The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

2332-3

School on Synchrotron and FEL Based Methods and their Multi-Disciplinary Applications

19 - 30 March 2012

Time resolved and high pressure science

S. Pascarelli
ESRF (France)

Strada Costiera 11, 34151 Trieste, Italy - Tel.+39 040 2240 111; Fax +39 040 224 163 - sci_info@ictp.it

Outline

XAS, XANES, EXAFS, and XMCD

- X-ray Absorption
- X-ray Absorption Fine Structure
- Simple Theoretical Description
- XANES
- Major historical EXAFS breakthroughs
- Examples of applications at ELETTRA
- EXAFS data analysis
- Introduction to XMCD

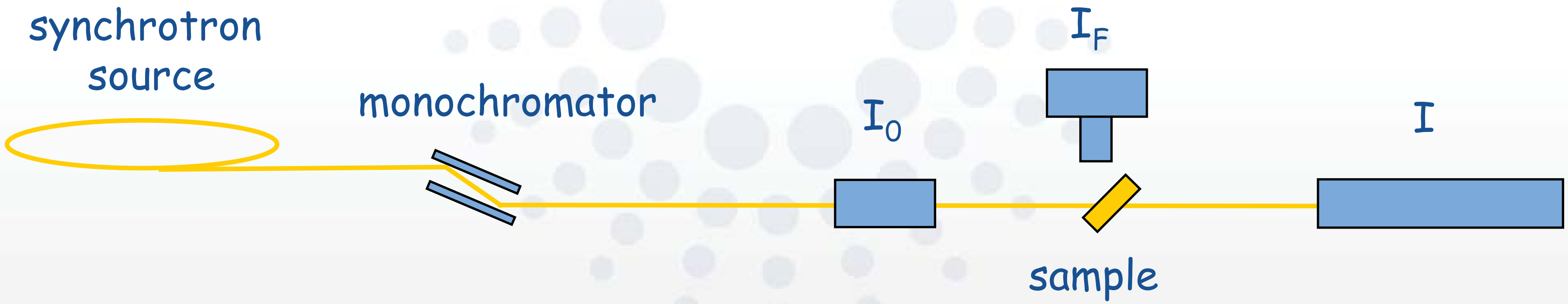
yesterday

Energy Dispersive XAS

- X-ray Absorption Spectrometers
- EDXAS
  - Basic principles, historical evolution
  - Examples of applications at ESRF
  - Future opportunities for studies of matter at extremes
- Probing laser induced extreme states of matter

today

XAS measurements



XAS measures the energy dependence of the x-ray absorption coefficient μ(E) at and above the absorption edge of a selected element.

μ(E) can be measured two ways:

Transmission:

The absorption is measured directly by measuring what is transmitted through the sample:

$$I = I_0 e^{-\mu(E)t}$$

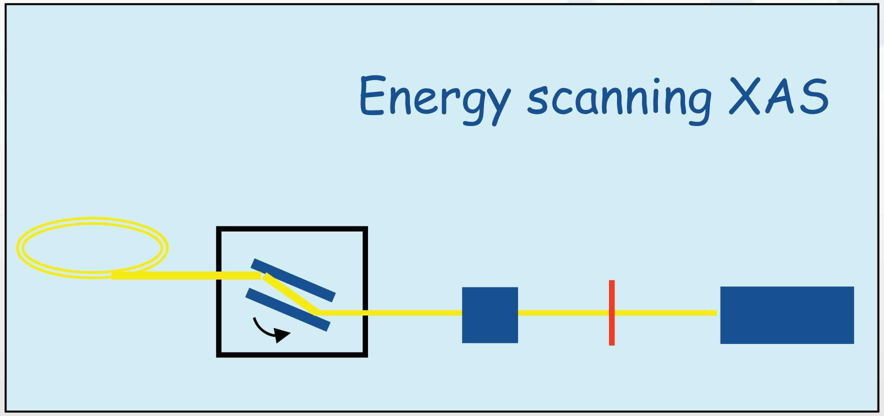
$$\mu(E)\, t = -\ln (I/I_0)$$

Fluorescence:

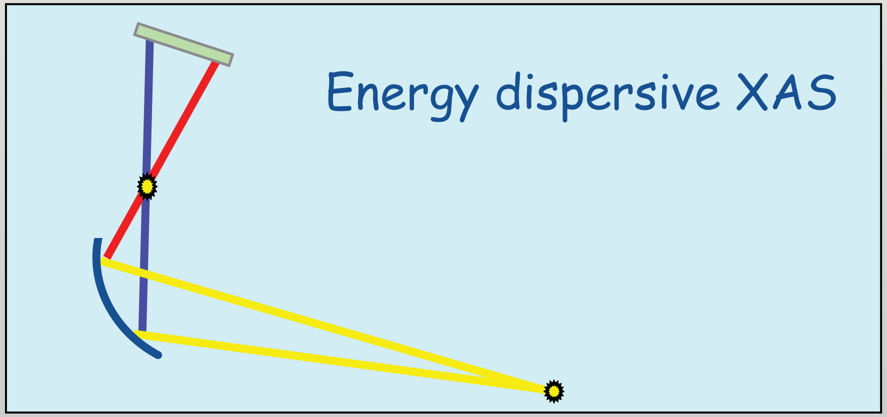
The re-filling the deep core hole is detected. Typically the fluorescent x-ray is measured.

$$\mu(E) \sim I_F / I_0$$

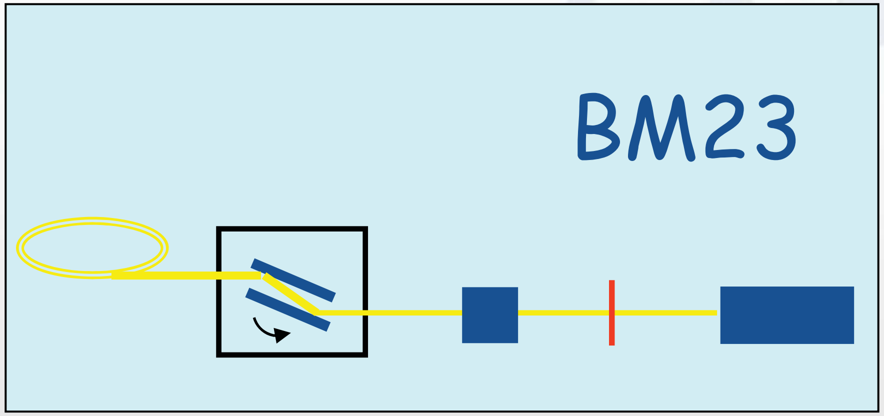
XAFS beamlines at the ESRF



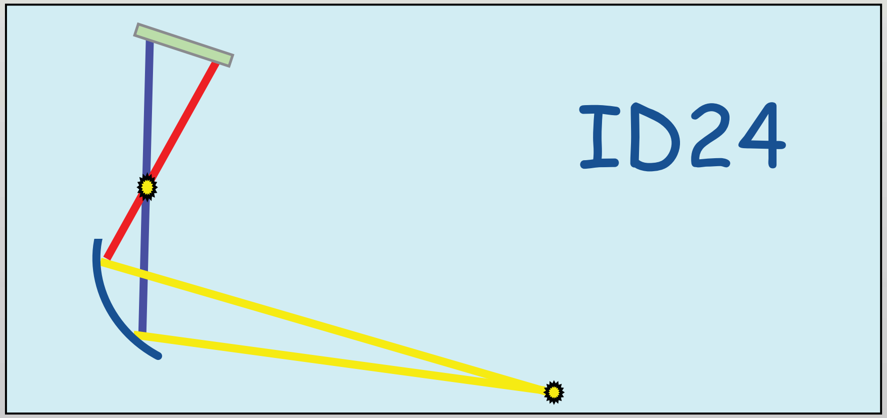
- ID12, ID26, ID32, ID22, etc ..
- BM23
- CRGs (BM08, BM20, BM30 etc..)



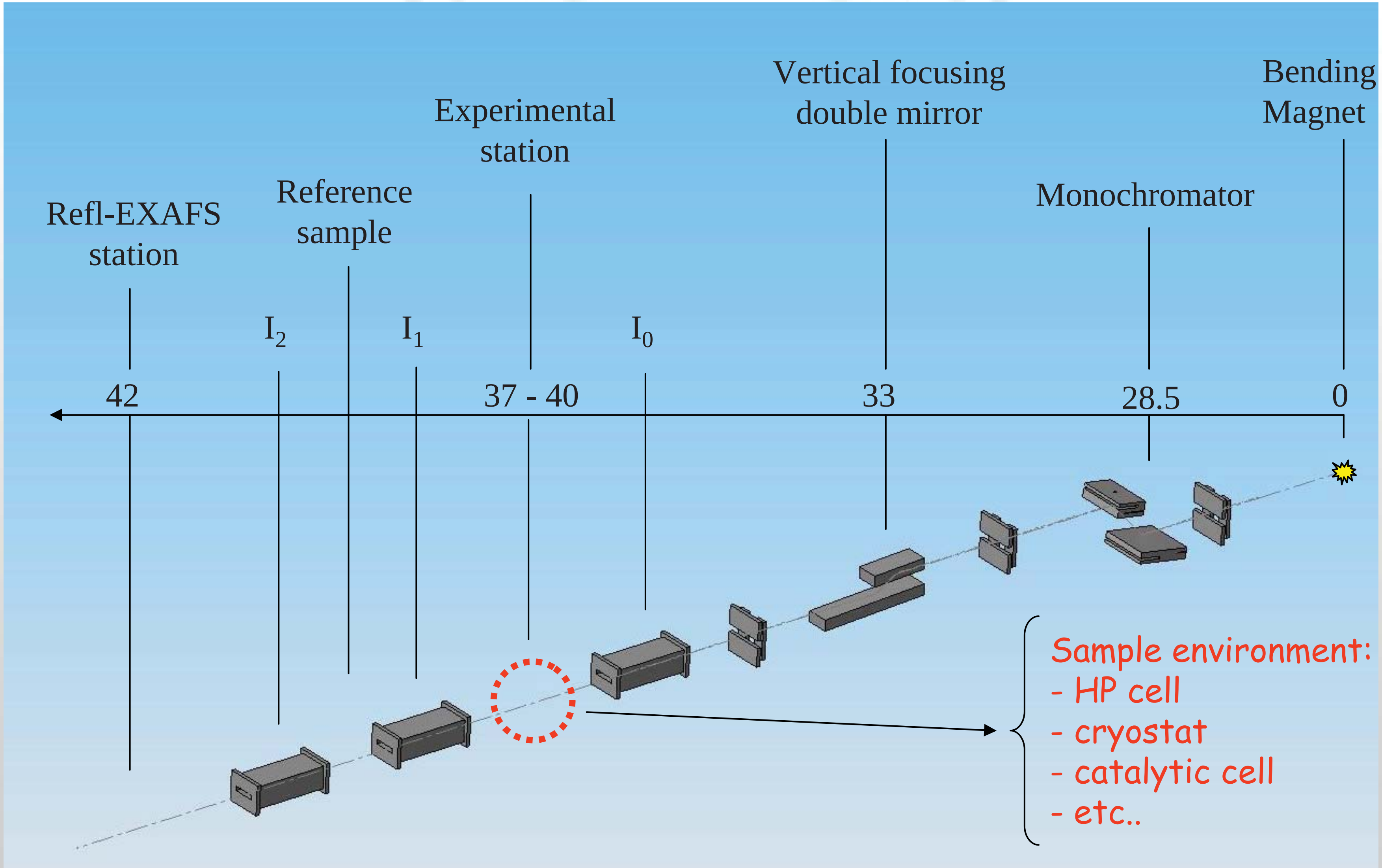
- ID24



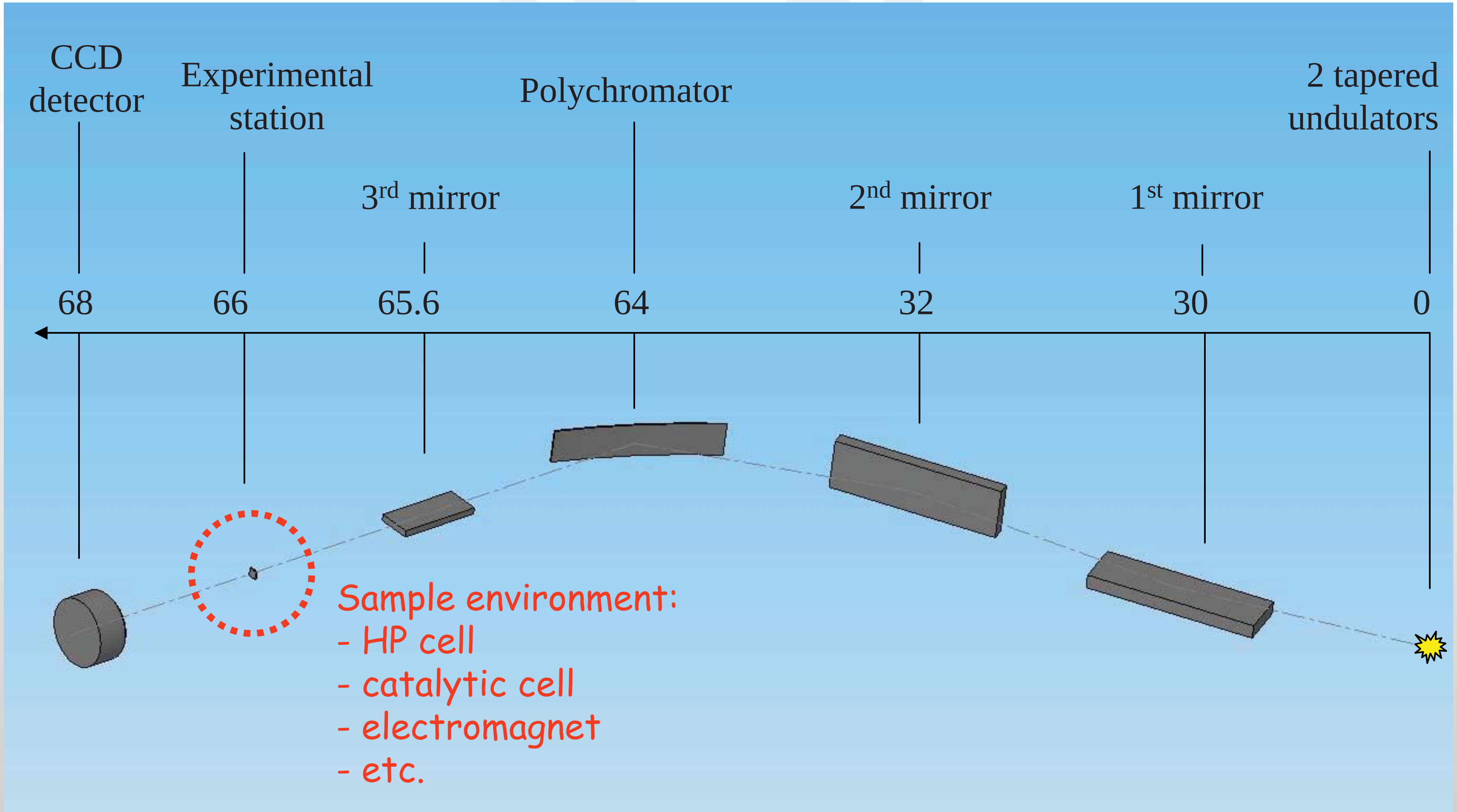
- excellent S/N ratio over a large k-range
- large energy range 4.5 – 75 KeV
- versatility
- high automation level



- small focal spot (~ 5 x 5 μm^2)
- fast parallel acquisition (~ 1 msec)
- high flux (~ 10^{13} ph/s/0.1%BW)


Bending
Magnet
Vertical focusing
double mirror
Experimental
station
Reference
sample
Refl-EXAFS
station
Monochromator
I_2
I_1
I_0
42
37 - 40
33
28.5
0
Sample environment:
- HP cell
- cryostat
- catalytic cell
- etc..

ID24 @ ESRF


CCD detector
Experimental station
Polychromator
2 tapered undulators
3rd mirror
2nd mirror
1st mirror
68
66
65.6
64
32
30
0
Sample environment:
- HP cell
- catalytic cell
- electromagnet
- etc.

Combining time resolved and extreme conditions XAS

1. Technical Challenges

Source

- high brilliance
- energy tunability

Optics

- small focal spot (μm → nm) - stability
- energy range (50-1000 eV) - stability

Detection

- fast acquisition (ms → ps)
- synchronization

2. Acquisition schemes

Pump-probe

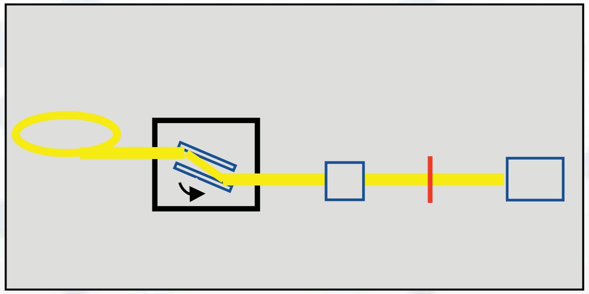
- reversible processes
- sample translation/cycle, ….

