Polarization Dependent Soft X-ray Studies at a Hard X-ray Source

Outline:

Short Overview

Some examples

Future possibilities

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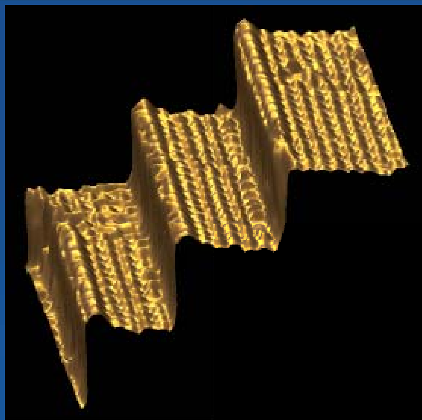
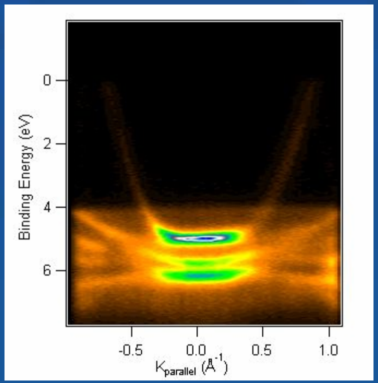
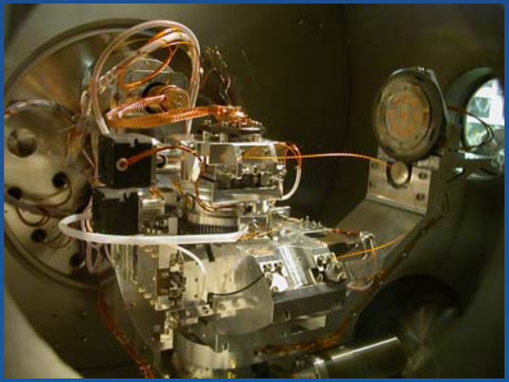
Overview: soft X-ray polarisation dependent studies



Angle-resolved photoemission



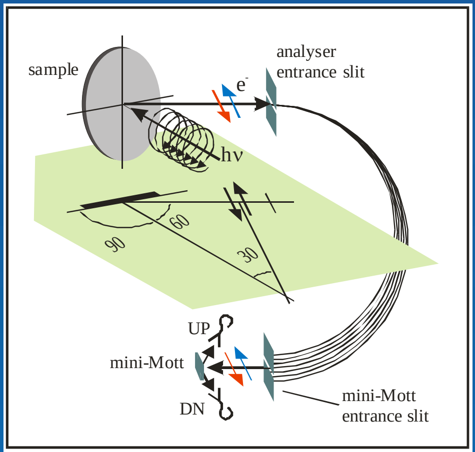


X-ray magnetic circular dichroism (XMCD) and linear dichroism (XMLD)

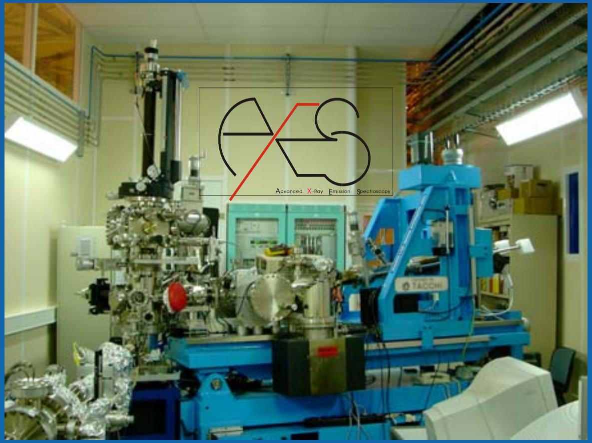
Highly stable and very intensity circular (left/right) and linear (horizontal/vertical) polarised soft x-rays needed.

X-ray magnetic scattering

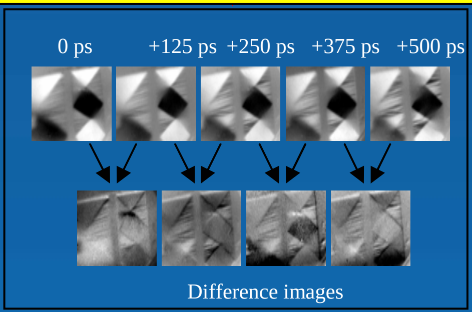
Spin polarised photoemission



Resonant inelastic X-ray scattering (RIXS)



Other:

