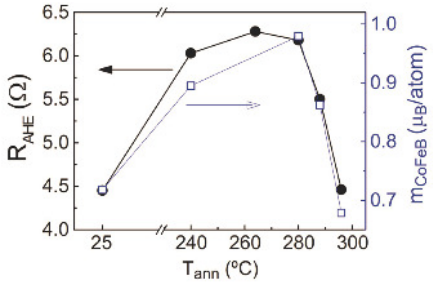


- **Element specific magnetic moments measured with XMCD**
- **Per-atom magnetic moment measured with XMCD applying sum rules analysis**



Example results

Inorganic Chemistry — Article — pubs.acs.org/IC

Stability of the Cationic Oxidation States in $Pr_{0.50}Sr_{0.50}CoO_3$ across the Magnetostructural Transition by X-ray Absorption Spectroscopy

Jessica Padilla-Pantoja,*,† Javier Herrero-Martín,‡ Pierluigi Gargiani,‡ Manuel Valvidares,‡ Vera Cuartero,‡,§ Kurt Kummer,§ Oliver Watson,§ Nicholas B. Brookes,§ and José Luis García-Muñoz†

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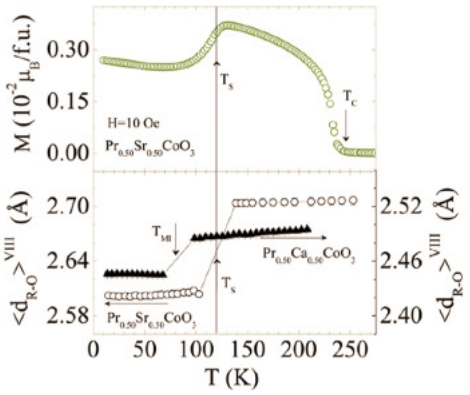
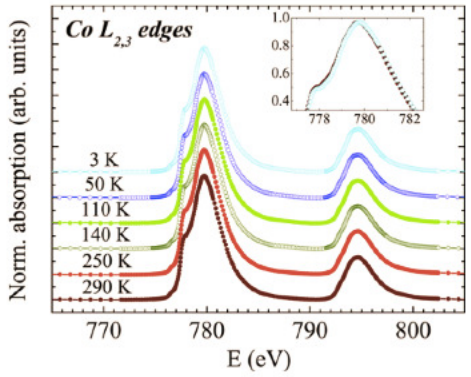
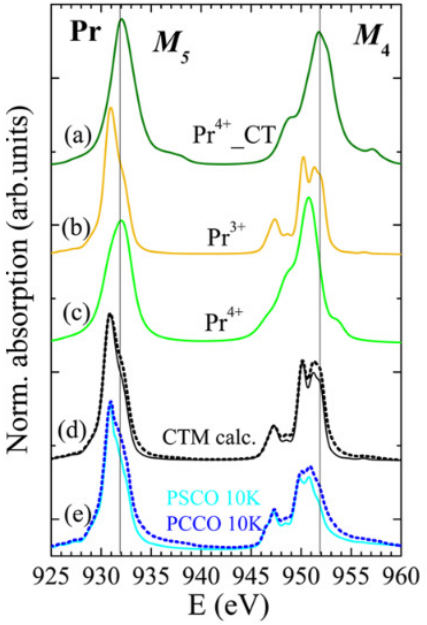
J. Padilla-Pantoja et al (PhD thesis in prep.)