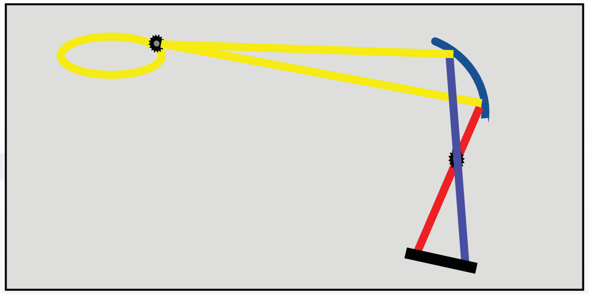
Single-shot

- non-reversible processes
- destruction of sample environment
- limited pump repeatability

3. Energy scanning vs energy dispersive spectroscopy

Energy scanning vs energy dispersive spectrometer

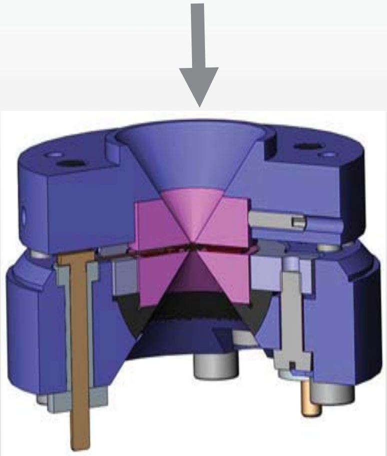




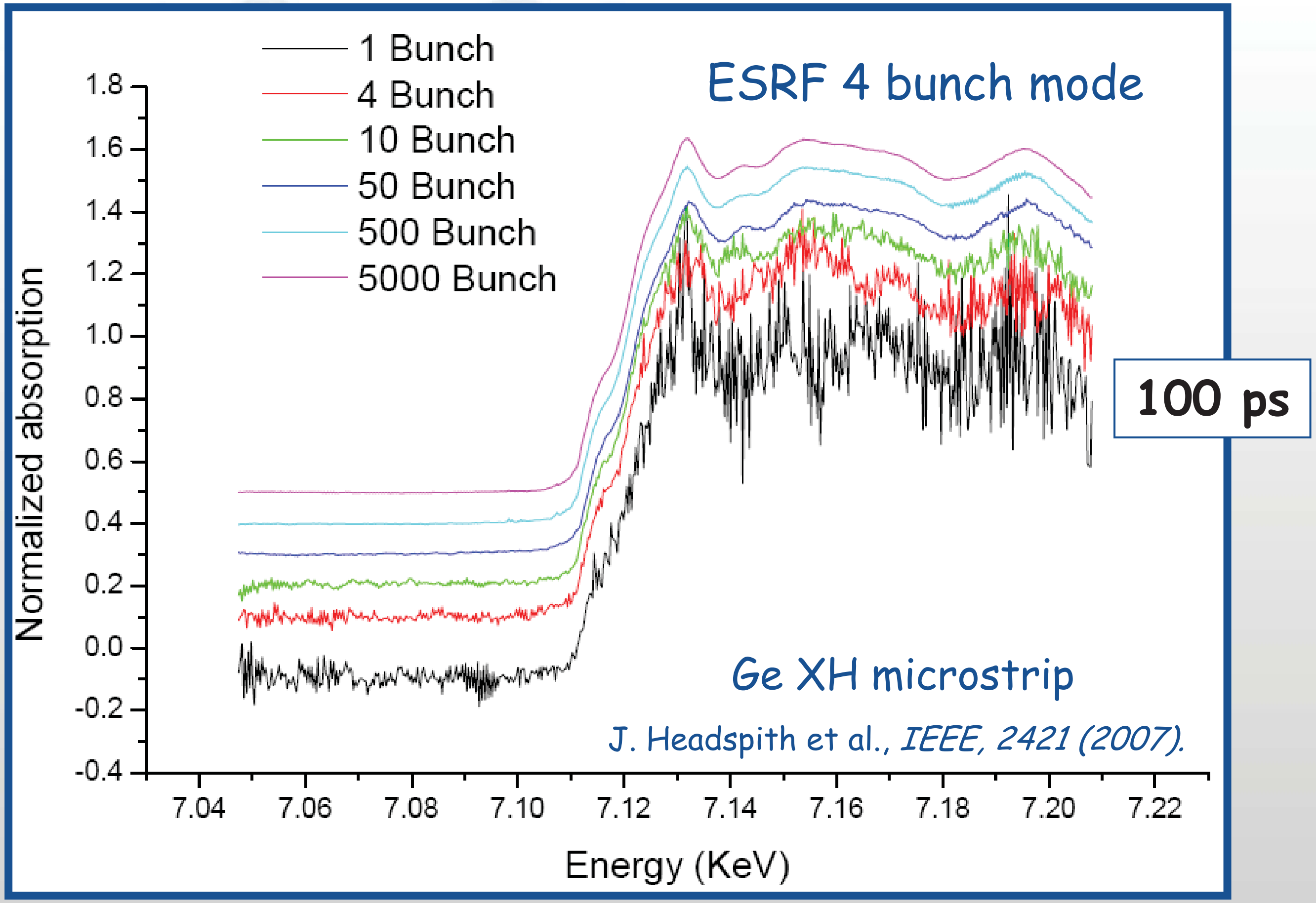
	Energy Scanning	Energy Dispersive
stability	mechanical movement	no movement of optics during acquisition
speed	energy points acquired sequentially	all energy points acquired simultaneously
optical scheme	simple	less simple
detection de-excitation channels (XRF, XES, RIXS)	straightforward	flux-energy resolution tradeoff
demands on sample microstruct	low	high
focal spot min	50-100 nm	2-3 μm
pump-probe	ps/energy point	ps/full spectrum
single shot	50 - 100 ms/spectrum	1 μs/spectrum at 3^{rd} gen

Detection limits for single shot studies on ID24

X ray beam



Fe foil



Edge shifts and XANES features clearly detectable with 50 bunches
(3 μs in Uniform mode)

Exploiting time resolution: present and future

time scale (s)	10^{0} · 10^{-3} · 10^{-6} · 10^{-9} · 10^{-12}
Time structure synchrotron	Continuous · Pulsed · Continuous
Optimal filling modes	Multibunch · Single bunch
Acquisition mode	film (single shot) · pump-and-probe
Detection	FReLoN ULTRA XH · streak
Application	Heterogeneous catalysis · Kinetics of chemical reactions · Melting at extremes · Shocked matter at local thermal equilibrium · Photochemistry · Pulsed magnetic fields · Out-of-equilibrium studies

Outline

XAS, XANES, EXAFS, and XMCD

- X-ray Absorption
- X-ray Absorption Fine Structure
- Simple Theoretical Description
- XANES
- Major historical EXAFS breakthroughs
- Examples of applications at ELETTRA
- EXAFS data analysis
- Introduction to XMCD

yesterday

Energy Dispersive XAS

- X-ray Absorption Spectrometers
- EDXAS
  - Basic principles, historical evolution
  - Examples of applications at ESRF
  - Future opportunities for studies of matter at extremes
- Probing laser induced extreme states of matter

today

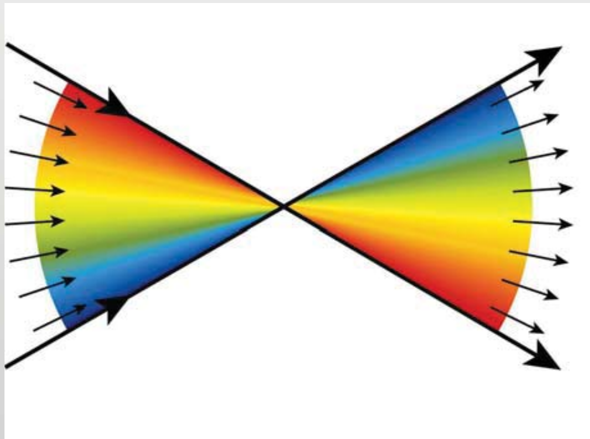
First idea of energy dispersive concept

1978

In 1978, a small workshop was held in Osaka on an EXAFS spectrometer to be constructed at the Photon Factory which started construction at that time.

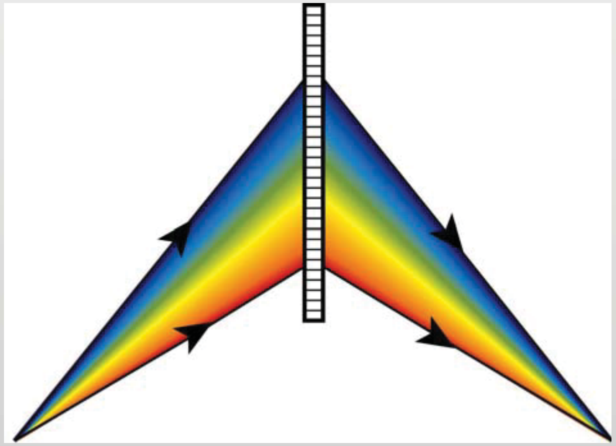
A professor of Tohoku university commented about the necessity of a quick EXAFS spectrometer for time-resolved study of reacting objects.

Immediately in the conference room



No mechanical movement during the measurement

On the train back to Tokyo



Focalization by a Laue-case single crystal

Taken from Prof. Matsushita's talk at 2009 Workshop @ ESRF

EDXAS on synchrotron beamline at Stanford

1981

Japanese Journal of Applied Physics
Vol. 20, No. 11, November, 1981 pp. 2223–2228

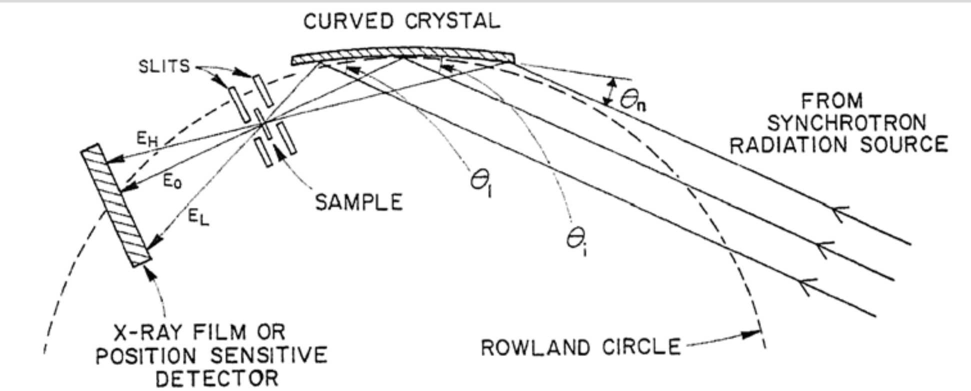
A Fast X-Ray Absorption Spectrometer for Use with Synchrotron Radiation

Tadashi Matsushita* and R. Paul Phizackerley

Stanford Synchrotron Radiation Laboratory, Stanford University, SLAC, P.O. Box 4349, Bin 69, Stanford, California 94305, USA

(Received July 6, 1981; accepted for publication August 22, 1981)

A quasi-parallel and polychromatic beam of synchrotron radiation is focused and dispersed by a curved crystal, so that the energy of each ray of the focused beam varies as a function of convergence angle through the focus. The specimen is placed at the focus. By measuring the X-ray intensity distribution across the beam behind the focus, in the presence and absence of the specimen, the absorption spectra of Cu and Ni metal foils were obtained. Using an X-ray film as the detector, a spectrum from a Cu foil was obtained in 0.1 seconds when the SPEAR storage ring at Stanford was operated at 3.1 GeV and 80 mA. The energy resolution is approximately 2.0 eV and the energy range of the spectrum is approximately 1 keV.



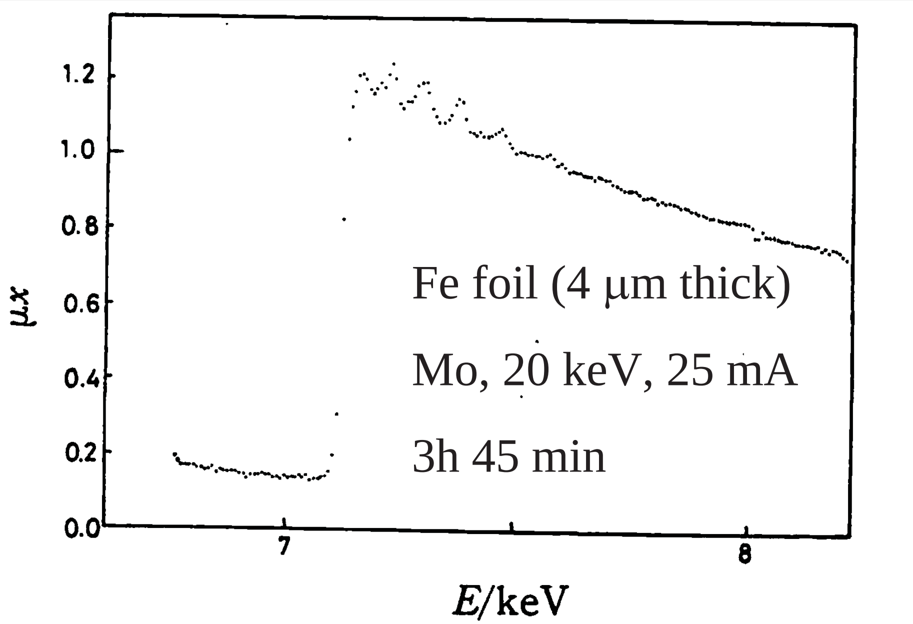
Lab EDXAS at Photon Factory

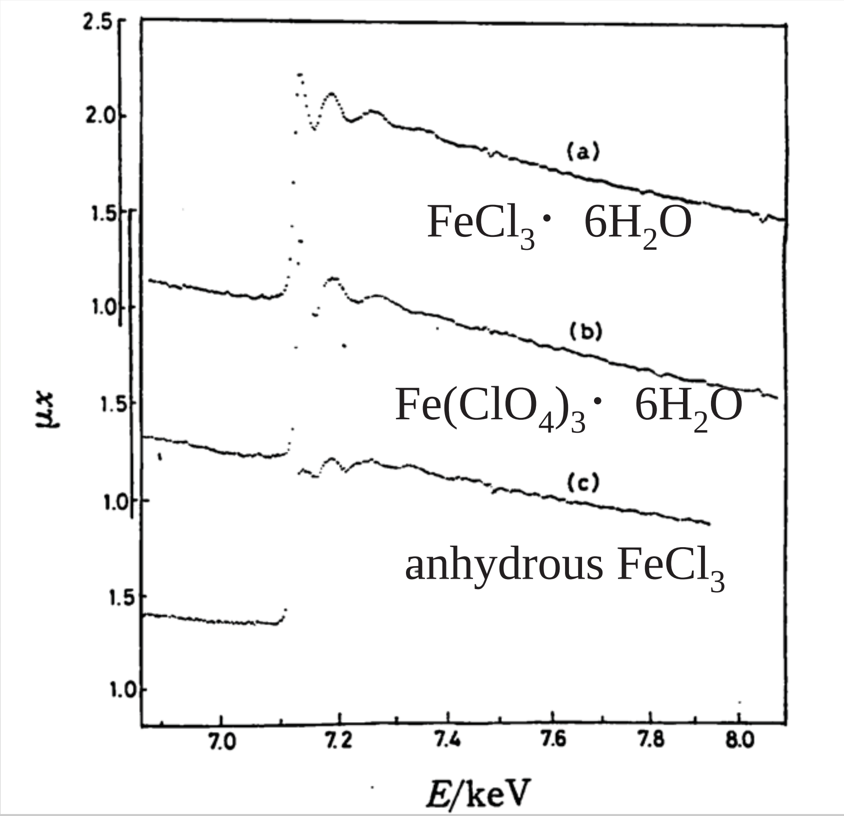
1982

December, 1982] © 1982 The Chemical Society of Japan Bull. Chem. Soc. Jpn., 55, 3911—3914 (1982)

EXAFS Spectroscopy of Some Iron(III) Compounds by Use of Dispersive-type In-laboratory X-Ray Spectrometer

Masaharu Nomura, Kiyotaka Asakura, Ukyo Kaminaga,† Tadashi Matsushita,†
Kazutake Kohra,† and Haruo Kuroda*
Department of Chemistry and Research Center for Spectrochemistry, Faculty of Science, The University of Tokyo, Hongo, Bunkyo-ku, Tokyo 113
†*Photon Factory, National Laboratory for High Energy Physics, Oho-Machi, Tsukuba, Ibaraki 305*
(Received June 28, 1982)





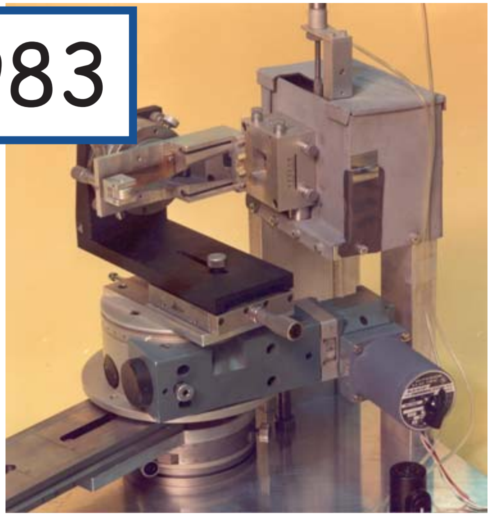
EDXAS around the world

Pioneer EDXAS beamlines (1980s)

BL	Source	Synch. facility	Location
BL-4A	BM	PF	Tsukuba, Japan
D11	BM	Lure	Orsay, France
7.4	BM	SRS	Daresbury, UK

Pioneering development of optics and detectors…

1983



R. P. Phizackerly, Z. U. Rek, G. B. Stephenson, S. D. Conradson, K. O. Hodgson, T. Matsushita and H. Oyanagi
J. Appl. Cryst. **16**, 220 (1983)

JAPANESE JOURNAL OF APPLIED PHYSICS
VOL. 25, NO. 7, JULY, 1986, pp. L523–L525

Twenty-Five Millisecond Resolution Time-Resolved X-Ray Absorption Spectroscopy in Dispersive Mode

Tadashi MATSUSHITA, Hiroyuki OYANAGI,† Satoshi SAIGO,†† Ukyo KAMINAGA,††† Hideki HASHIMOTO,* Hitoshi KIHARA,†† Noboru YOSHIDA** and Masatoshi FUJIMOTO**

Photon Factory, National Laboratory for High Energy Physics, Oho-machi, Tsukuba-gun, Ibaraki 305
†Electrotechnical Laboratory, Umezono, Sakura-mura, Niihari-gun, Ibaraki 305
††Department of Physics, Jichi Medical School, Minamikawachi-machi, Kawachi-gun, Tochigi 329–04
†††Rigaku Corporation, Matsubara-cho, Akishima, Tokyo 196
**Toray Research Center Inc., Sonoyama, Ohtsu, Shiga 520*
***Department of Chemistry, Faculty of Science, Hokkaido University, Kitajujoh, Kita-ku, Sapporo, Hokkaido 062*