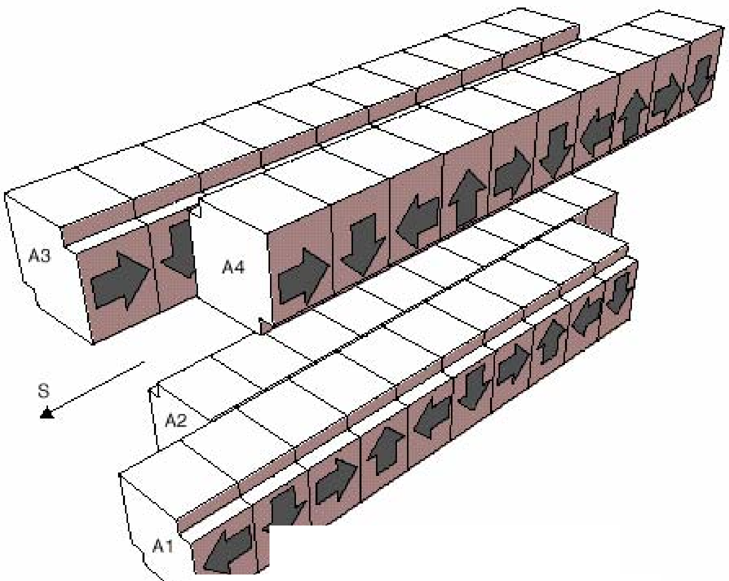


Time-resolved PEEM/scattering/XMCD

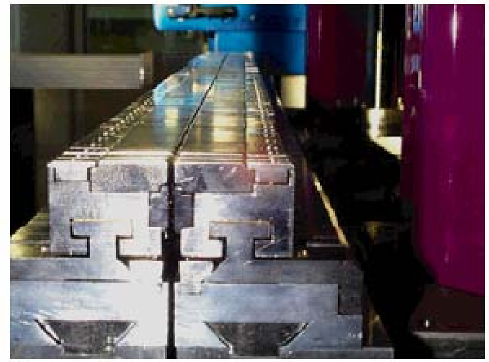
Helical undulator X-ray source

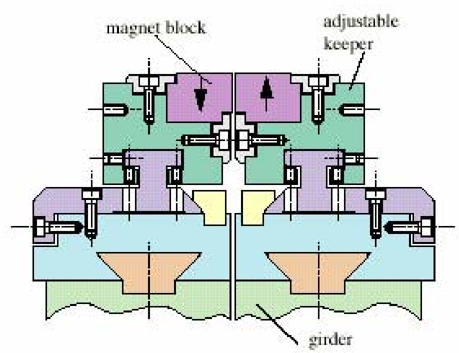
ID08

APPLE II STRUCTURE



*18 * 88mm periods;*
two undulators





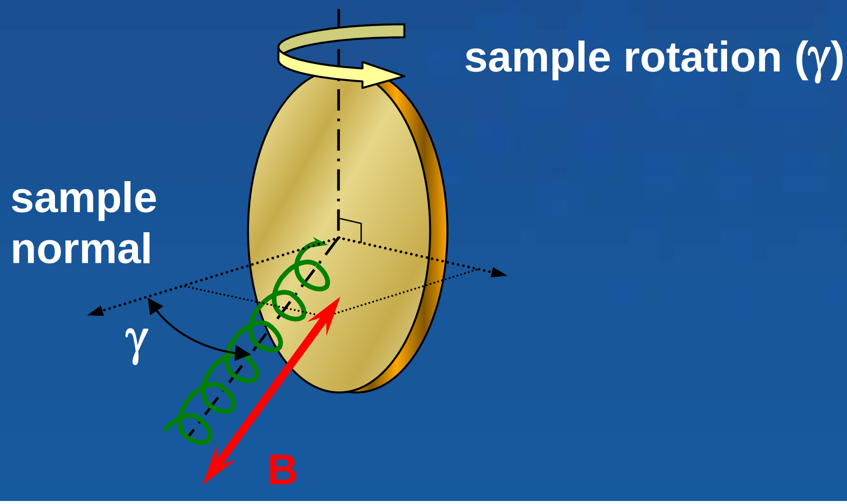
APPPLE II

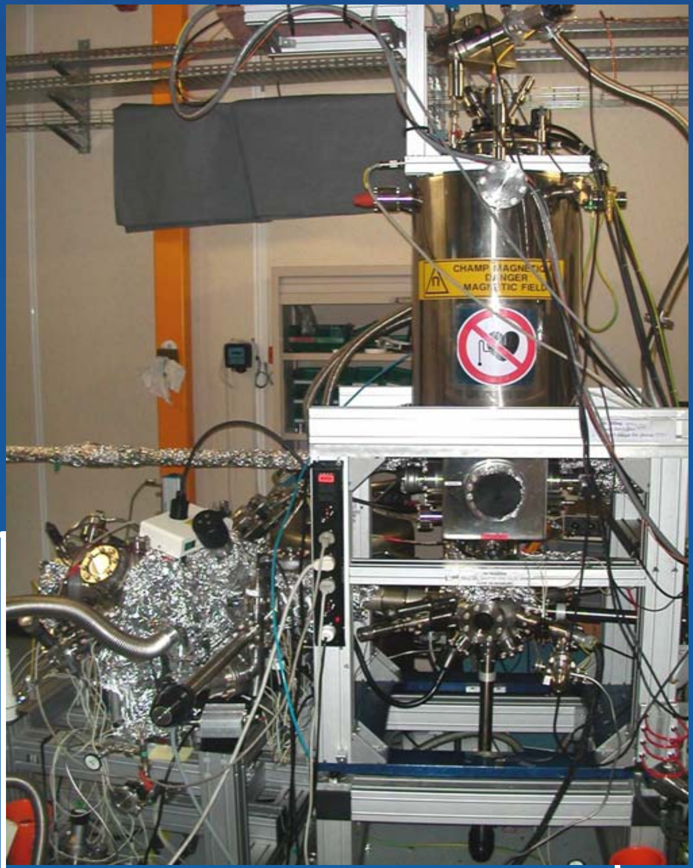
~100% polarised circular (left and right), linear (vertical and horizontal) soft X-rays.

hν=0.3-1.6keV with 1[st] harmonic ⇒

- The 3d transition metal $L_{2,3}$ edges
- The rare-earth $M_{4,5}$ edges
- K edges Oxygen, Nitrogen

X-ray Dichroism experimental setup





- Superconducting magnet (+/− 5T)
- 6.5K < T_{sample} < 300K
- Ultra-High Vacuum, p » 5×10^{-11} mbar
- Sample transfer
- Electron and fluorescence yield detection
- In-situ e-beam evaporators and sample preparation facilities – STM/LEED/Auger/sample heating/sputtering etc.
- New: electric field capabilities.