dx.doi.org/10.1021/ic403117j | Inorg. Chem. 2014, 53, 8854−8858

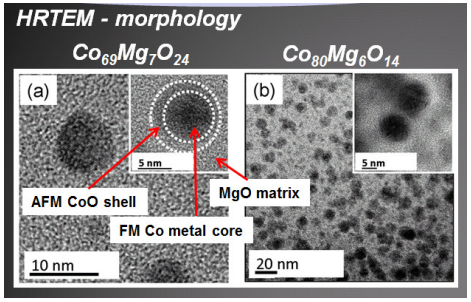


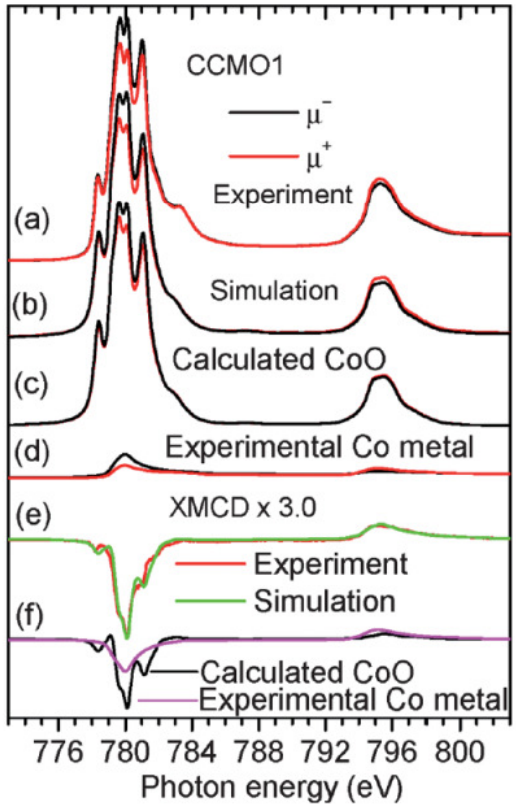




- **Element-specific oxidation state investigation (Co and Pr) via XAS across magneto structural phase transition**
- **No change in valence of both Co and Pr ions suggests a more complicated mechanism involving LS/HS mixture of Co ions to explain magnetic phase transition**

Example results





Nanoscale

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Direct observation of rotatable uncompensated spins in the exchange bias system Co/CoO–MgO

Cite this: *Nanoscale*, 2013, **5**, 10236

Chuannan Ge,[ab] Xiangang Wan,*[a] Eric Pellegrin,*[c] Zhiwei Hu,[d] S. Manuel Valvidares,[c] Alessandro Barla,[ce] Wen-I. Liang,[f] Ying-Hao Chu,[f] Wenqin Zou[a] and Youwei Du[a]

We have observed a large exchange bias field $H_E \approx 2460$ Oe and a large coercive field $H_C \approx 6200$ Oe at $T = 2$ K for Co/CoO core–shell nanoparticles (~4 nm diameter Co metal core and CoO shell with ~1 nm thickness) embedded in a non-magnetic MgO matrix. Our results are in sharp contrast to the small exchange bias and coercive field in the case of a non-magnetic Al_2O_3 or C matrix materials reported in previous studies. Using soft X-ray magnetic circular dichroism at the Co-$L_{2,3}$ edge, we have observed a ferromagnetic signal originating from the antiferromagnetic CoO shell. This gives direct evidence for the existence of rotatable interfacial uncompensated Co spins in the nominally antiferromagnetic CoO shell, thus supporting the uncompensated spin model as a microscopic description of the exchange bias mechanism.

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www.rsc.org/nanoscale

Separation of different dichroic contribution with exp/simulation comparion:

- Uncompensated rotatable Co2+ spins in nominally AFM CoO shell stabilized by MgO matrix.
- Metallicity cancels CoO FM contribution
- 30% Co metal + 70% ferromagnetic Co2+ in dichroic spectrum.
- Larger part of ferromagnetic signal stems from CoO shell

Example results

PRL 113, 156802 (2014) PHYSICAL REVIEW LETTERS week ending 10 OCTOBER 2014

Two-Dimensional Electron Gases at $LaAlO_3/SrTiO_3$ Interfaces: Orbital Symmetry and Hierarchy Engineered by Crystal Orientation