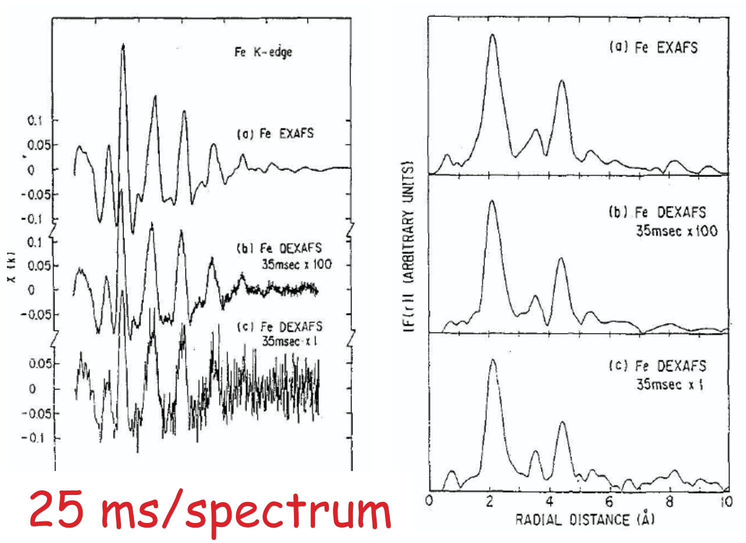
(Received May 22, 1986; accepted for publication June 21, 1986)

JOURNAL DE PHYSIQUE
Colloque C8, supplément au n° 12, Tome 47, décembre 1986 C8-139

LINEAR DETECTOR FOR TIME-RESOLVED EXAFS IN DISPERSIVE MODE

H. OYANAGI, T. MATSUSHITA*, U. KAMINAGA** and H. HASHIMOTO***

Electrotechnical Laboratory, Sakuramura, Niiharigun, Ibaraki 305, Japan
**National Laboratory for High Energy Physics, Ohomachi, Ibaraki 305, Japan*
***Rigaku Corporation, Matsubaracho, Akishima, Tokyo 196, Japan*
****Toray Research Center Inc., Sonoyama, Ohtsu, Shiga 520, Japan*



25 ms/spectrum

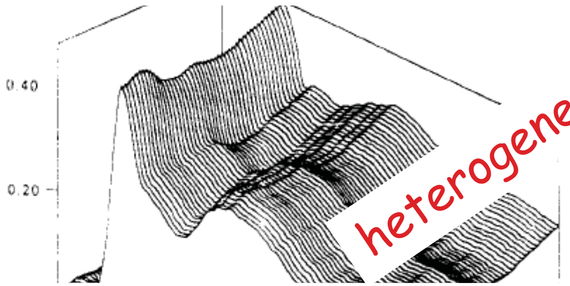
Pioneering work at BL-4A, D11 and 7.4

The Journal of Physical Chemistry

VOLUME 94, NUMBER 17 AUGUST 23

In Situ Studies of the Dehydration of Zeolitic Catalysts by Time-Resolved Energy-Dispersive X-ray Absorption Spectroscopy

J. W. Couves, J. M. Thomas,* C. R. A. Catlow,*
Davy Faraday Research Laboratory, The Royal Institution, 21 Albemarle Street, London W1X 4BS, U.K.
G. N. Greaves,* G. Baker, and A. J. Dent
SERC Daresbury Laboratory, Daresbury, Warrington WA4 4AD, U.K. (Received: May 1



heterogeneous catalysis

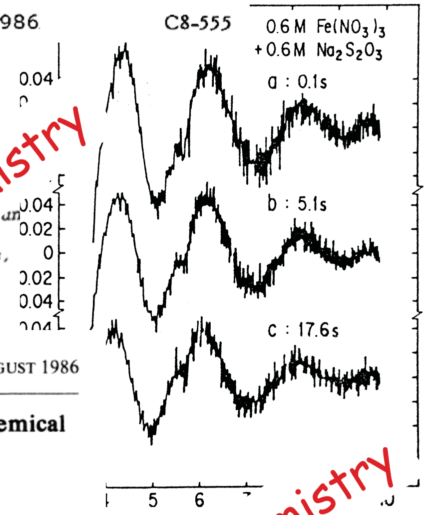
JOURNAL DE PHYSIQUE
Colloque C8, supplément au n° 12, Tome 47, décembre 1986 C8-555

STOPPED-FLOW X-RAY ABSORPTION SPECTROSCOPY IN DISPERSIVE MODE

S. SAIGO, H. OYANAGI*, T. MATSUSHITA**, H. HASHIMOTO***, N. YOSHIDA*, M. FUJIMOTO* and T. NAGAMURA**

Department of Physics, Jichi-Medical School, Minamimikawachi-gun, Tochigi 329-04, Japan
*Electrotechnical Laboratory, Umezono, Sakura-mur
Ibaraki 305, Japan
**Photon Factory, National Laboratory for H ysics, Oho-machi, Tsukuba-gun, Ibaraki 305, Japan
***Toray Research Center, Sonoyama, Oh 20, Japan
*Department of Chemistry II, Facult , Hokkaido

stopped flow chemistry



NUMBER 5 PHYSICAL REVIEW L 4 AUGUST 1986

Dispersive X-Ray Spectroscopy for Time-Resolved Observation of Electrochemical Inclusion of Metallic Clusters within Conducting Polymer

G. Tourillon, E. Dartyge, A. Fontaine, and A. Jucha
Laboratoire pour l'Utilisation du Rayonnement Electromagnétique, Centre Nationale d 91405 Orsay, France
(Received 27 June 1985)

electrochemistry

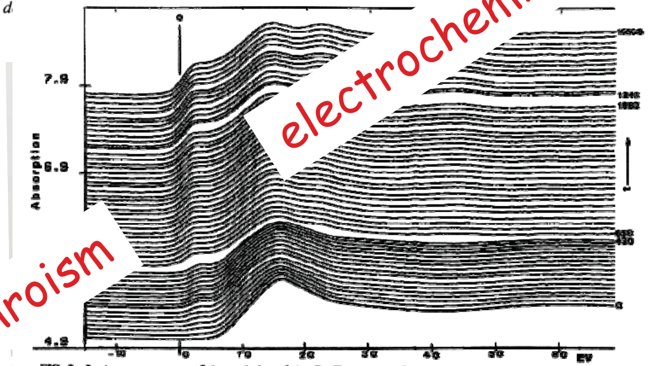


FIG. 2. In situ measurements of the evolution of the Cu K edge when PMeT is cathodically polarized in an H_2O-$CuCl_2$ 50-mM electrolytic medium.

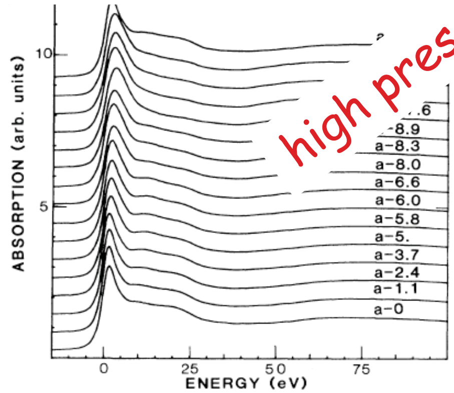
Europhys. Lett., 13 (8), pp. 751-757 (1990)

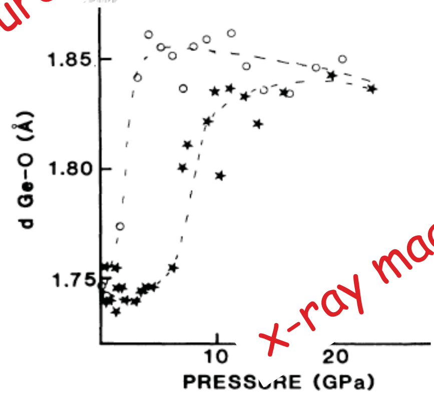
VOLUME 63, NUMBER 4 PHYSICAL REVIEW LETTERS 24

Pressure-Induced Coordination Changes in Crystalline and Vitreous GeO_2

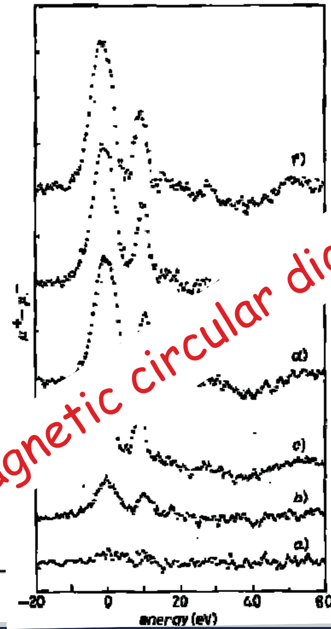
J. P. Itie,[1] A. Polian,[1] G. Calas,[2] J. Petiau,[2] A. Fontaine,[3] and H. Tolentino[3]
[1]Laboratoire de Physique des Milieux Condensés, Université de Paris 6, 75252 Paris, France
[2]Laboratoire de Minéralogie-Cristallographie, Universités de Paris 6 et 7 and Centre National de la Recherche Scientifique, 75252 Paris, France
[3]Laboratoire pour l'Utilisation du Rayonnement Electr tique, Centre National de la Recherche Scientifi Commissariat à l'Energie Atomique, Ministère de l'Educat , Université de Paris-Sud, 91405 Orsay CEDE

high pressure





x-ray magnetic circular dichroism

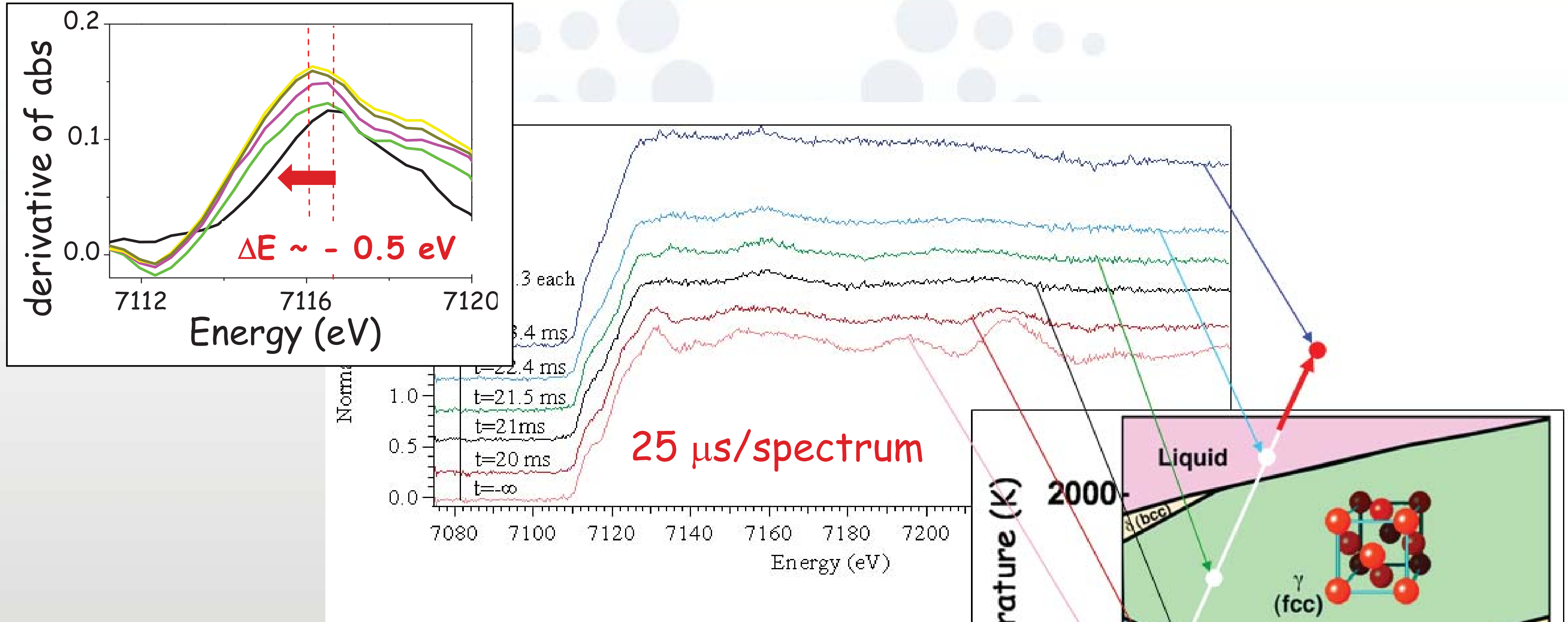


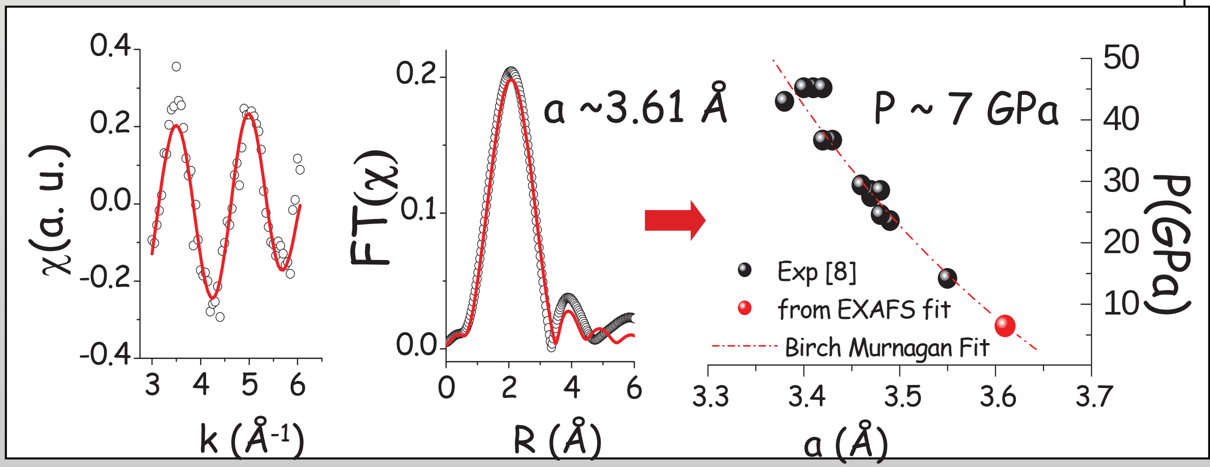
Magnetic Properties of $REFe_2$ (RE: Ce, Gd, Lu) Compounds Studied by Magnetic X-Ray Dichroism.

F. BAUDELET (*), C. BROUDER (**), E. DARTYGE (*), A. FONTAINE (*)
J. P. KAPPLER (***) and G. KRILL (**)
(*) LURE, LP CNRS 008, Université de Paris-Sud - 91405 Orsay, France
(**) Laboratoire de Physique des Solides, UA CNRS 155, Université de Nancy BP 239, 54506 Vandoeuvre-les-Nancy, France
(***) IPCMS, GEMME, UM CNRS 380046, Université Louis Pasteur 67070 Strasbourg, France

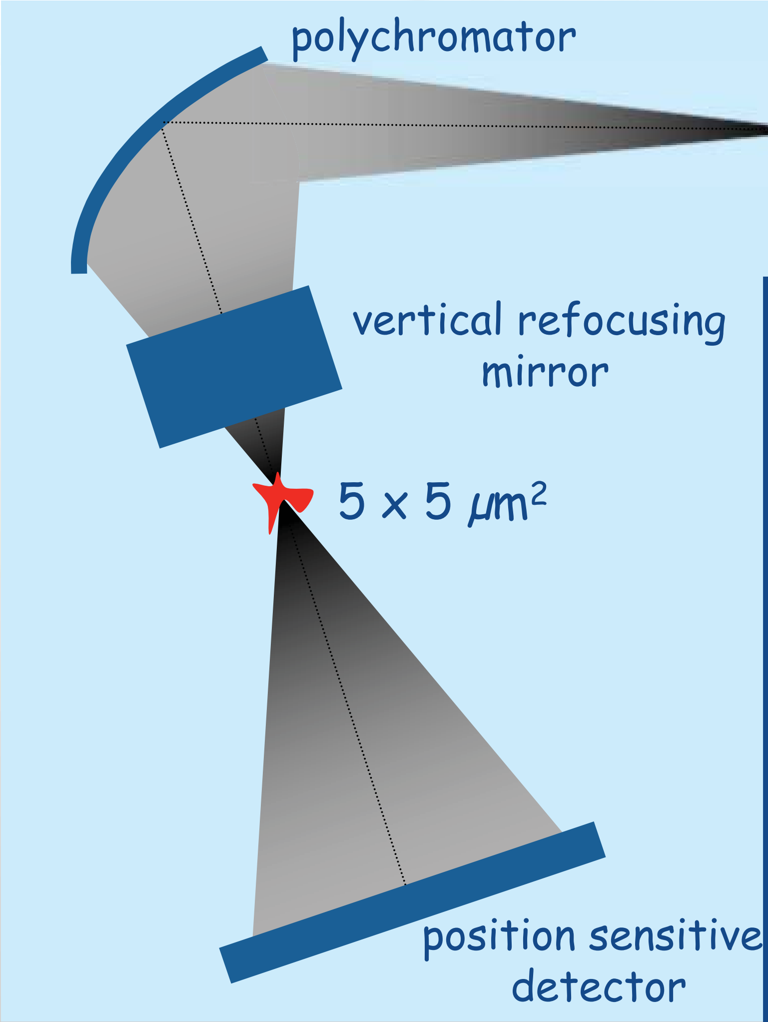
EDXAS around the world

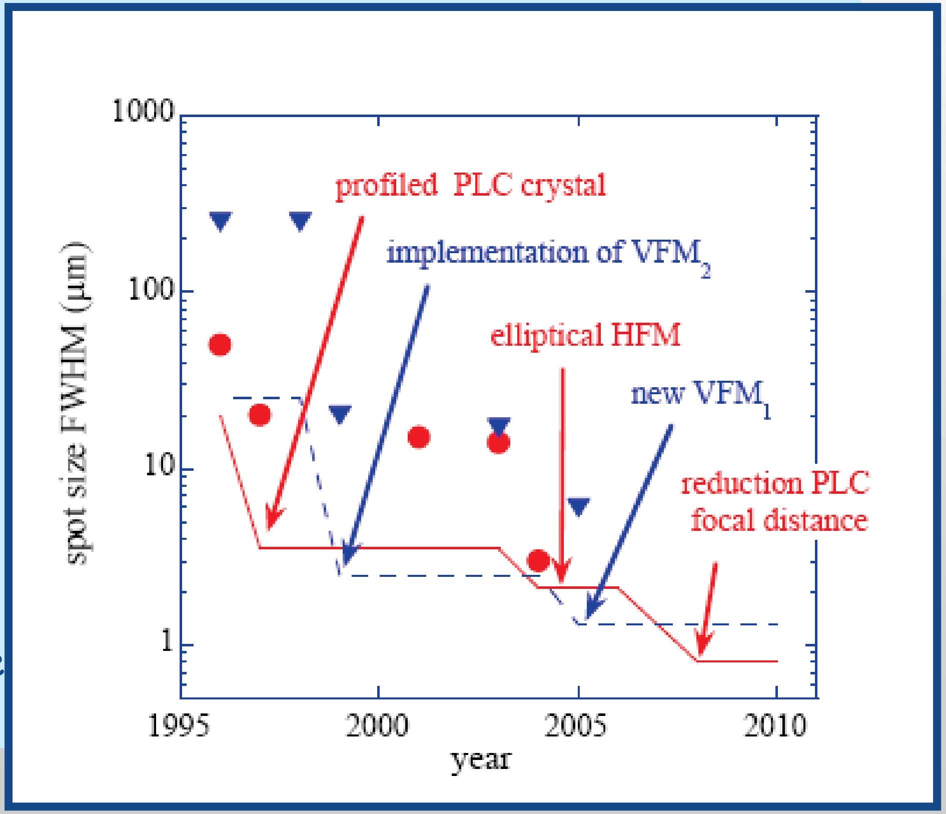
Advances in detection: μ-sec resolved XANES