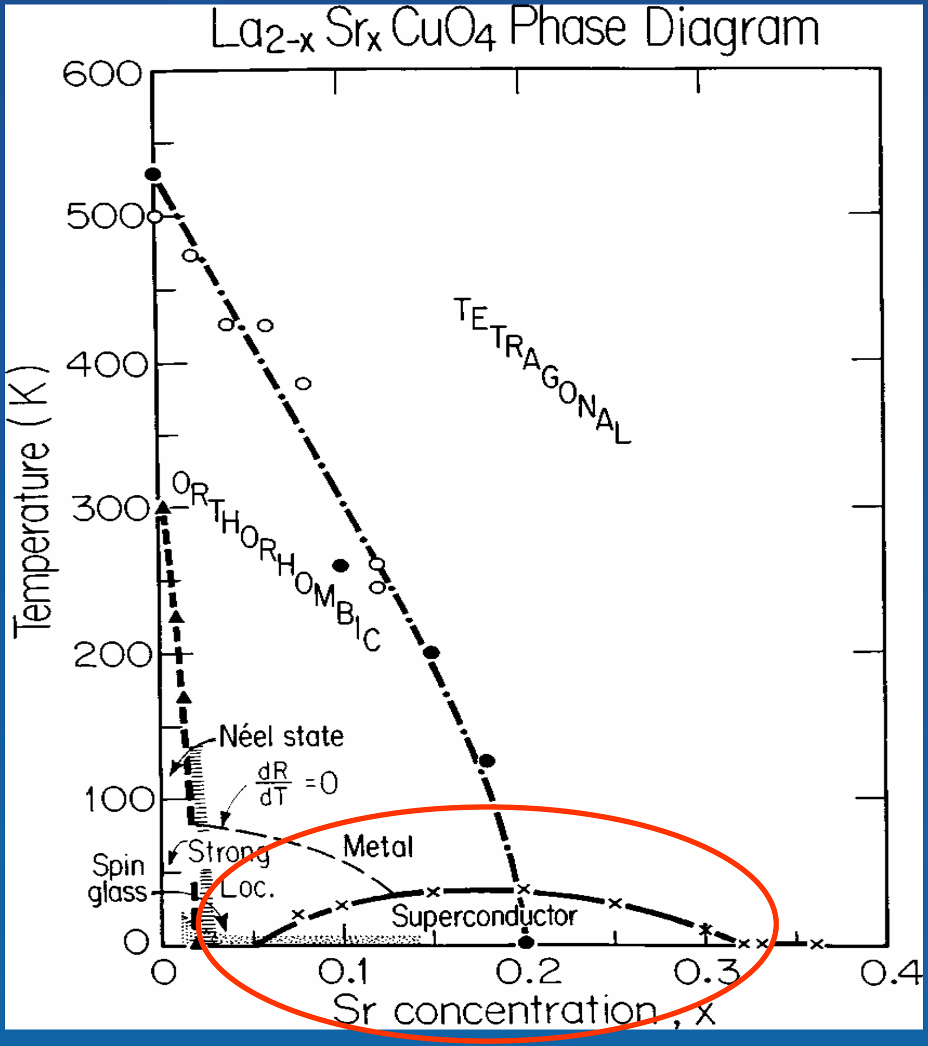
Example 1:

Electric field doping of High Temperature Superconductors.

M. Salluzzo, G. M. De Luca, R.Vaglio CNR-INFM Napoli, Italy
F. Fracassi, G. Ghiringhelli, CNR-INFM Milano, Italy
J. C. Cezar, N. B. Brookes, ESRF, France.