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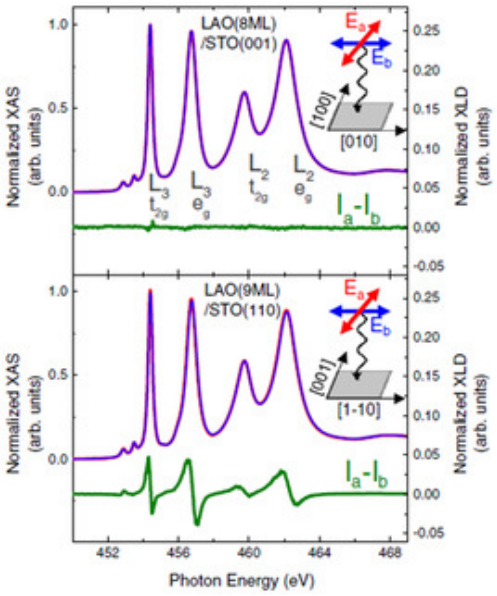
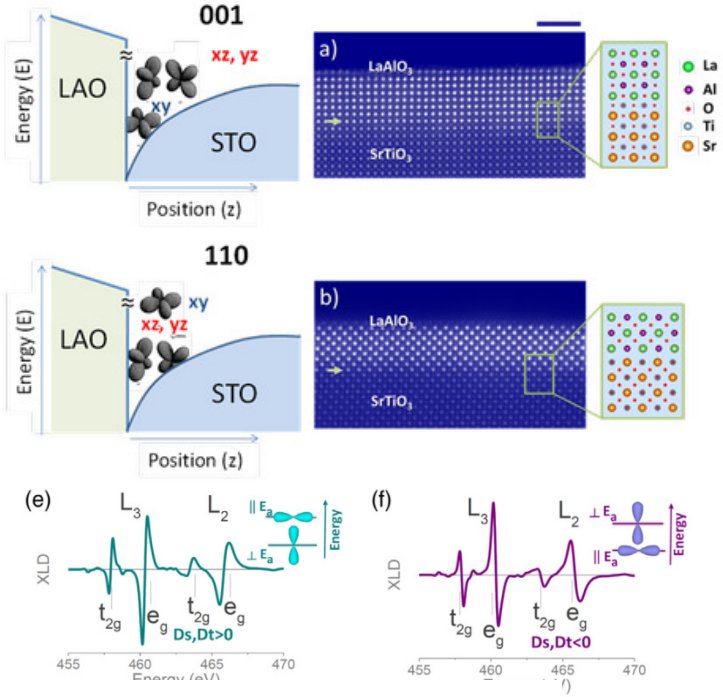
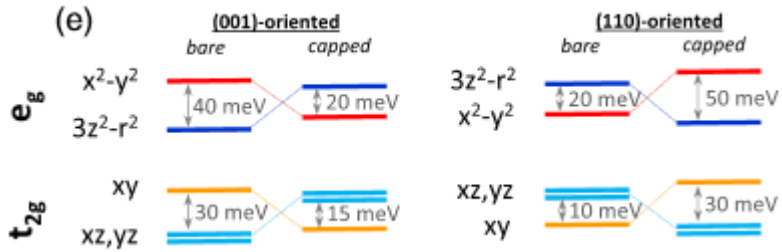
(Received 9 May 2014; revised manuscript received 24 July 2014; published 7 October 2014)

Recent findings show the emergence of two-dimensional electron gases (2DEGs) at $LaAlO_3/SrTiO_3$ interfaces along different orientations; yet details on band reconstructions have remained so far unknown. Via x-ray linear dichroism spectroscopy, we demonstrate that crystal symmetry imposes distinctive 2DEG orbital hierarchies on (001)-and (110)-oriented quantum wells, allowing selective occupancy of states of different symmetry. Such orientational tuning expands the possibilities for electronic engineering of 2DEGs and opens up enticing opportunities to understand the link between orbital symmetry and complex correlated states at $LaAlO_3/SrTiO_3$ quantum wells.



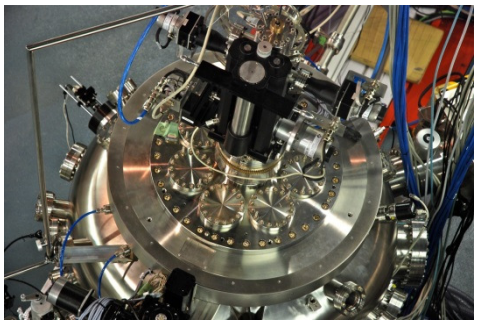


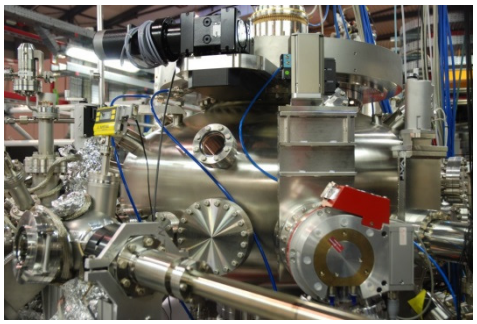


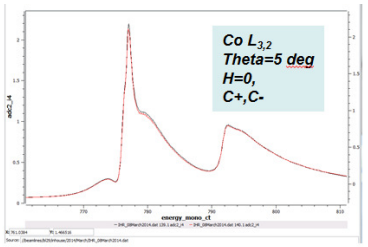
- **LAO/STO interface crystal orientation dependent orbital hierarchy resolved by XLD at Ti L2,3 edge**
- **High resolution/high energy reproducibility needed to perform such experiment**