Collaboration with:
F. Occelli and P. Loubeyre, CEA Bruyeres-les-Chatel

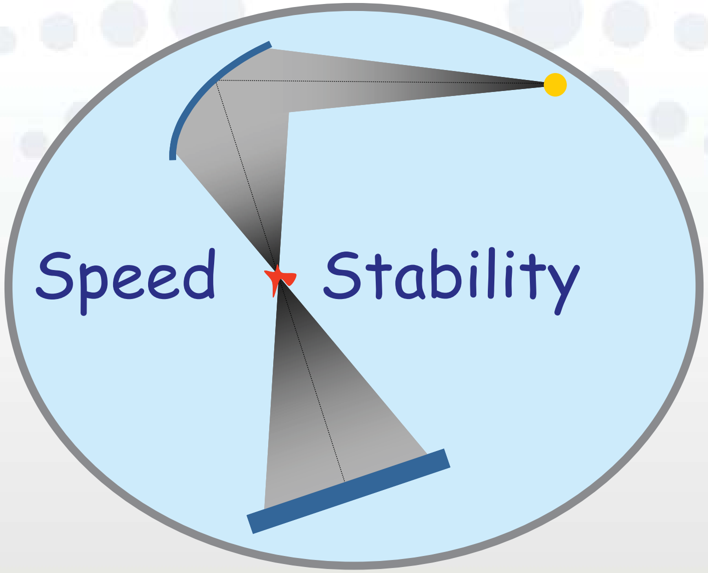




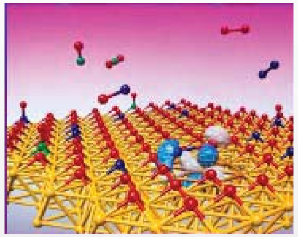
Hagelstein J. Phys. IV France 1997

Pascarelli J. Synchrotron Rad. 2006

Main areas of applications

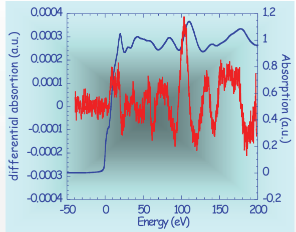


Time resolved XAS



Full energy spectrum acquired simultaneously

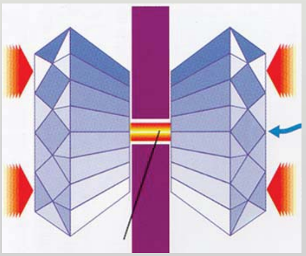
Differential XAS



Monitor subtle changes in XAS exploiting X-ray polarization

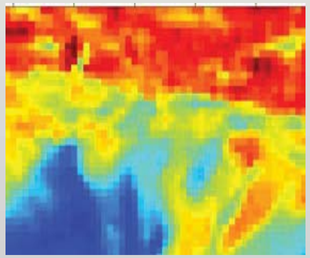
Micro XAS

Extreme conditions



Structural studies on tiny samples in extreme environments

2D mapping



Full XAS spectrum in each pixel (fluorescence or transmission)

Review paper: Pascarelli PCCP 2010

Outline

XAS, XANES, EXAFS, and XMCD

• X-ray Absorption
• X-ray Absorption Fine Structure
• Simple Theoretical Description
• XANES
• Major historical EXAFS breakthroughs
• Examples of applications at ELETTRA
• EXAFS data analysis
• Introduction to XMCD

yesterday

Energy Dispersive XAS

• X-ray Absorption Spectrometers
• EDXAS
  • Basic principles, historical evolution
  • Examples of applications at ESRF
  • Future opportunities for studies of matter at extremes
• Probing laser induced extreme states of matter

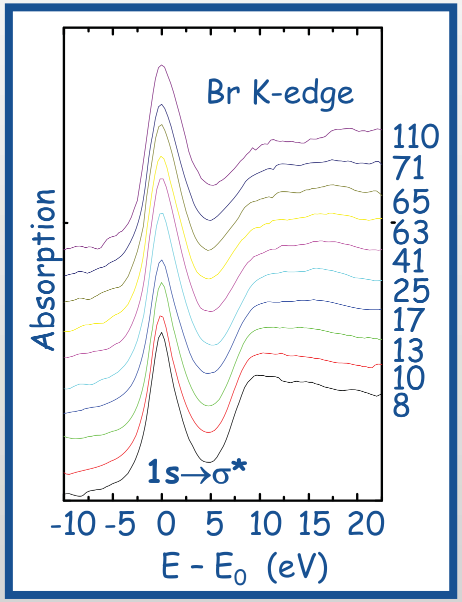
today

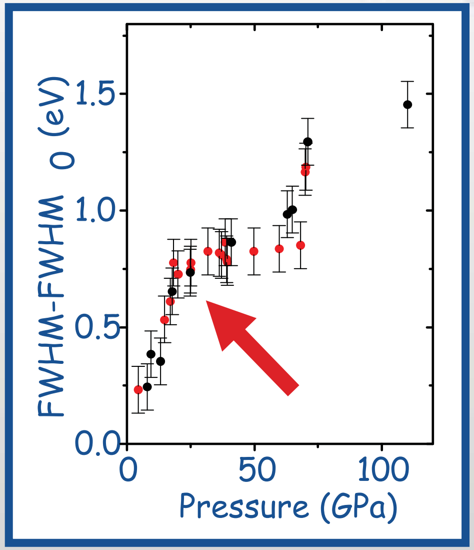
EDXAS at ESRF

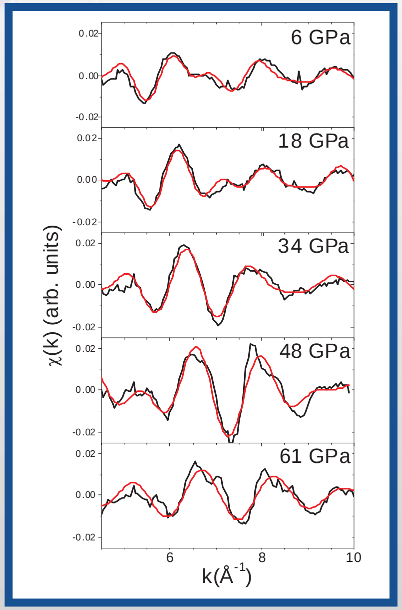
- Structure and magnetism in compressed matter
- Geochemistry
- Element selective magnetism at pulsed 30T fields

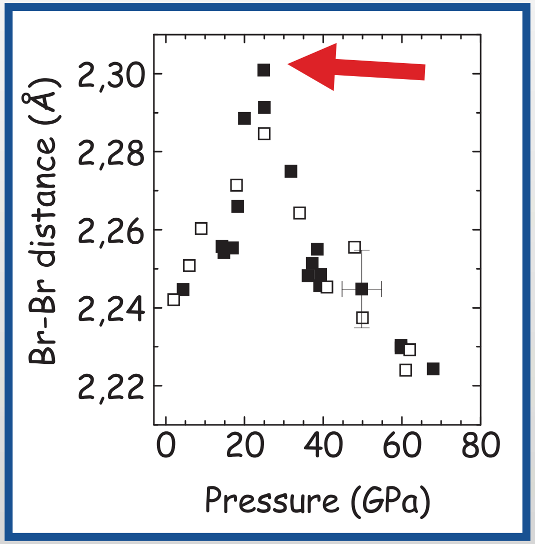
Metallization and dissociation of diatomic molecules

- Heavier halogens (Br_2, I_2), constitute model systems for the study of simple molecular solids under high pressure
- Metallization and dissociation: Br_2 ~ 60 GPa and 115 GPa [84 GPa IP]
- XRD : Molecular phase stable up to 80 GPa - intramolecular distance rigid









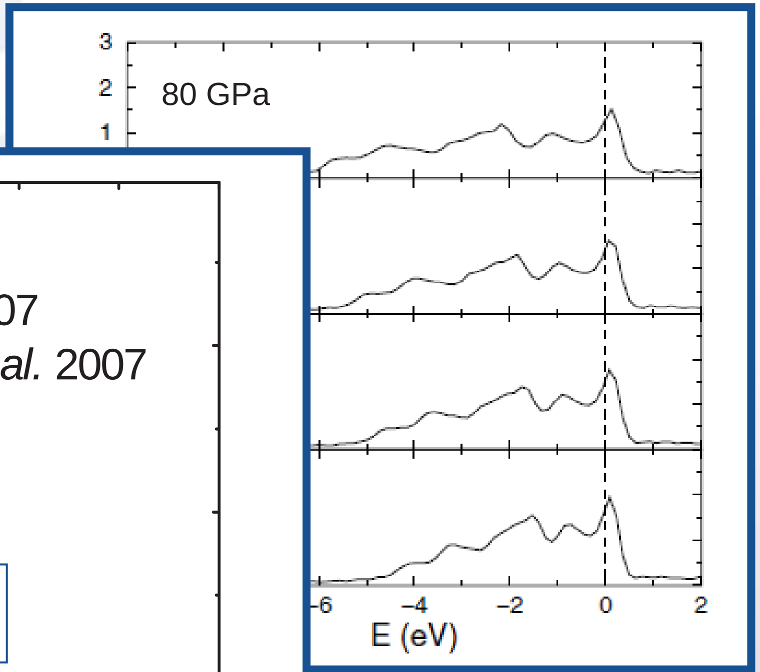
New phase transition at 25 GPa with a loss of molecular character

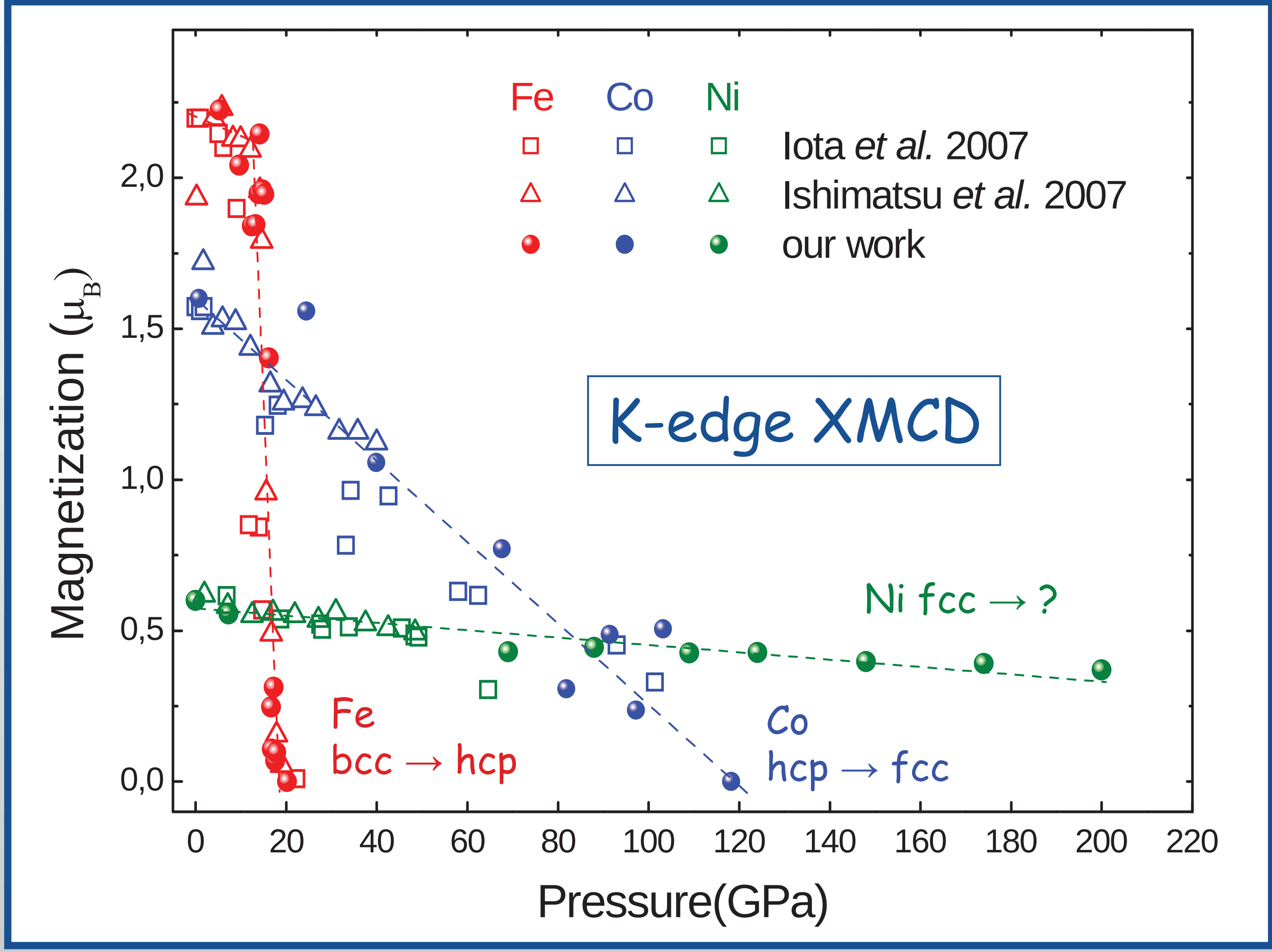
A. San Miguel et al., Eur. Phys. J. B (2000)

A. San Miguel et al., PRL 99 015501 (2007)

Collapse of ferromagnetism in 3d metals

In the 3d metals, application of pressure leads to the loss of ferromagnetism



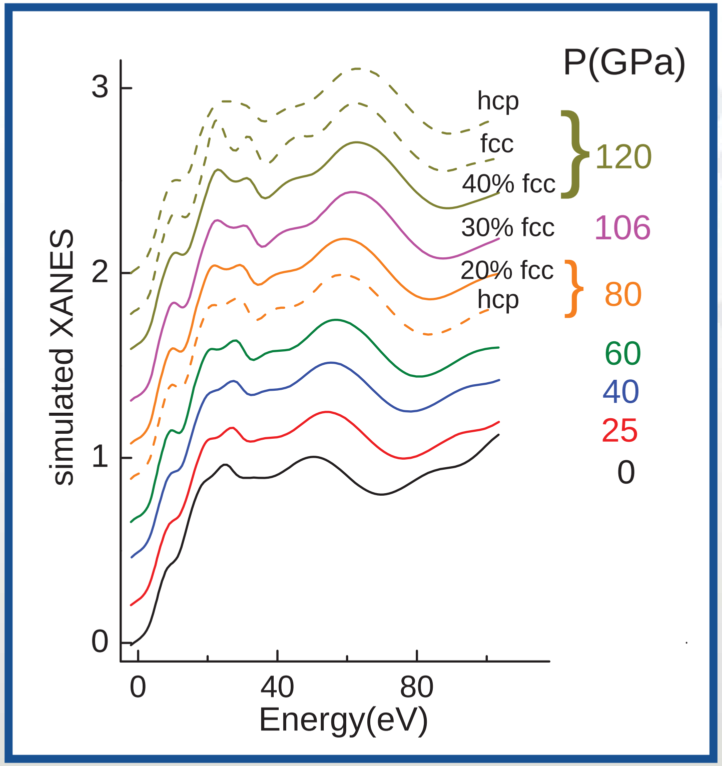


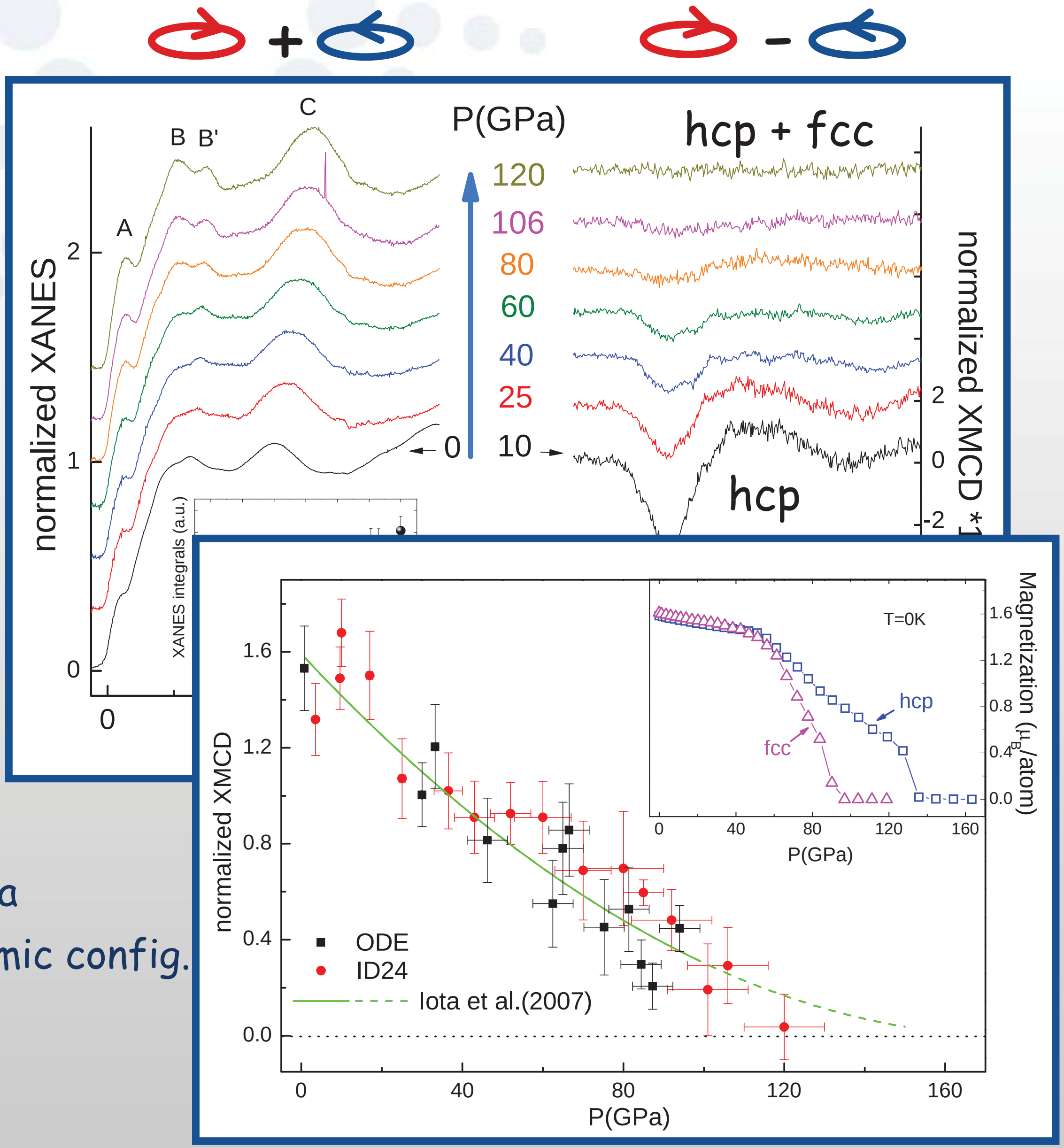
itinerant-electron ferromagnetism

x DOS (E_F) > 1

Stoner (1939)