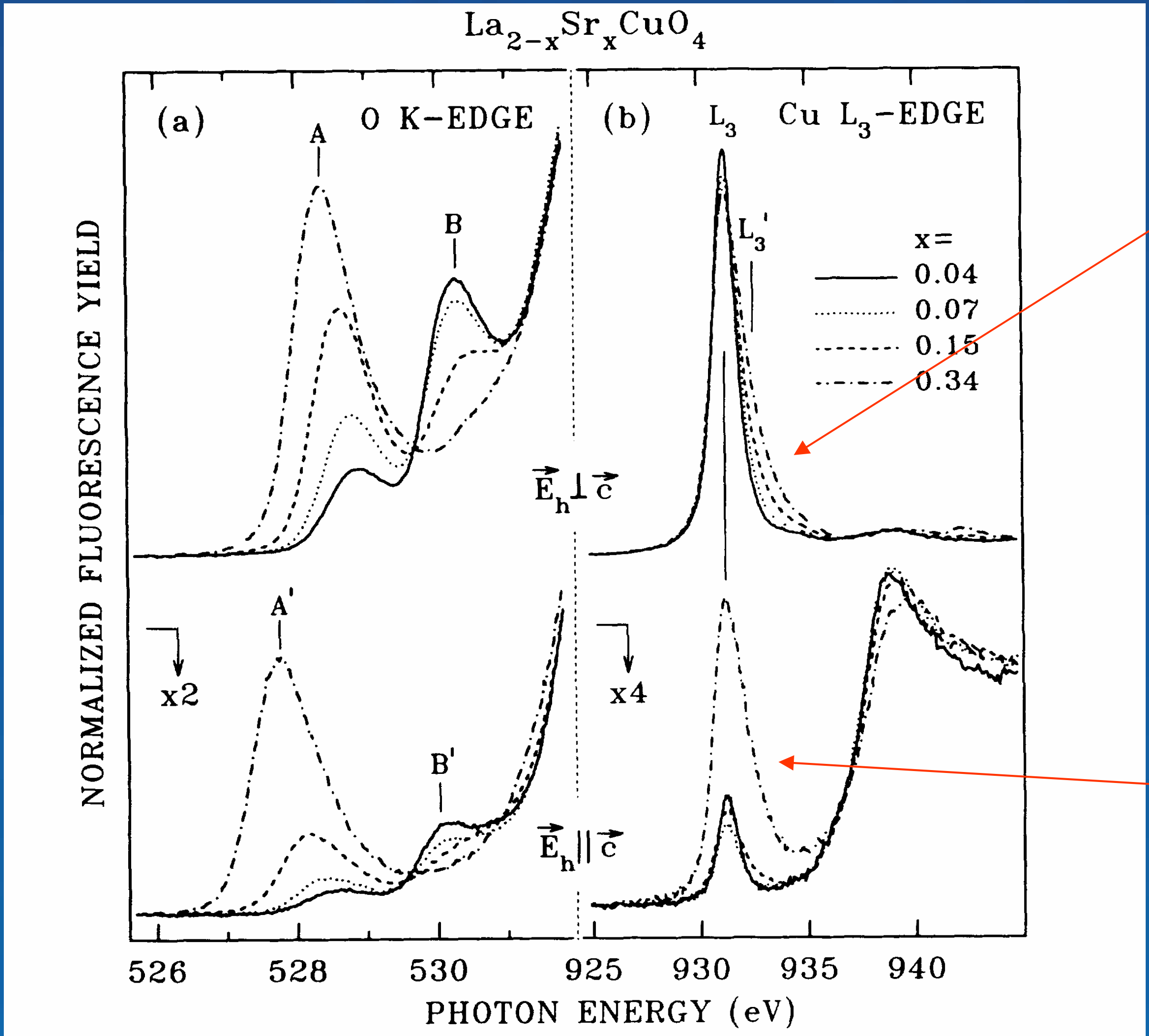
Chemical doping

In materials like high temperature superconductors the superconducting transition is controlled by chemical doping.



Keimer et al. PRB **46**, 14034 (1992).

X-ray Absorption studies of chemical doping



Increased intenisty with doping

Cu L_3 edge

Polarisation dependence gives the symmetry of the empty d orbitals

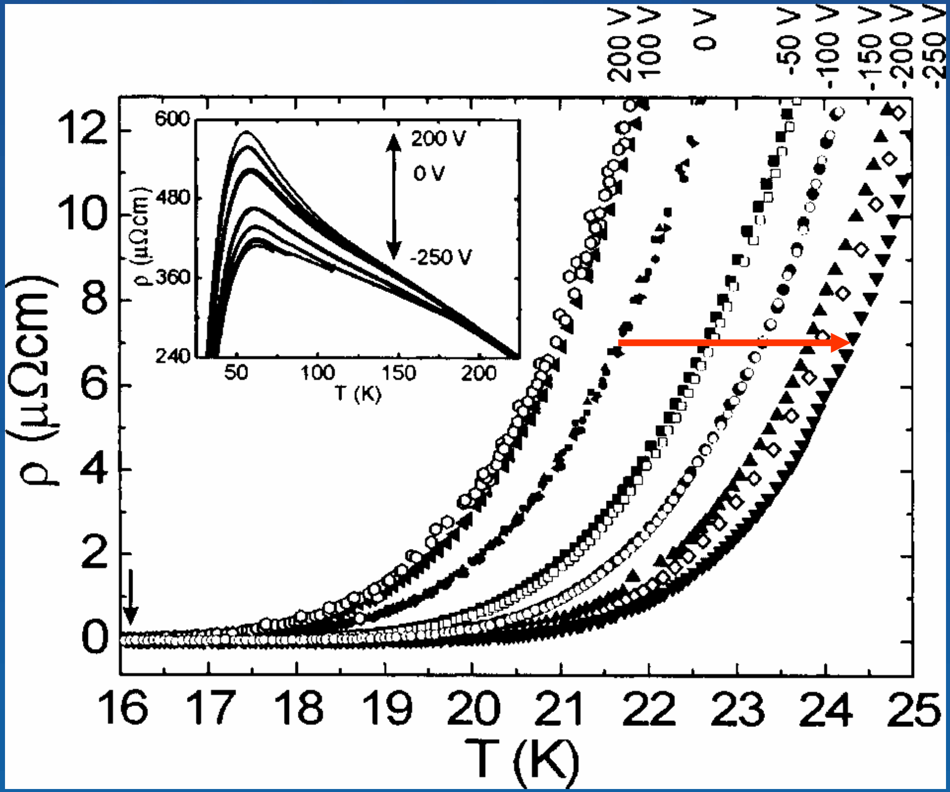
C.T. Chen et al. PRL **68**, 2543 (1992).

