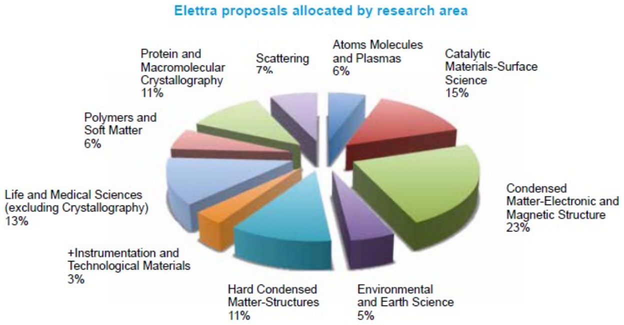
Experimental Perspectives for Elettra 2.0

Tevfik OnurMenteş

Elettra Sincrotrone Trieste

Elettra Sincrotrone Trieste

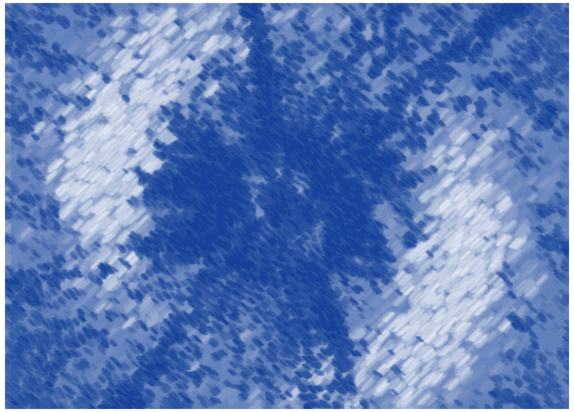
Elettra 1.0



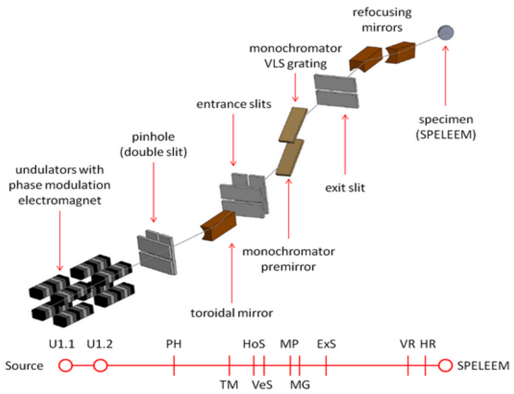
- 480 proposals allocated
- 1322 users hosted

Summary

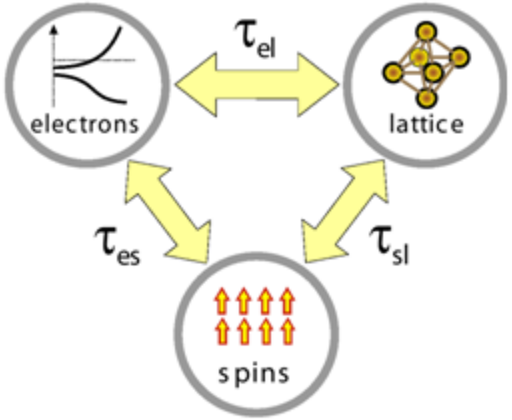
Coherent X-ray Diffraction



What does the upgrade signify for an existing beamline?