Collapse of ferromagnetism in Co

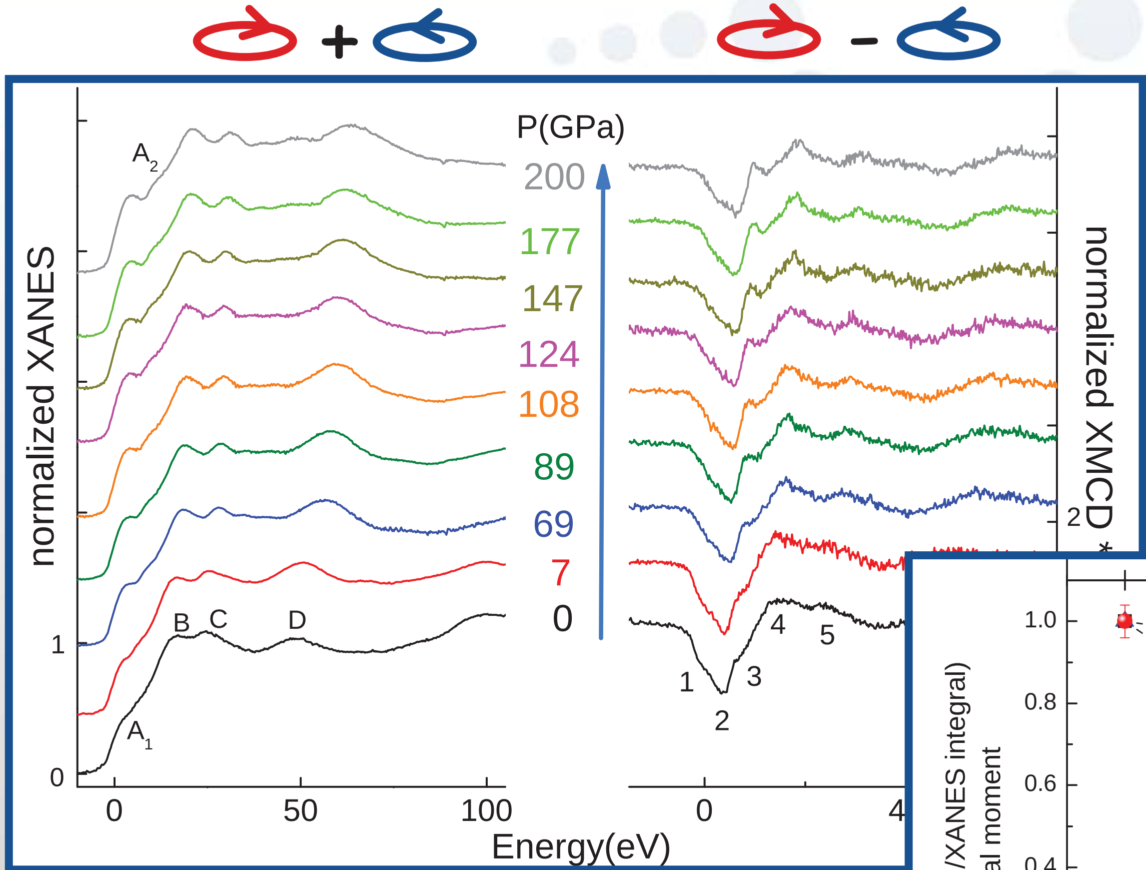


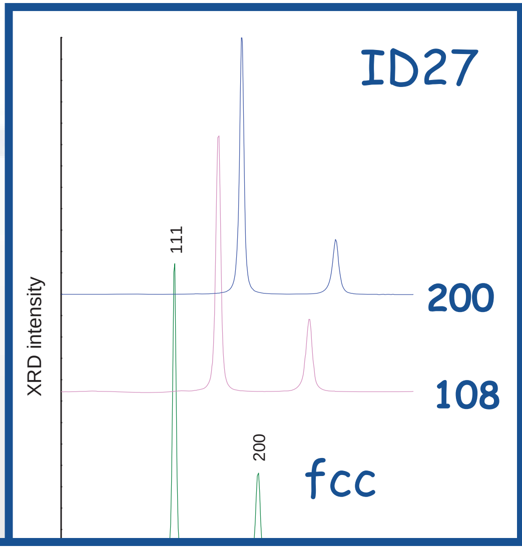


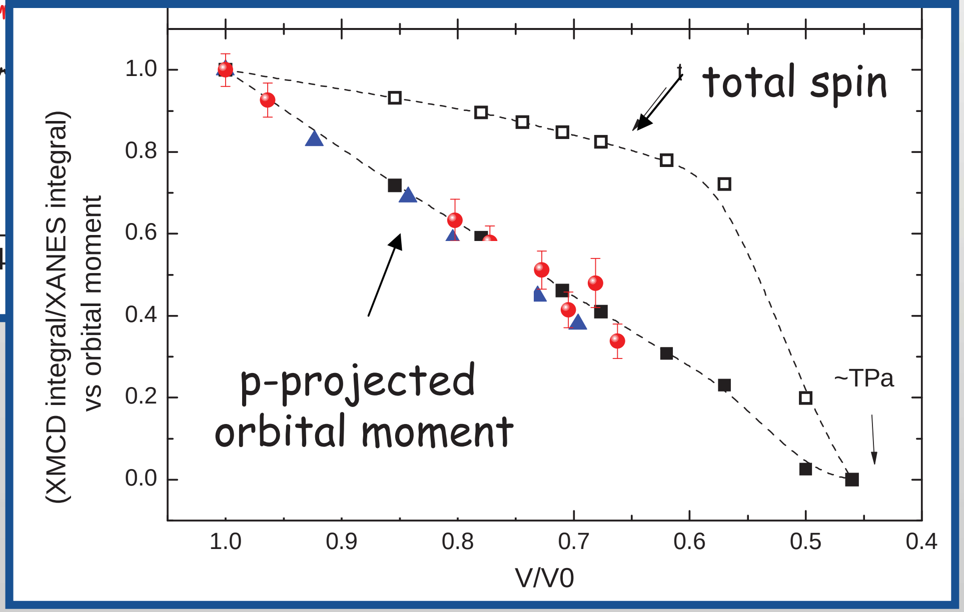
1. XMCD signal disappears at 120 GPa
2. 80 GPa: onset of local fcc-like atomic config.
3. major differences with Fe case

R. Torchio et al. , *PRB 84, 060403R 2011*

Resistant ferromagnetism in Ni







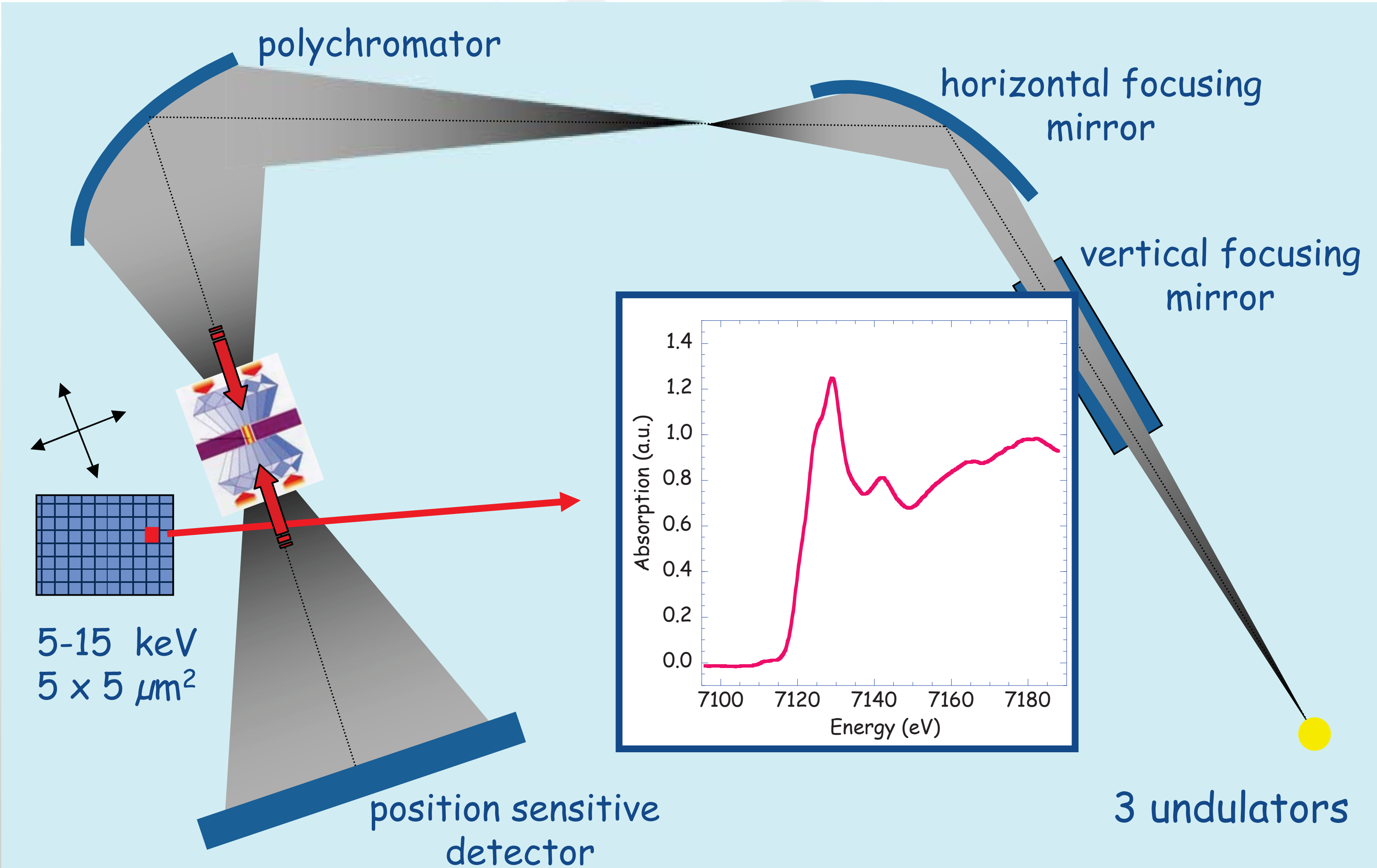
1. no structural change observed
2. fcc Ni still ferromagnetic at 200 GPa
3. comparison with DFT calculations
4. expected collapse above 400 GPa

R. Torchio et al., *PRL 107, 237202 2011*

EDXAS at ESRF

- Structure and magnetism in compressed matter
- Geochemistry
- Element selective magnetism at pulsed 30T fields

μ-XAS 2D mapping



S. Pascarelli et al. *J. of Synchrotron Rad. 13, 351 (2006)*

Redox and speciation mapping in the DAC

lack of in situ experiments under relevant P and T conditions

- opens the way to quantitative «in situ» observations of absorber redox & speciation
- allows to quantify P and T gradients & absorber inhomogeneities across the laser heated spot

Effect of spin crossover on Fe partitioning ?

How much Fe in PPv ?

Valence of Fe in PPv ?