Electric field induced doping

The superconducting transition can also be influenced by field doping by applying an electric field.

However, given the number of carriers injected why is the effect not as large as one would expect from chemical doping?

Positive negative field



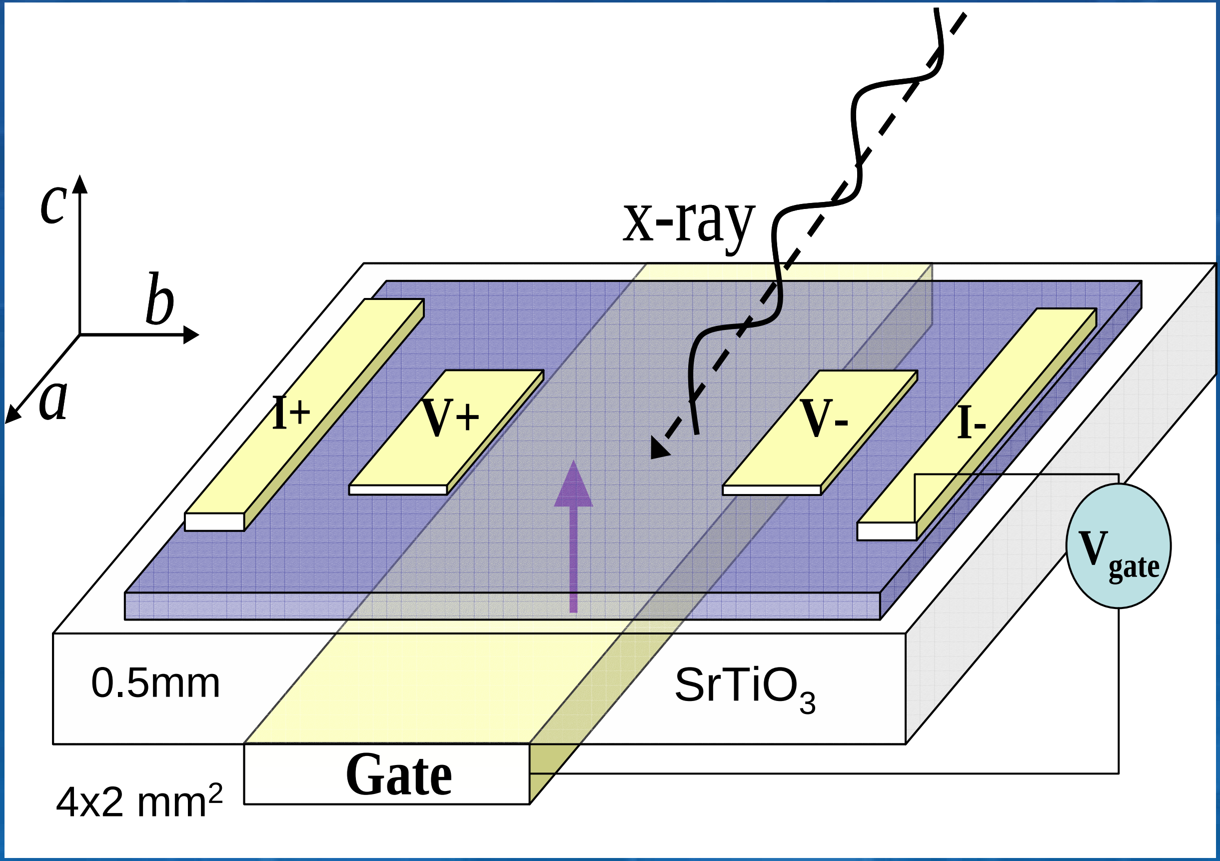
A *Tc* enhancement of 2.8 K was obtained for an applied field of –1.8 MV/m.

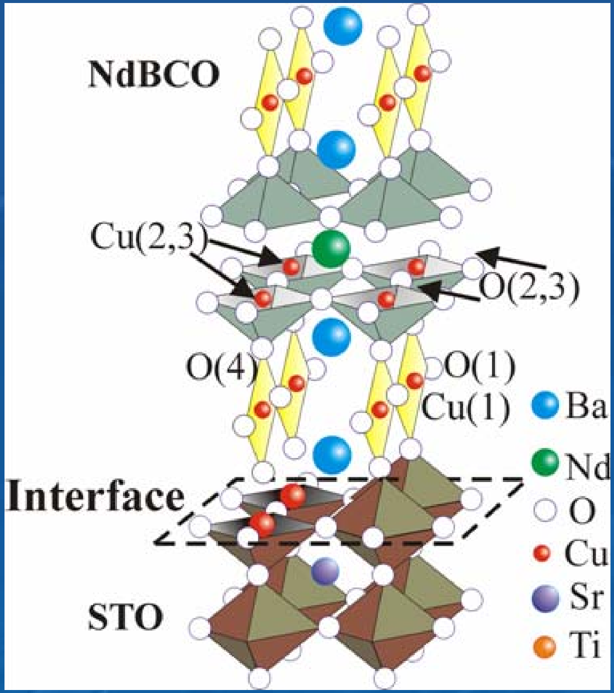
$NdBa_2Cu_3O_{7-\delta}$ ultrathin films

Matthey et al. Appl. Phys. Lett. **83**, 3758 (2003).