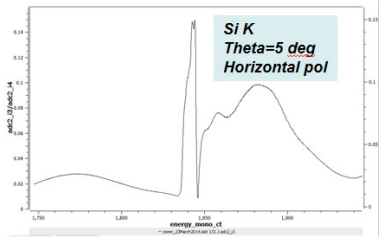
MARES – first results

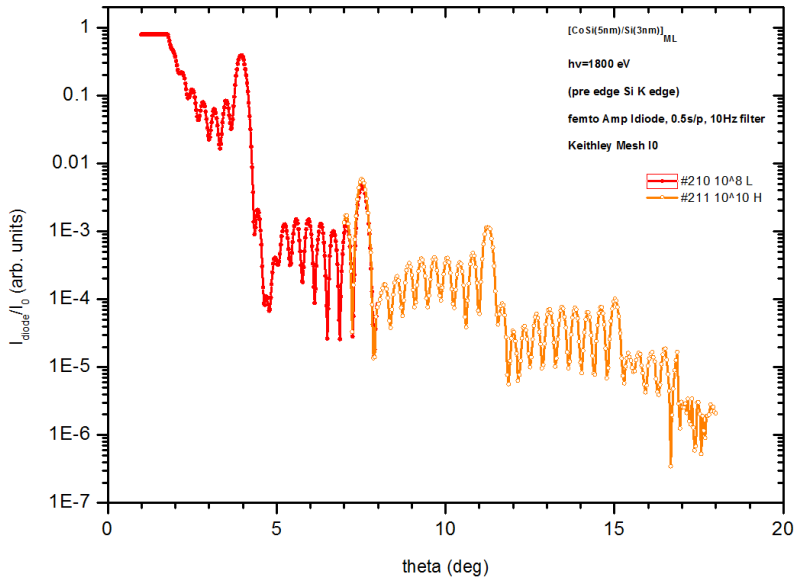
[CoSi(5nm)/Si(3nm)] Multilayer test sample reflectivity
March 2013 in-house/commissioning time
Diode detector mounted on a “temporary” support