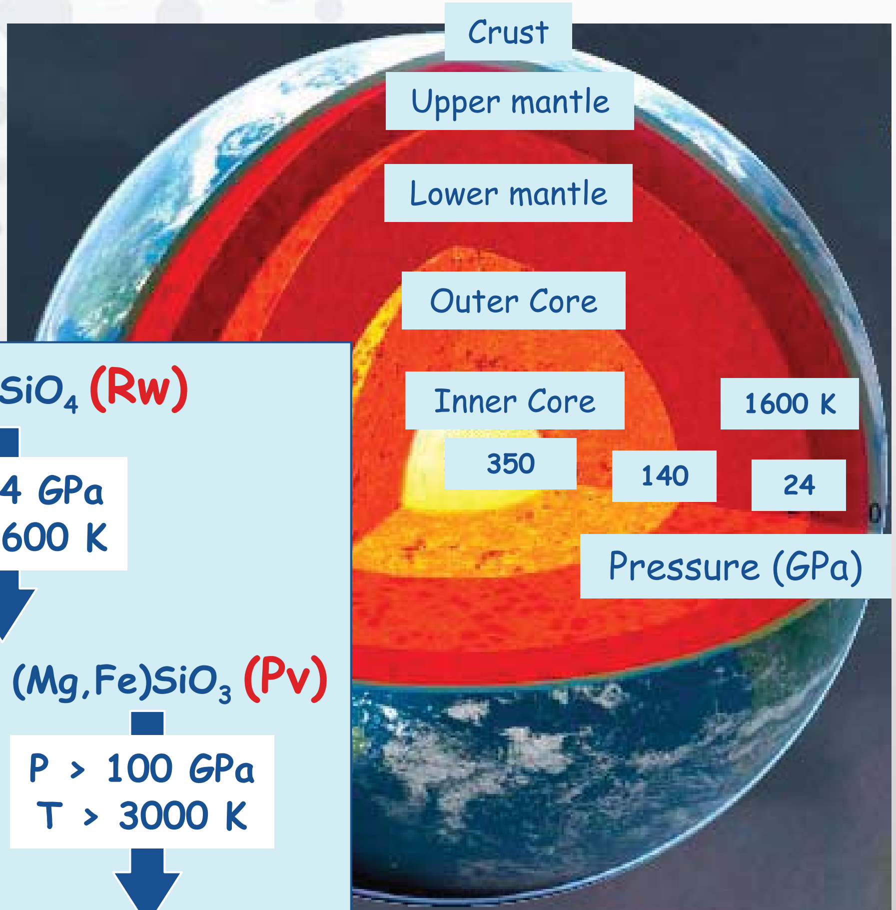
$(Mg_{1-x}Fe_x)_2SiO_4$ **(Rw)**

P ~ 24 GPa
T ~ 1600 K

$(Mg,Fe)O$ **(Fp)** + $(Mg,Fe)SiO_3$ **(Pv)**

P > 100 GPa
T > 3000 K

PPv



M. Muñoz et al *High Pressure Research 28, 665 (2008)* G. Aquilanti et al., *J. Synchr. Rad. 16, 376 (2009)*

ructural decomposition of $(Mg_{1-x}Fe_x)_2SiO_4$ ringwoodite

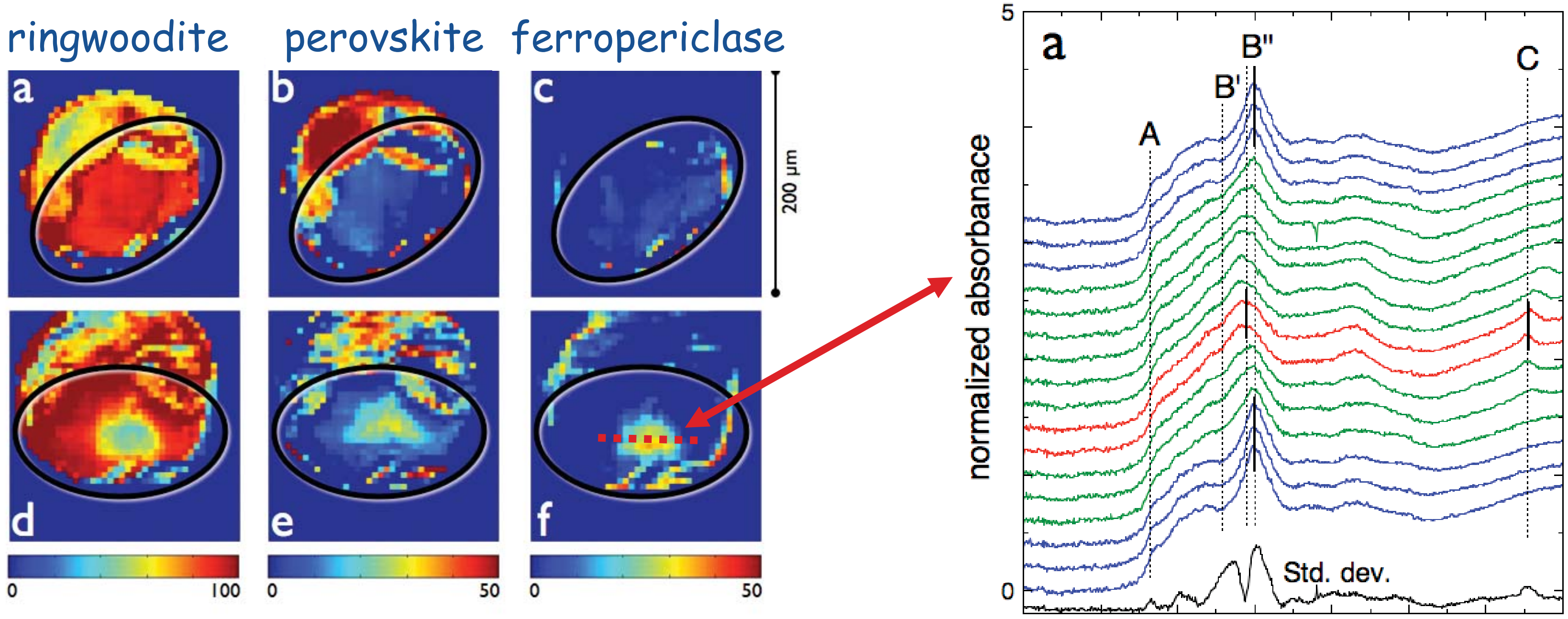
$(Mg_{1-x}Fe_x)_2SiO_4$ **(Rw)**

P ~ 24 GPa
T ~ 1600 K

$(Mg,Fe)O$ **(Fp)** + $(Mg,Fe)SiO_3$ **(Pv)**

26 GPa before laser

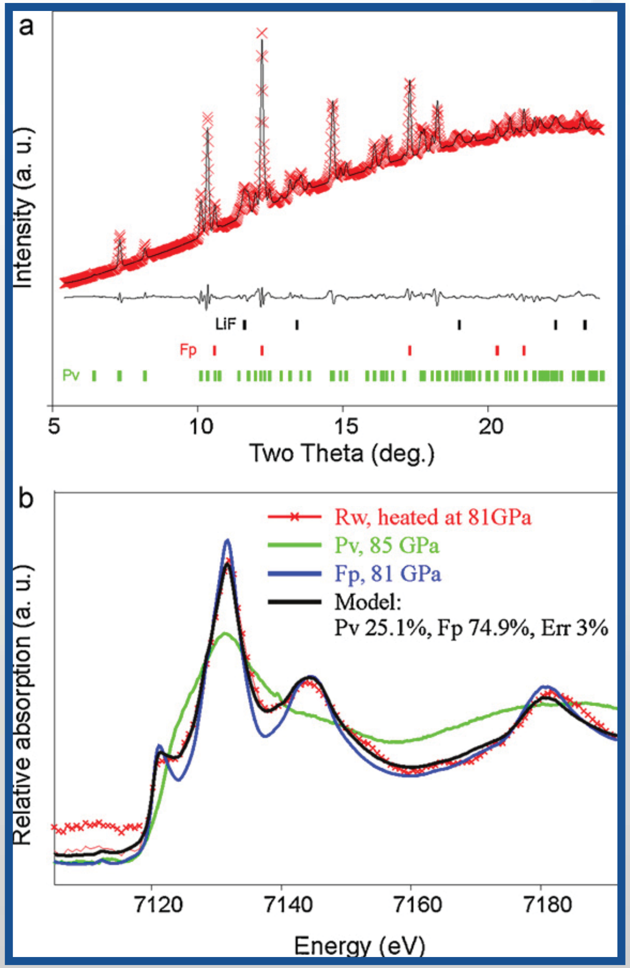
37 GPa after laser

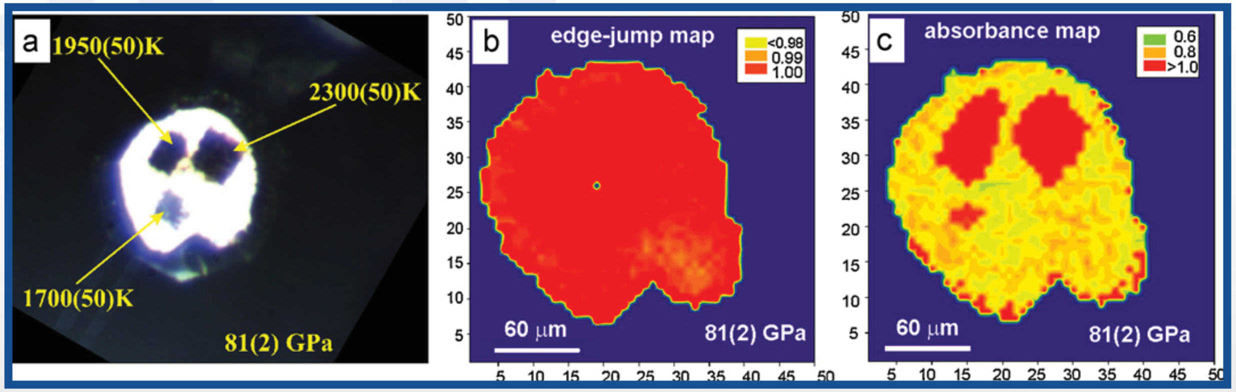


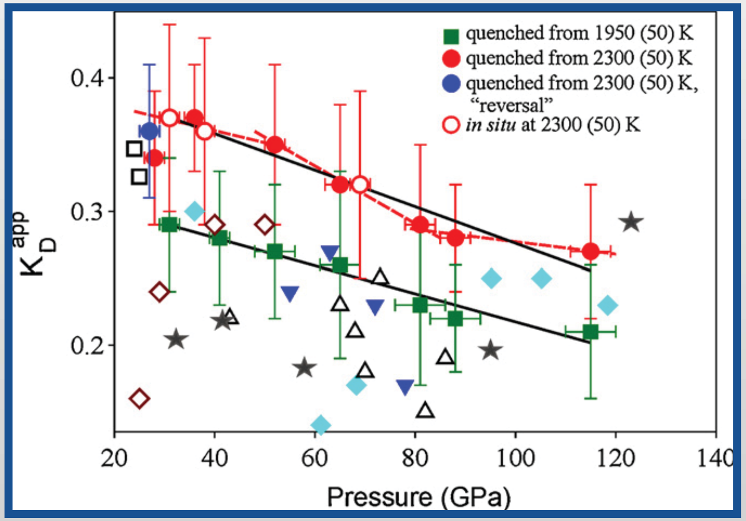
M. Muñoz et al *High Pressure Research* 28, 665 (2008)

Partitioning of Fe between Pv and Fp

O. Narygina et al.,*Physics of the Earth and Planetary Interiors 185, 107, (2011)*







1. T promotes Fe partitioning in Pv, P acts oppositely
2. no major effect of spin crossover on Fe partitioning
3. no appreciable chemical dishomogeneity in lower mantle

Valence of Fe in (Mg,Fe)SiO_3 postperovskite phase

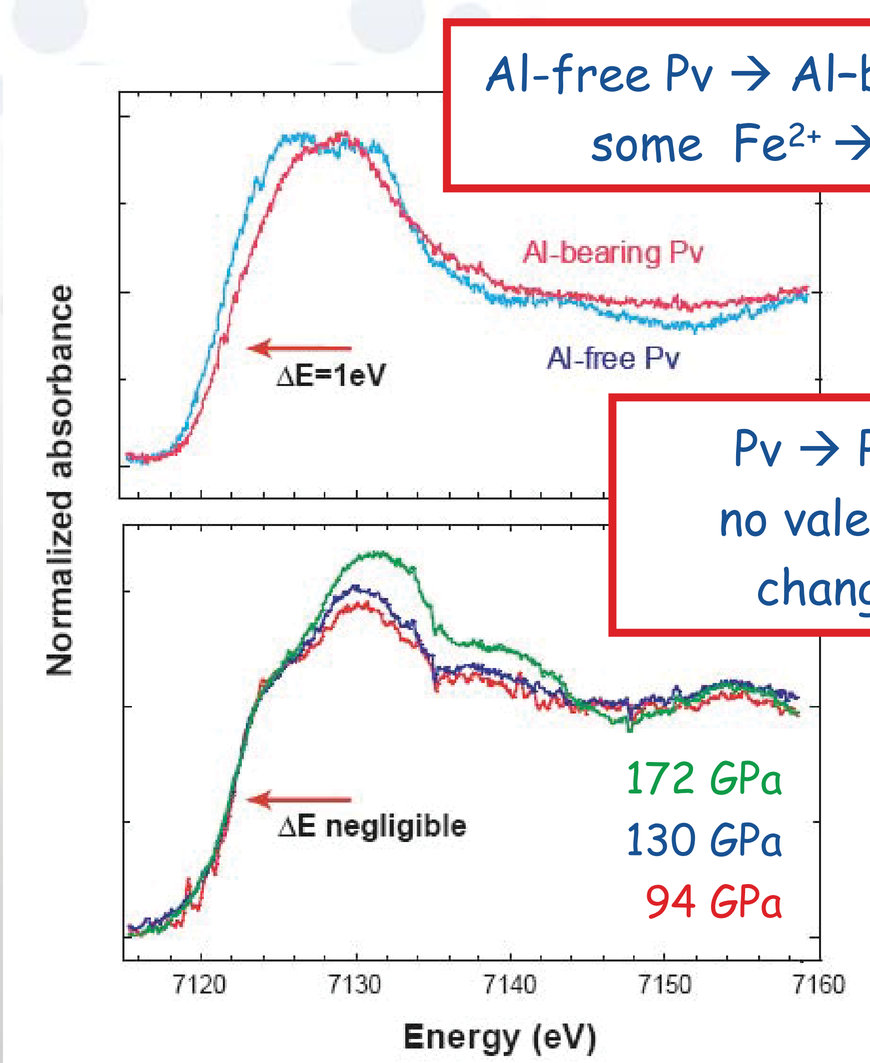
$(Mg_{1-x}Fe_x)_2SiO_4$ **(Rw)**

P ~ 24 GPa
T ~ 1600 K

(Mg,Fe)O **(Fp)** + (Mg,Fe)SiO_3 **(Pv)**

P > 100 GPa
T > 3000 K

PPv



Al-free Pv → Al-bearing Pv
some Fe^{2+} → Fe^{3+}

Pv → PPv
no valence change

D. Andrault et al., EPSL *293, 90-96 (2010)*

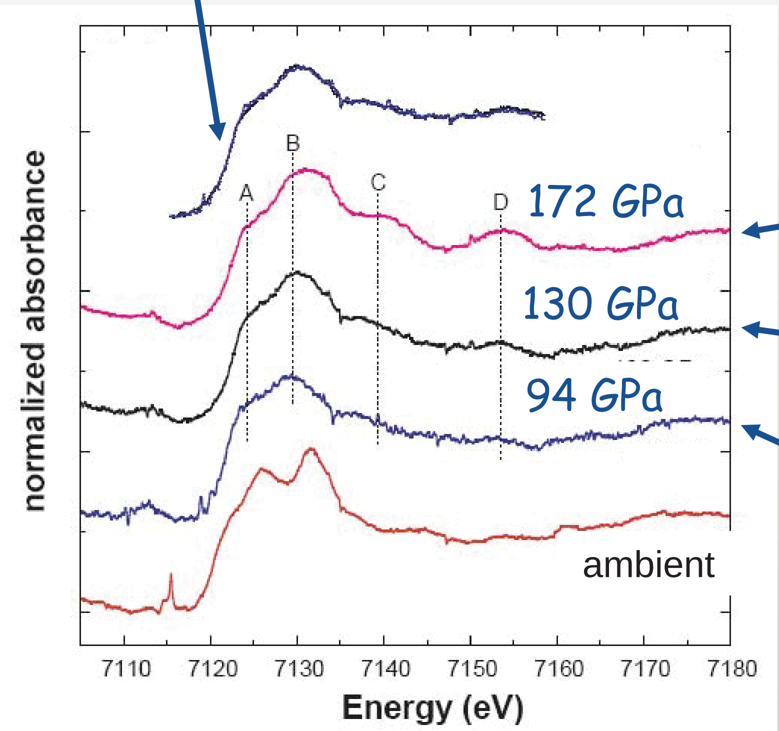
Partitioning of Fe between perovskite and postperovskite phase

$(Fe,Al)_{19}(Mg,Si)_{81}O_3$

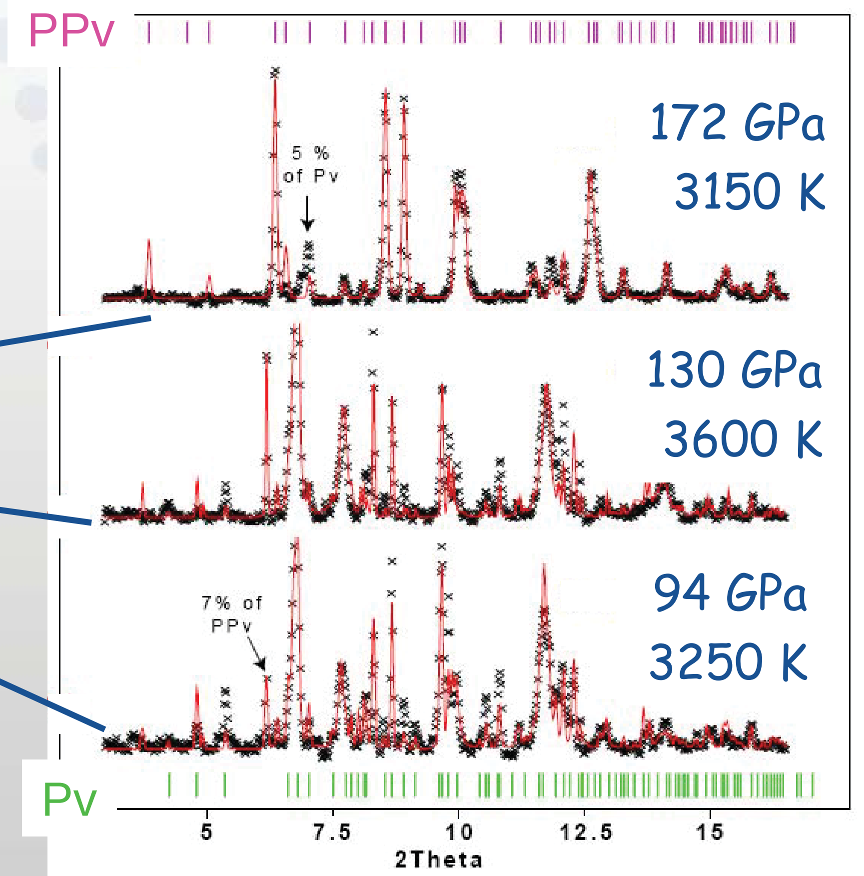
D. Andrault et al., EPSL *293, 90 (2010)*

Fe K-edge XANES (ID24)

[130 GPa] = 85% [94 GPa] + 15% [172 GPa]



X-ray Diffraction (ID27)



The PPv phase appears largely depleted in Fe compared to Pv ➡ $K_{Fe}^{Pv/PPv} = 4.2 \pm 0.5$

EDXAS at ESRF

- Structure and magnetism in compressed matter
- Geochemistry
- Element selective magnetism at pulsed 30T fields

Ferrimagnetic materials: high fields

- spinel ferrites PQ_2X_4: Fe_3O_4, $MgFe_2O_4$, MnO_3 …
- rare earth iron garnets $P_3Q_2R_3O_{12}$: $Y_3Fe_5O_{12}$, $Er_3Fe_5O_{12}$, $Yb_3Fe_5O_{12}$
- double perovskites $A_2BB'O_6$: Ca_2FeReO_6, Sr_2FeMoO_6 …
- intermetallics R-T: $ErCo_2$, $GdNi_2$, Ho_2Fe_{17}…
- hexagonal magnetoplumbites $PO{\cdot}6Fe_2O_3$: $BaFe_{12}O_{19}$ …
- …

high fields are required to break ferrimagnetic correlations

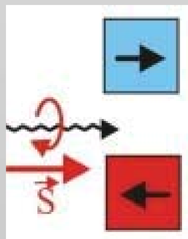
Louis Néel

$$H_R = H_0 + \lambda_{RR}M_R - \lambda M_{Fe}$$
$$H_{Fe} = H_0 - \lambda M_R + \lambda_{FeFe}M_{Fe}$$