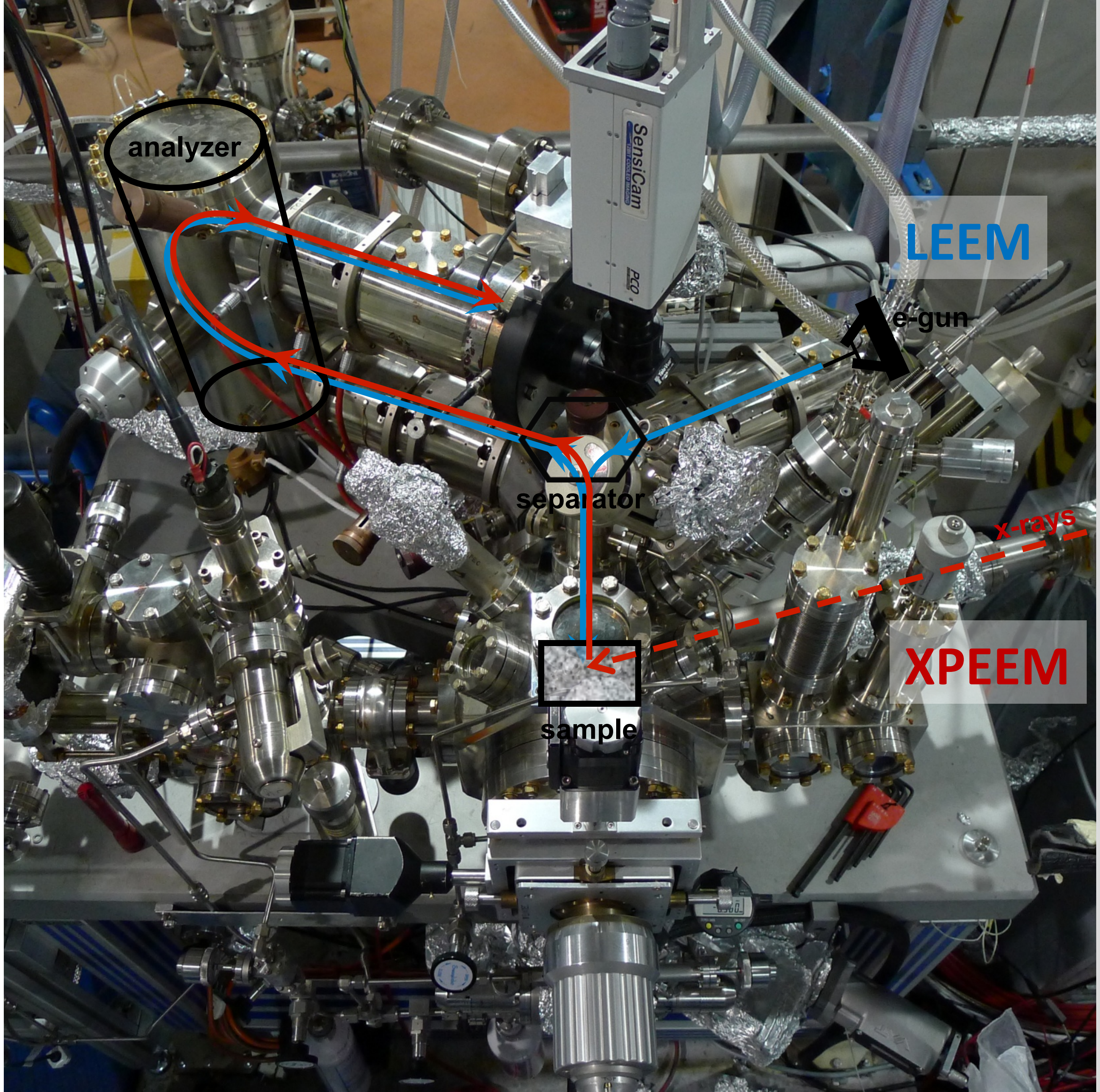


Time-Resolved Spectroscopies



SPELEEM instrument @ Nanospectroscopy

Locatelli et al, *Surf. Interface Anal.* **38**, 1554 (2006).
Mentes et al, Beilsten J. Nanotechnology **5**, 1873 (2014).



Soft X-rays
30 eV – 1000 eV

Elliptical Undulators

Microspot focusing
25 µm (H) × 2 µm (V)
(with KB mirrors)

High flux
10^{13} photons/sec

Improvement in numbers

	'natural'undulator emission
σ_r (μm)	12
$\Sigma_{r'}$ (μrad)	20

reduction factors shown

	Present	Upgrade 4-BA	Upgrade 6-BA
Σ_x (μm)	253	82 (3.1)	57 (4.4)
Σ_y (μm)	22	13 (1.7)	13 (1.7)
$\Sigma_{x'}$ (μrad)	35	23 (1.6)	21 (1.7)
$\Sigma_{y'}$ (μrad)	21	21 (1)	21 (1)

In horizontal plane:

- Reduced source size (**3.1**; **4.4**)
- Reduced divergence (**1.6**; **1.7**)

In vertical plane:

- Reduced source size (**1.7**; **1.7**)
- Almost unchanged divergence

About a factor 20 increase in brilliance

Calculations by: Anna Bianco & Luca Rebuffi, Elettra Optics Group

Improvement in numbers

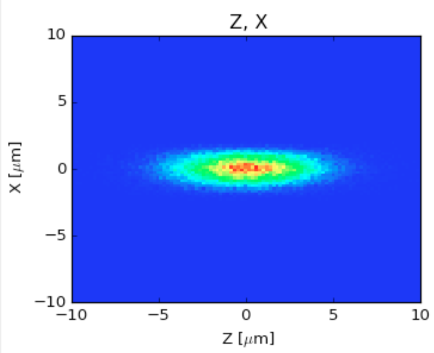
Elettra Sincrotrone Trieste

- **Increase of the spectral photon flux through the beam defining aperture**
  - From $1.9\cdot10^{14}$ to $4.7\cdot10^{14}$ ph s^{-1} mm^{-2} $mrad^{-2}$ 0.1%BW (gain 2.5)

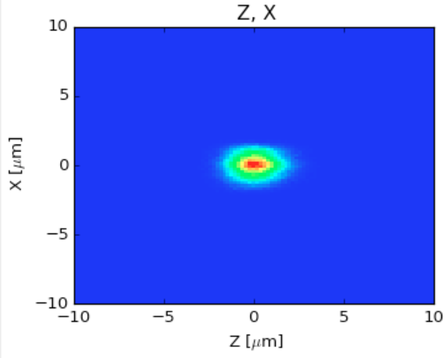
  (with present settings of the aperture: 56 µrad x 63 µrad, 400 eV)