Experimental Configuration

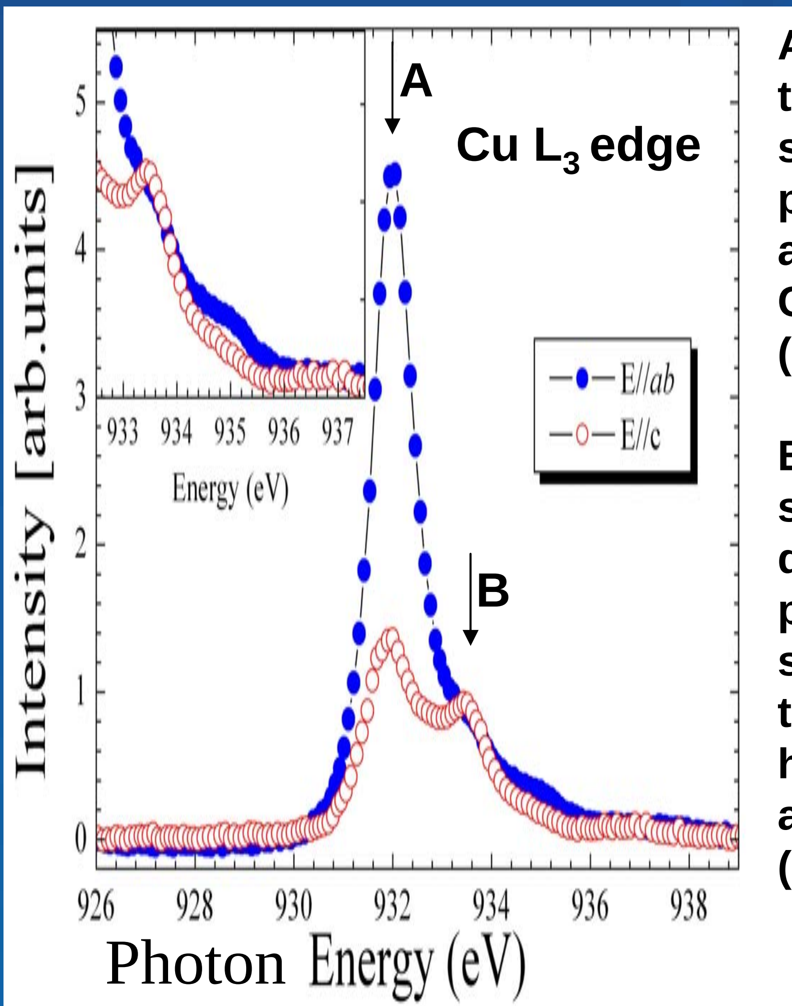
Idea: measure in-situ the transport properties and probe the same sample under those conditions using polarised X-ray absorption spectroscopy to follow the charge transfer into the superconducting layers.