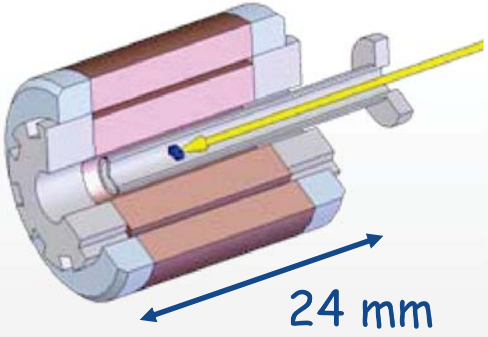
X-ray Magnetic Circular Dichroism

allows to address sublattices independently

$$XMCD = \frac{\mu^L - \mu^R}{\mu^L + \mu^R}$$

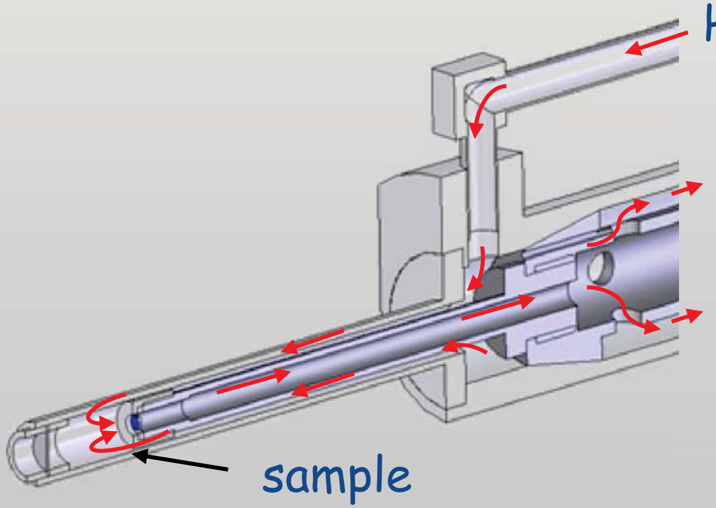


Pulsed high magnetic fields at ID24

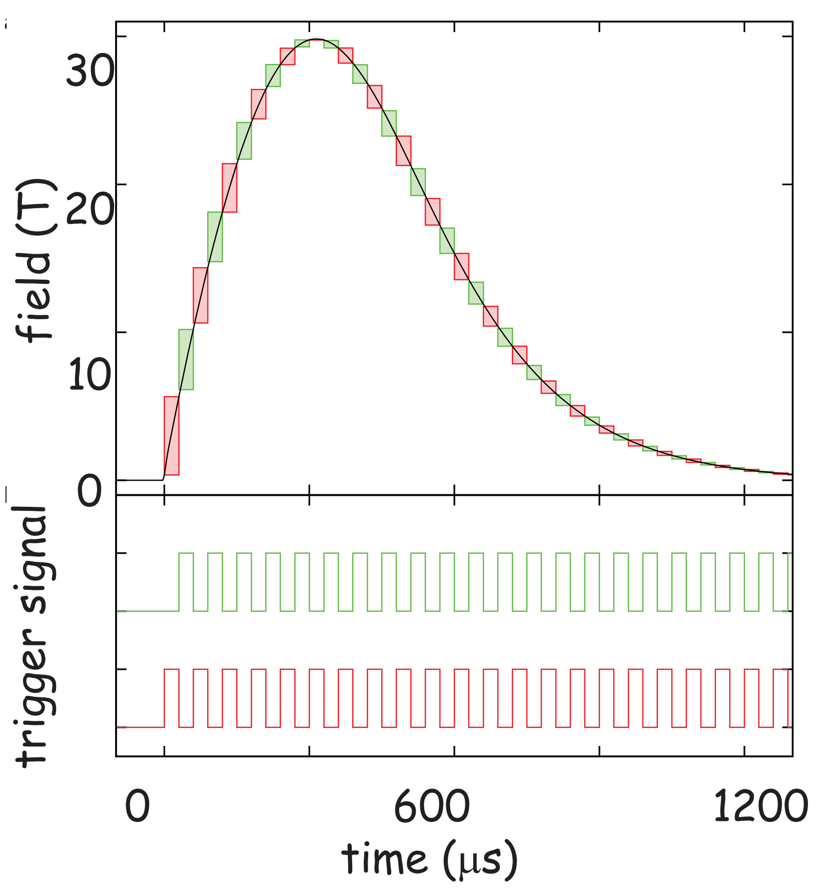


- compact size
- high repetition rate, 30 T every 12 seconds
- independent sample cryostat 5 K – 300 K

P. van der Linden, et al. *Rev. Sci. Inst.* **79**, 075104 (2008)



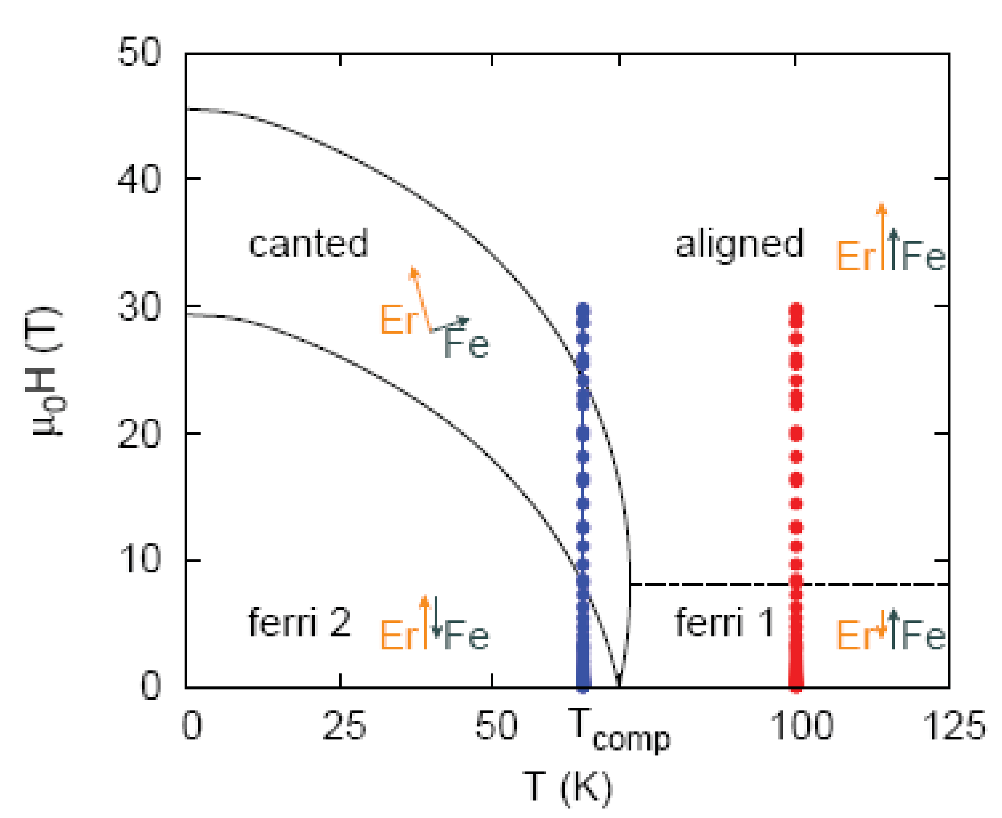
field pulse and acquisition windows



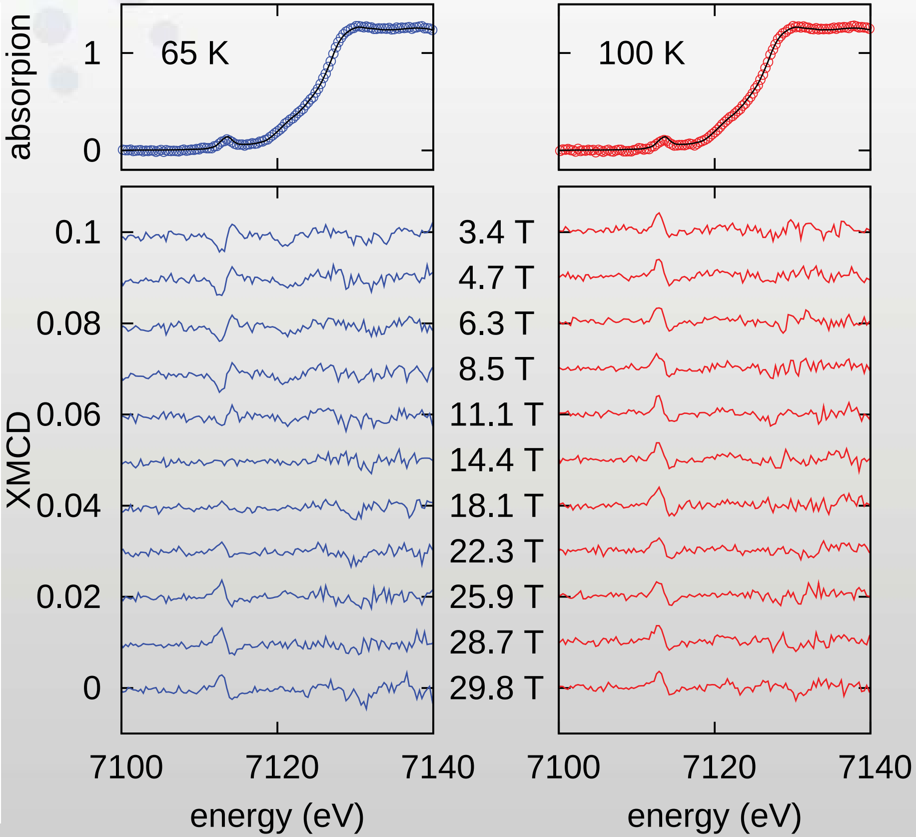
fast PSD "Ultra System": Headspith et al proc. of NSS-MIC2007
XMCD in pulsed fields: O. Mathon et al. *JSR* **14**, 409 (2007)
Multiframe detection: C. Strohm et al. *accepted in JSR* (2011)

Fe K-edge XMCD in $Er_3Fe_5O_{12}$

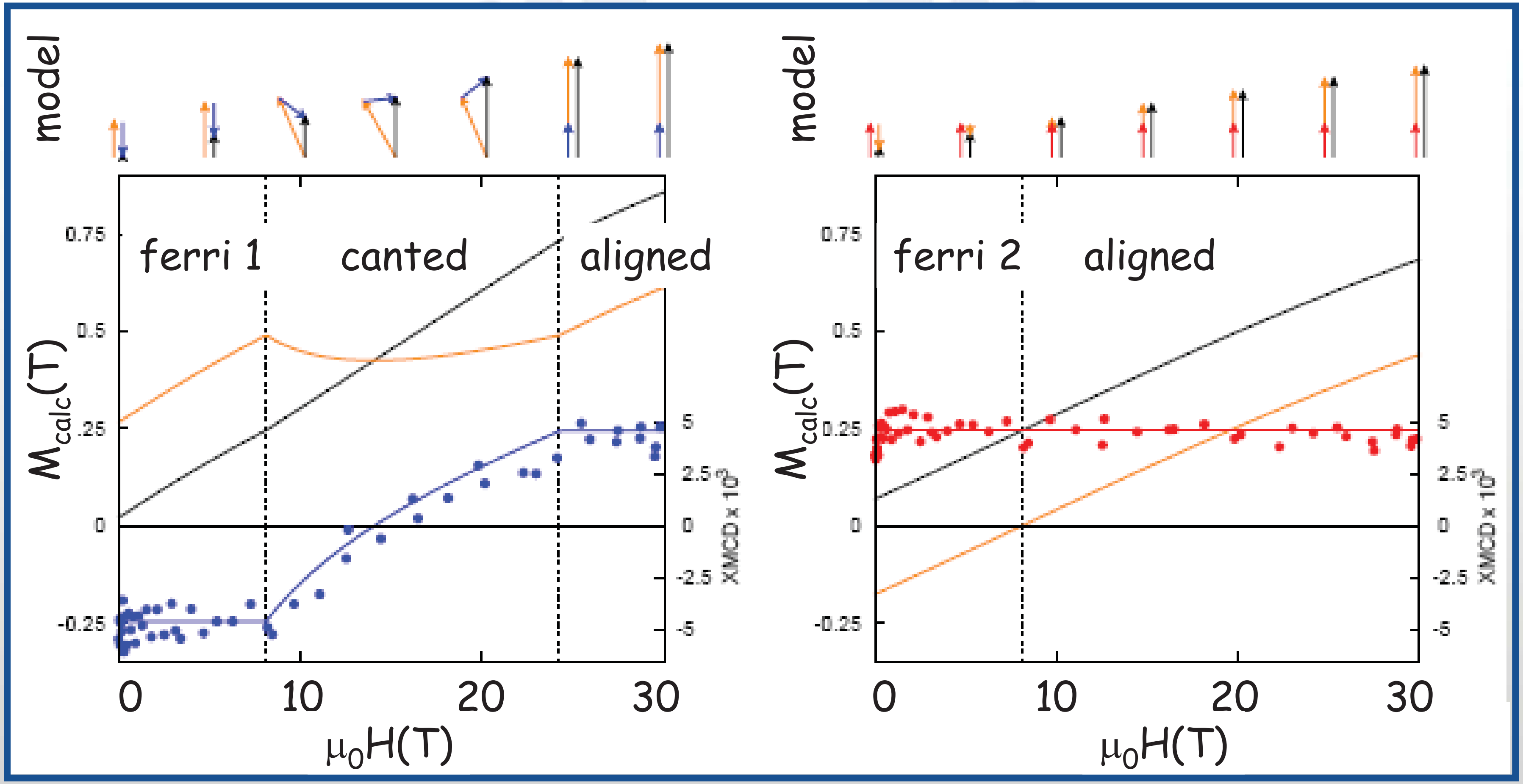
phase diagram (field along 100)



Fe K edge XMCD spectra



Fe sublattice magnetization in $Er_3Fe_5O_{12}$



- XMCD amplitude – direct probe of Fe-sublattice magnetization
- direct observation of spin reorientation in canted phase

C. Strohm et al. *in preparation*

XAS, XANES, EXAFS, and XMCD

- X-ray Absorption
- X-ray Absorption Fine Structure
- Simple Theoretical Description
- XANES
- Major historical EXAFS breakthroughs
- Examples of applications at ELETTRA
- EXAFS data analysis
- Introduction to XMCD

yesterday

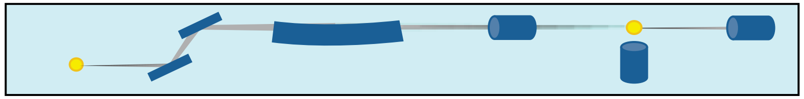
Energy Dispersive XAS

- X-ray Absorption Spectrometers
- EDXAS
  - Basic principles, historical evolution
  - Examples of applications at ESRF
  - Future opportunities for studies of matter at extremes
- Probing laser induced extreme states of matter

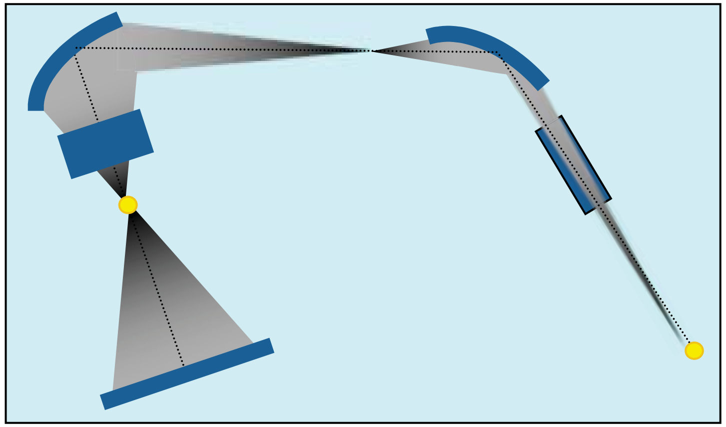
today

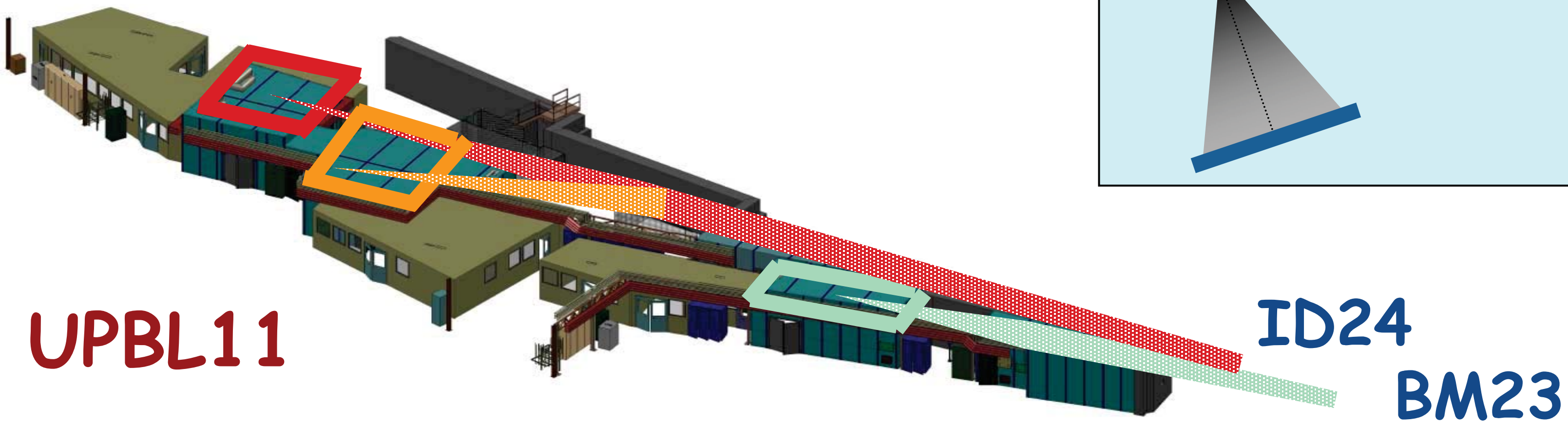
UPBL11: Time Resolved and Extreme Conditions XAS

- Transfer of EXAFS bl BM29 to BM23



- Re-design of EDXAS bl ID24





- Stability → re-design of optics and experimental stations
- Focal spot → double branch (3 vs 100 μm) on time-shared basis
- Detection → new generation of micro-strip detectors (μs)

Opening dates for public:

BM23:	March 2011
ID24:	May 2012

UPBL11: scientific case

time resolved

heterogeneous catalysis

ms cleaner chemical processes
emission free vehicles
new energy resources

μs

solution chemistry
microfluidics

ns photochemistry
recombination
radiative decay

ps rotational motion

fm atomic displacements
magnetostriction, piezoelectricity
reversible H_2 storage processes
energy-driven magnetic materials

time resolved + extreme conditions

pulsed laser heating

kinetics at HP HT

melting, chemical reactions

matter at high pulsed magnetic fields

laser shocked matter

warm dense matter

extreme conditions

P > 100 GPa; T > 3000 K

melts
local order
electronic structure

earth and planetary science
speciation, oxidation states
partition coefficients
complexation in aqueous fluids