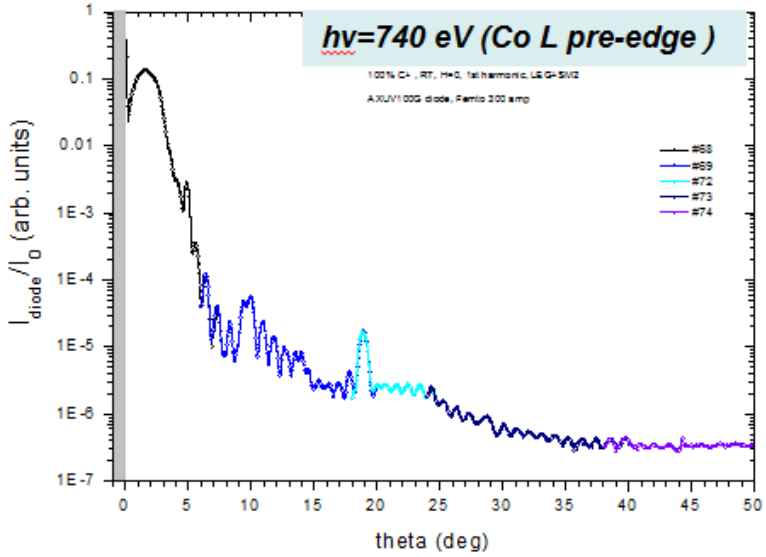




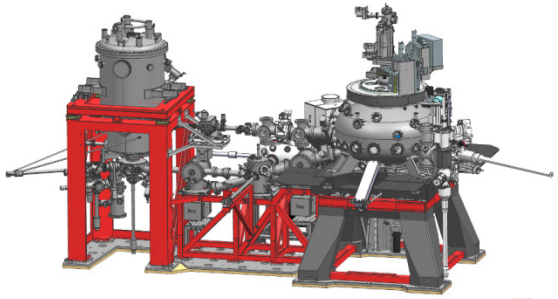




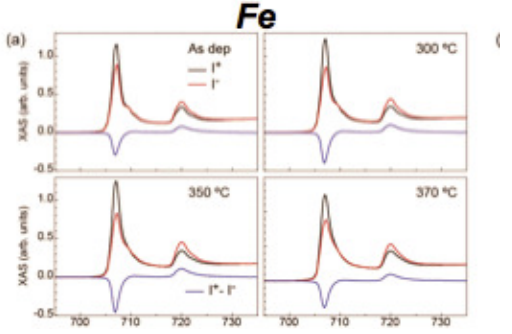


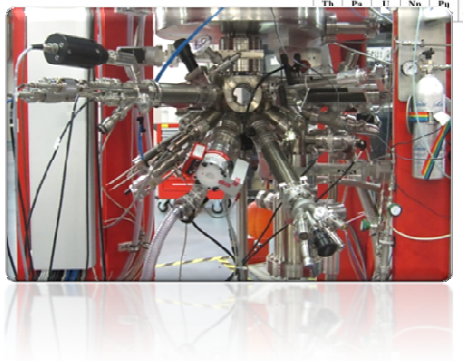


Remarks

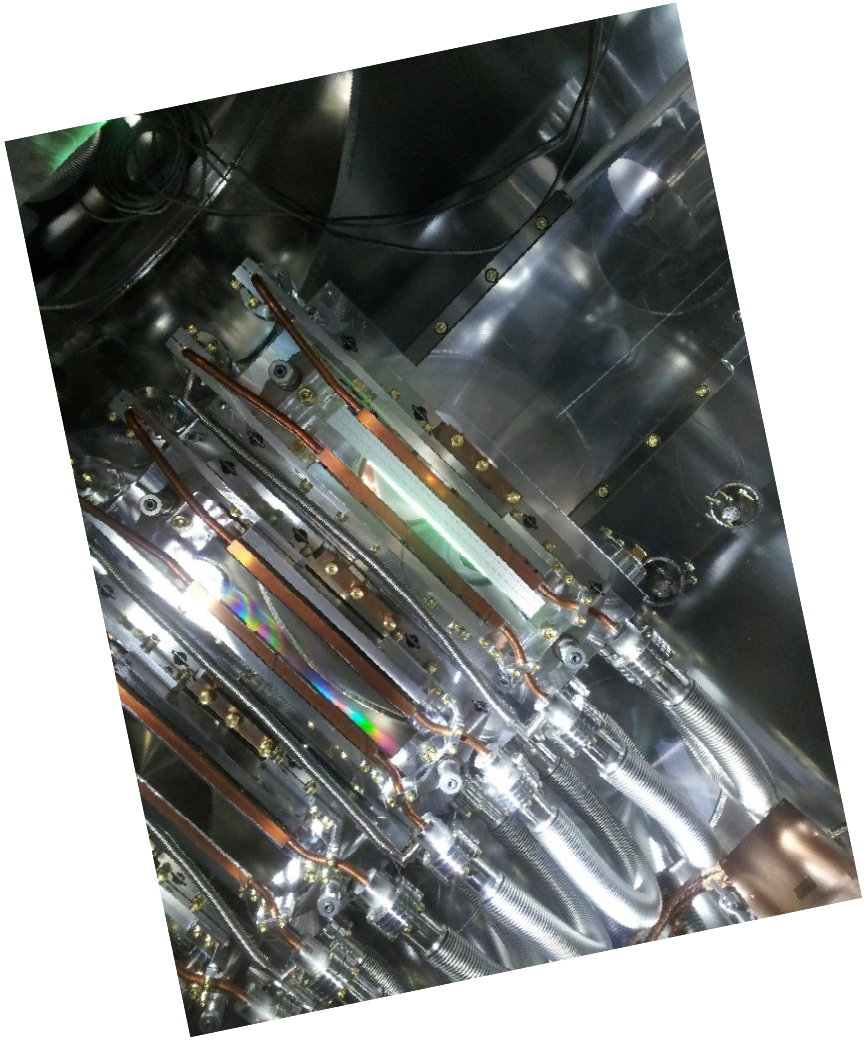


- Two endstation beamline for **X-ray absorption**, **magnetic circular dichroism** and **X-ray magnetic resonant scattering**
- **Element specific magnetic properties**: orbital/spin moment, magnetic anisotropy
- X-ray resonant magnetic scattering experiment for element specific magnetic/structural properties
- Peculiar energy range allowing **4d elements magnetic studies** and **intermediate K-edge elements** (Sulphur, Calcium..)
- Very good instrumentation available for sample preparation and surface science experiments





Acknowledgments



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