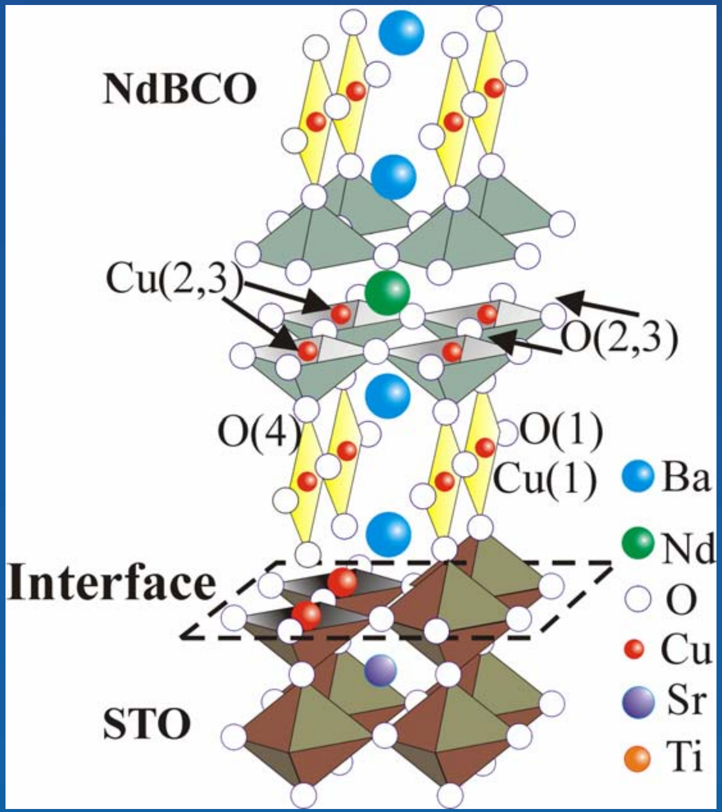
COHERENTIA INFM

Electric Field effect in high tempertaure superconductors



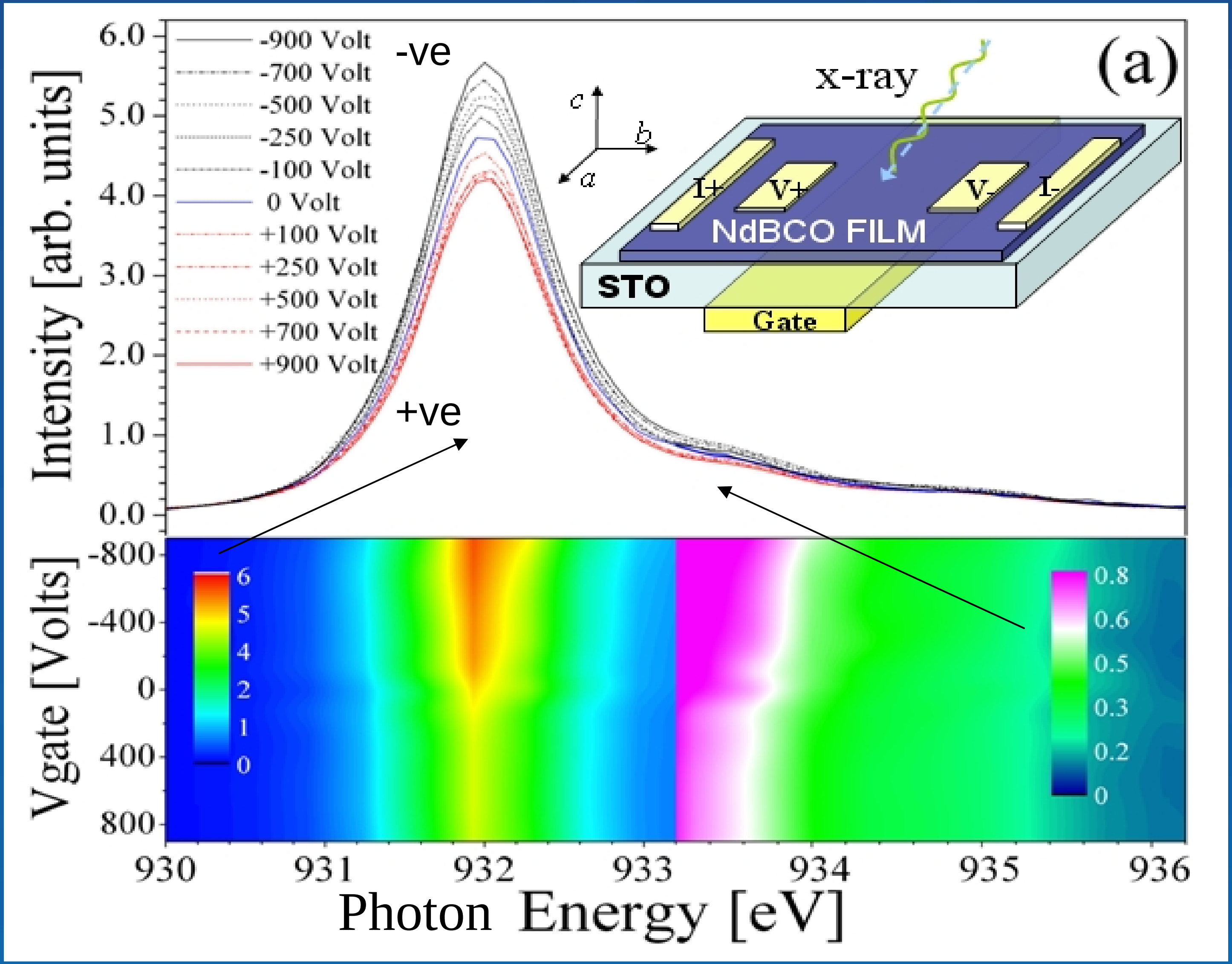
A – sensitive to the undoped sites in the CuO_2 planes Cu(2,3) and to the doped Cu^{3+} chain sites (Cu(1)).

B – E//ab spectra sensitive to the doped CuO_2 planes and E//c spectra sensitive to the Cu sites hybridised to the apical oxygens (O(4)).



$NdBa_2Cu_3O_{7-\delta}$ (001) ultrathin films

XAS and Electric field effect



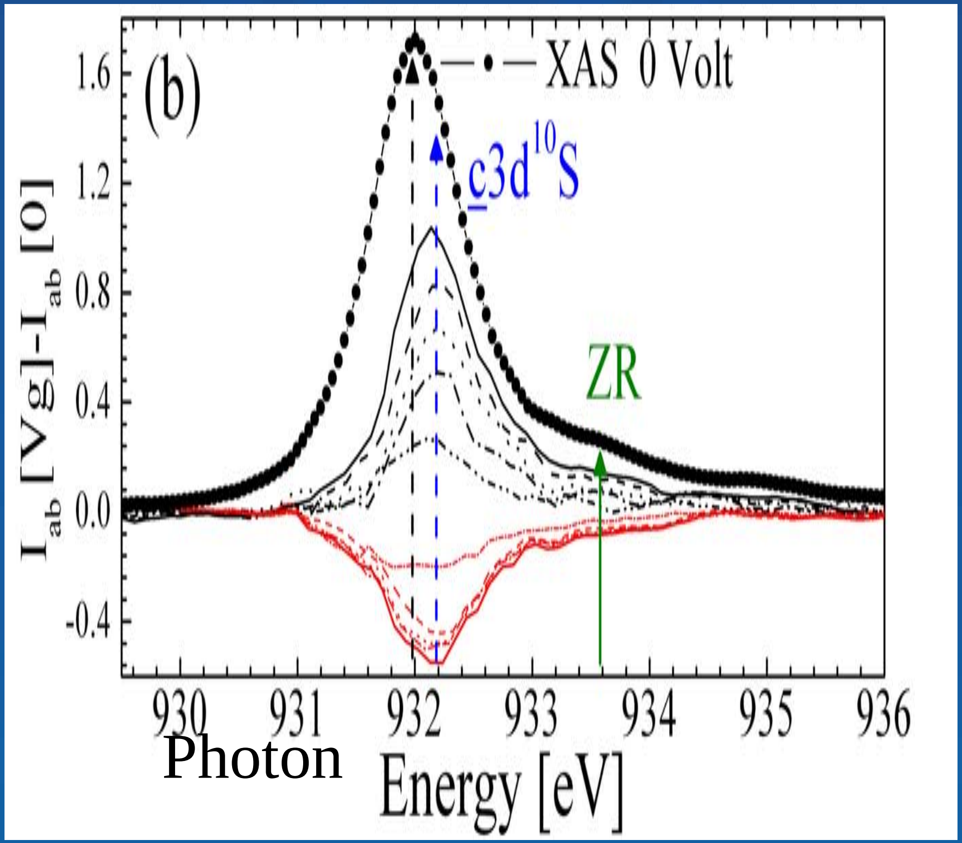
Gate voltage dependence of the absorption spectra E//ab.