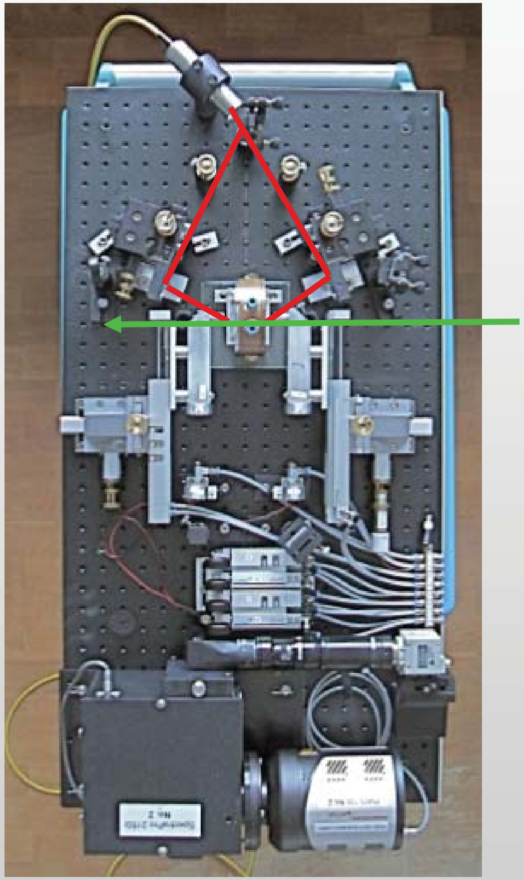
materials science
HP properties of catalysts
synthesis of new materials

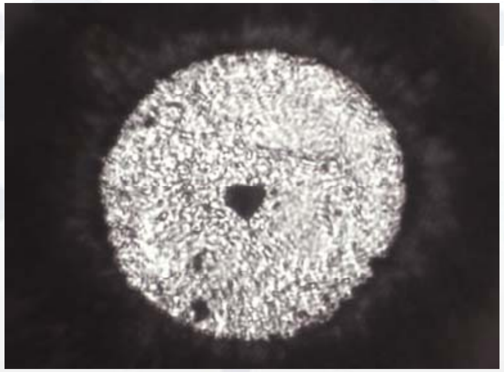
P > 100 GPa; T < 10 K

structure and magnetism at HP
magnetism/structure correlation
breakdown of ferromagnetism
local structure

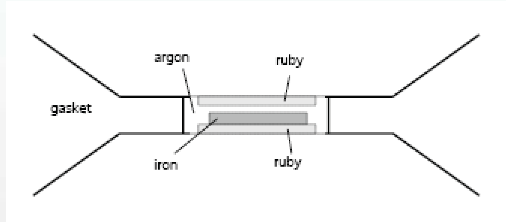
Melting of Fe in the DAC

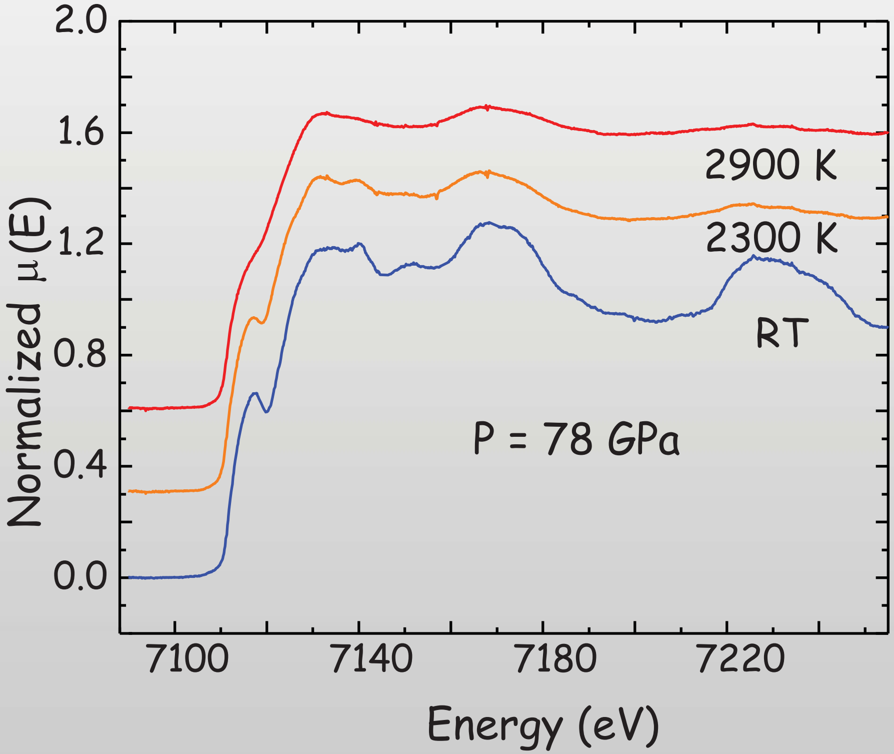
Fiber pumped near infrared laser (P=110 W, λ=1070 nm)





- spherical shape
- size commensurate with laser beam (< 30 μm)

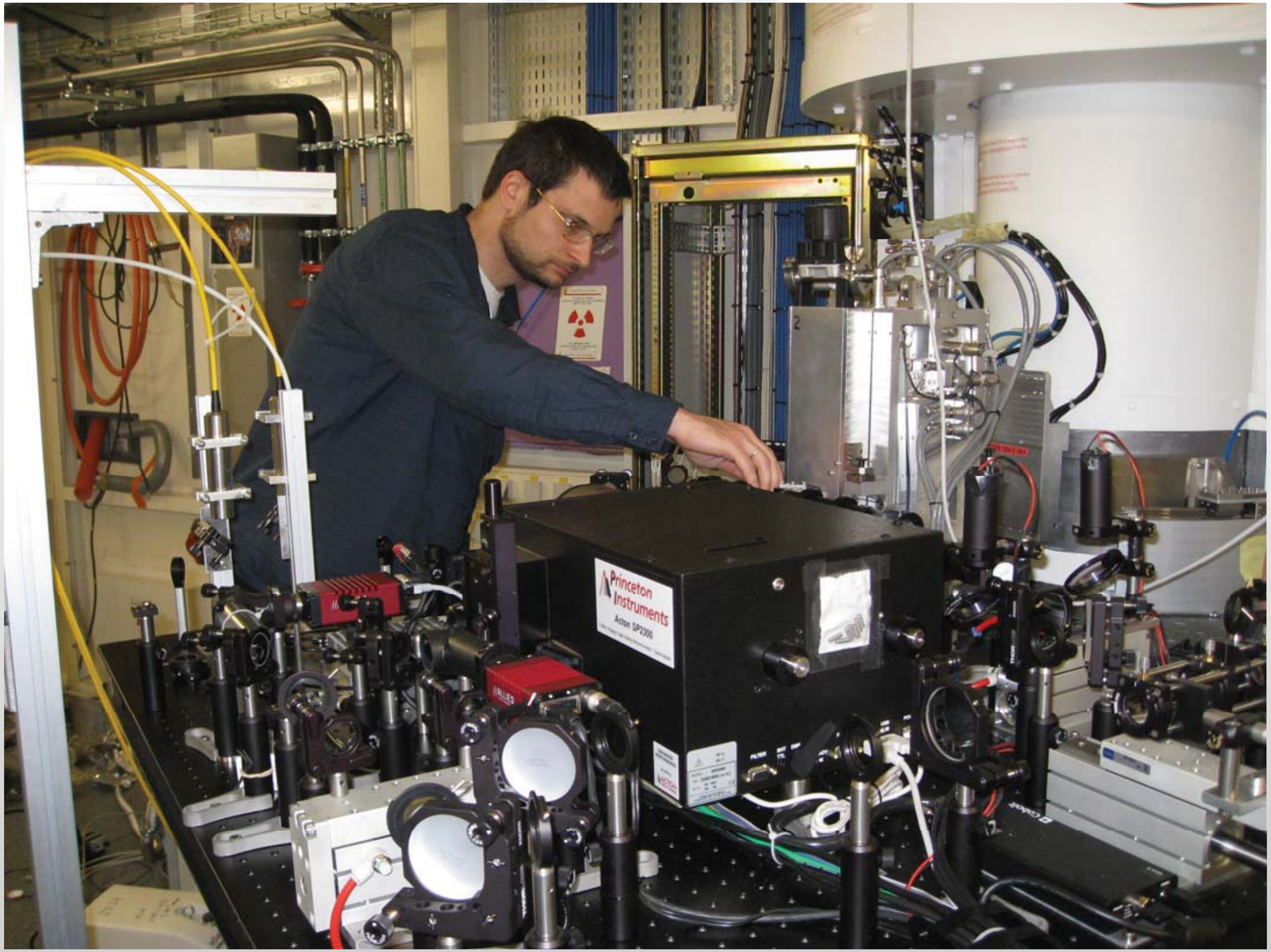




R. Boehler et al., *Rev. Sci. Instr. 80, 045103 (2009)*

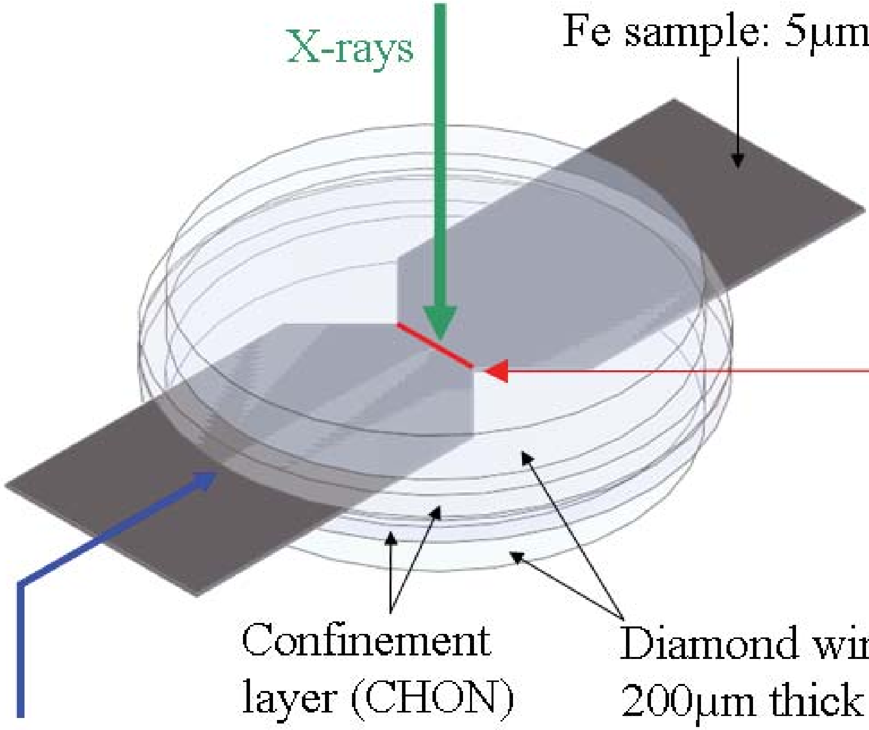
UPBL11 : commissioning of laser heating facility

Innokenty Kantor

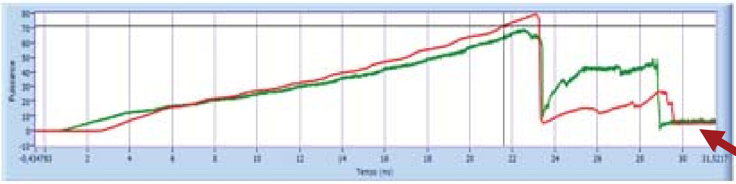


HP/HT laser setup installed on EDXAS-S for commissioning (Nov 2011)

Electric discharge through a conducting sample: first attempts to probe warm dense Fe



Current: I from 0 to ~12 A in ~20ms.

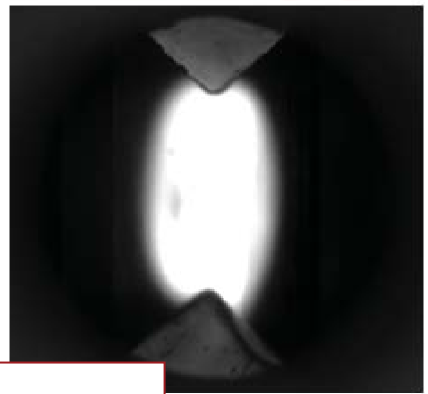


Power ramp monitoring

Warm zone:

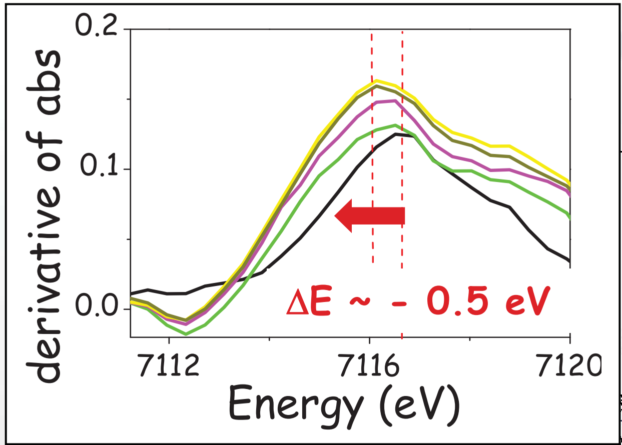
Pyrometry

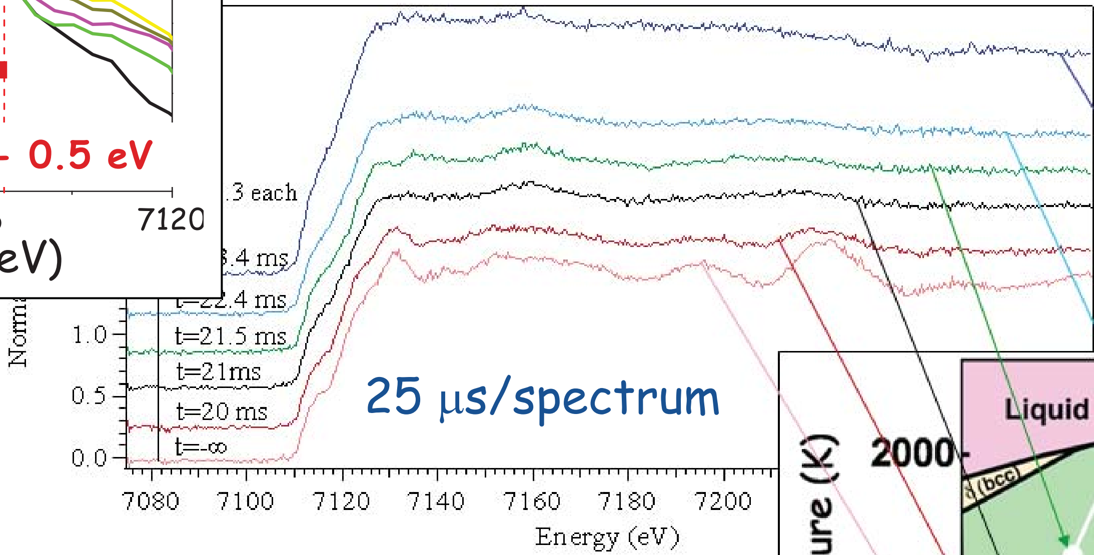
& Fast imaging

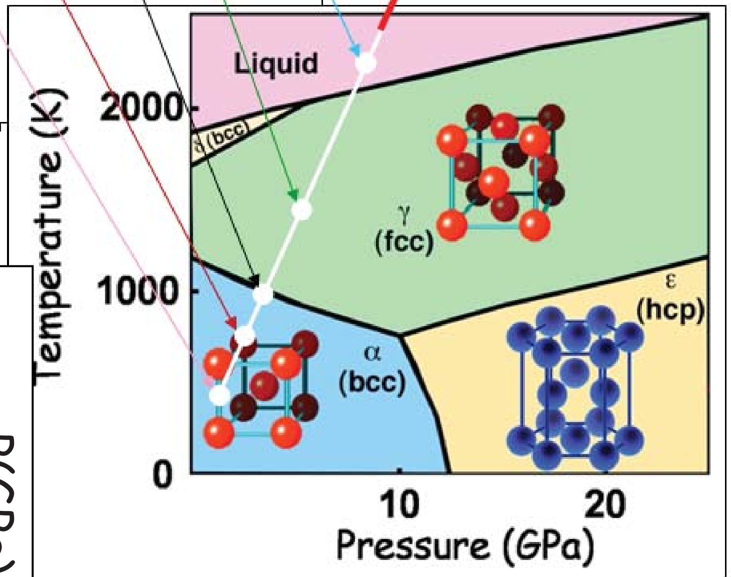


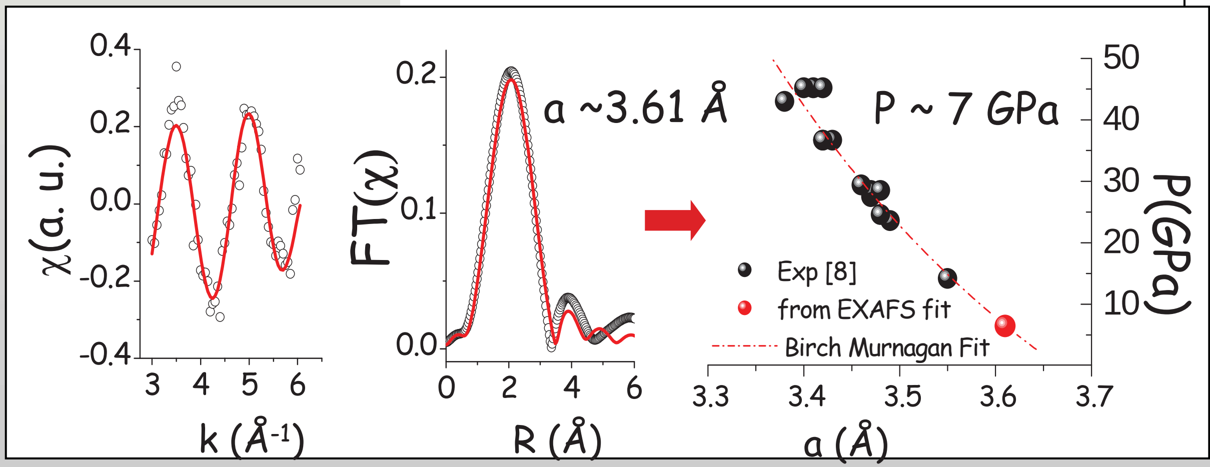
sample loss
DAC explosion

First data on Fe









Collaboration with:
F. Occelli and P. Loubeyre, CEA
Bruyeres-les-Chatel