- **decrease of beam-spot size**

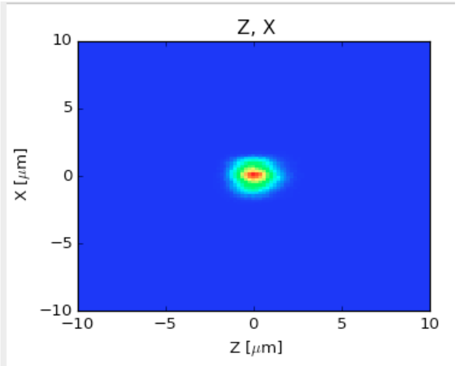
Spot at the sample position



5.6 µm * 1.7 µm FWHM



2.1 µm * 1.6 µm FWHM

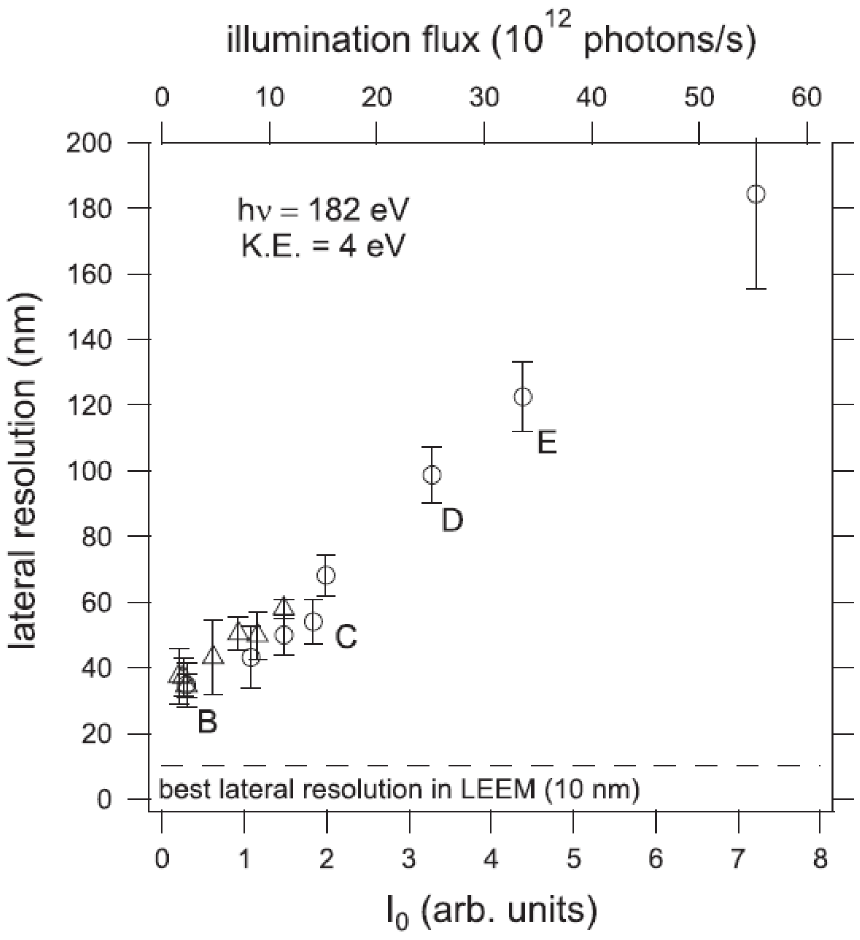


1.7 µm * 1.6 µm FWHM

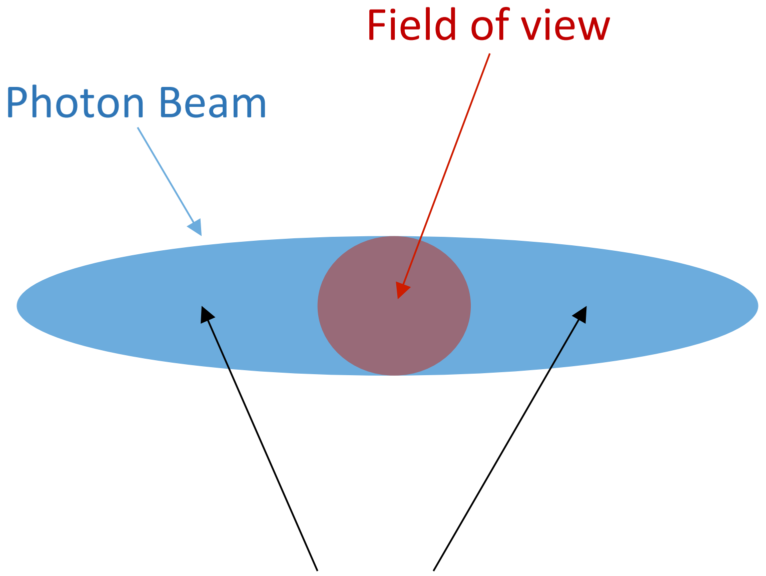
Calculations by: Anna Bianco & Luca Rebuffi, Elettra Optics Group

Round beam would reduce space-charge

Degradation of resolution due to space-charge



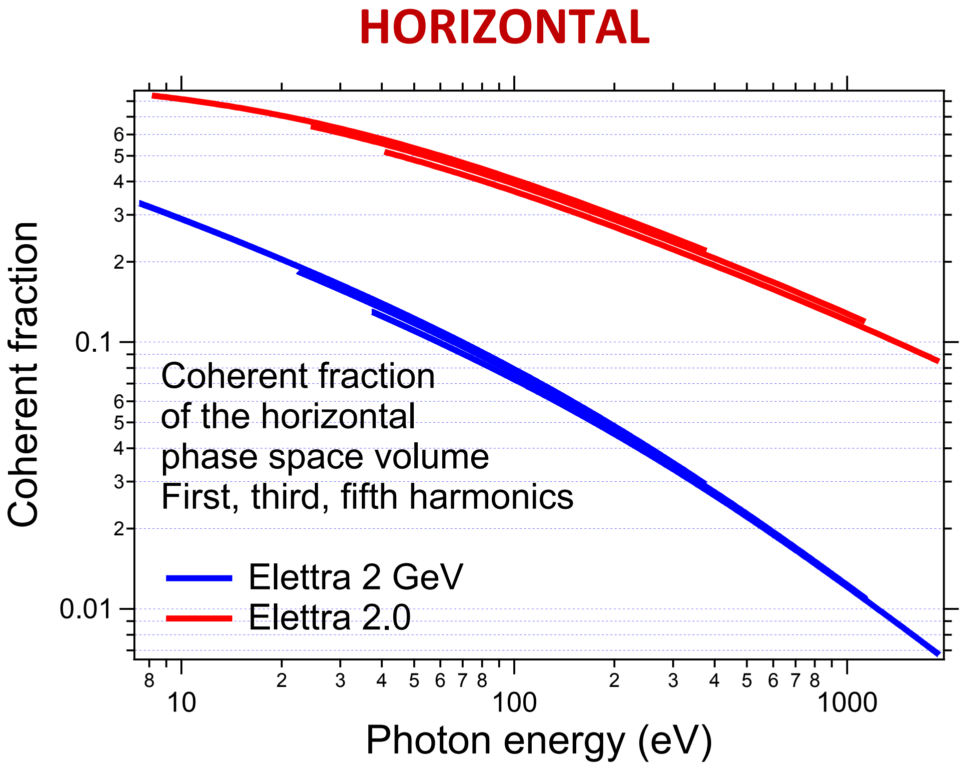
A. Locatelli *et al.,* Ultramicroscopy **111**, 1447 (2011)