3 u.c.

Cu L_3 edge

XAS and Electric field effect

Cu L_3 edge

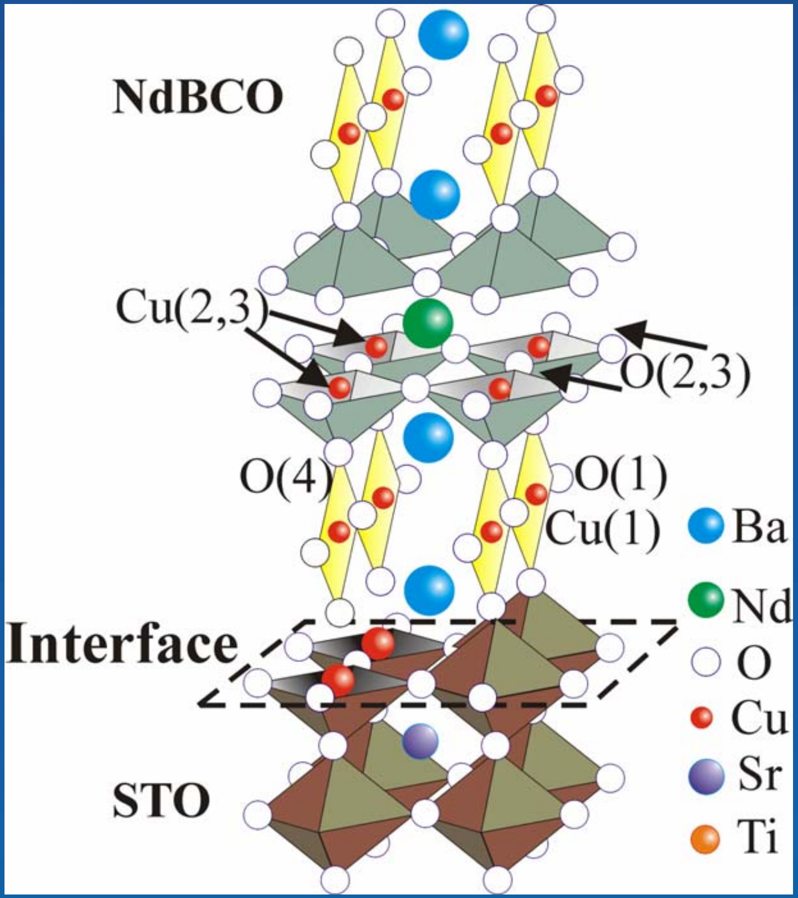


3 u.c.

The effect of the gate voltage is highlighted by subtracting the zero voltage spectra at each voltage. The changes are attributed to charge transfer with the Cu chains.

Conclusions:

The experiment demonstrates that in the “123” cuprates only a fraction of the charge created at the interface, is transferred to the CuO_2 planes, while the majority of holes actually dope the Cu(1)O chains.



M. Salluzzo et al.
PRL **100**, 056810 (2008).

Next….

magnetic and electric fields

E.g. Studies of multiferroics

thin films and bulk materials with applied electric and high magnetic fields using absorption spectroscopy.

Future Possibilities:

Short and medium term: focus activities

X-ray magnetic circular/linear dichroism,
expand complementary in-situ techniques (on going)
and develop a new superconducting magnet end station
(discussing possbilities).

Improve intensity and energy resolution for resonant x-ray emission spectroscopy e.g.improved focussing and detector (on going).

Improve photoemission capabilities e.g. time-of-flight detector for spin polarised photoemission (on going).

Upgrade Program:

A new Soft X-ray Beamline? In addition or replacing ID08?

A soft X-ray beamline is one of the candidate beamlines for the upgrade program UPBL7. An evolution of projects from the Purple book.

Initial Aims:

Smaller spot sizes 100nm-100microns
e.g. allow smaller samples to be studied in XMCD –
possibly combine with local probes.

High energy resolution >>10000 but with sufficient intensity
e.g. for RIXS or soft X-ray Angle resolved photoemission.
Both would also gain from small spot sizes e.g. for RIXS 1 micron.
Soft X-ray diffraction, use of coherence?

Status:
In consultation and brainstorming phase for a new conceptual design to be ready for the November SAC.