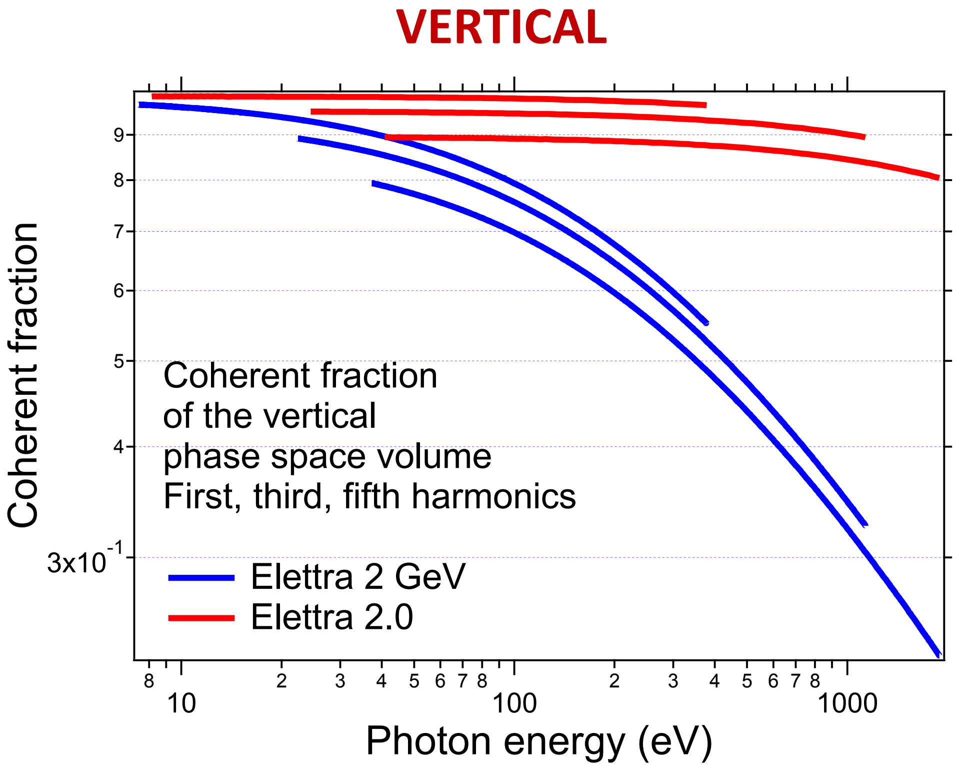


Unwanted photons which contribute to space charge but not the image statistics

Coherence!!

Elettra Sincrotrone Trieste





Calculations by: Anna Bianco, Elettra Optics Group

Coherent X-Ray Diffraction Imaging

Elettra Sincrotrone Trieste

REVIEW OF IMAGE FORMATION METHODS
WITH THE SOFT X-RAY PHOTON

D. Sayre

IBM T. J. Watson Research Center
Yorktown Heights, New York 10598

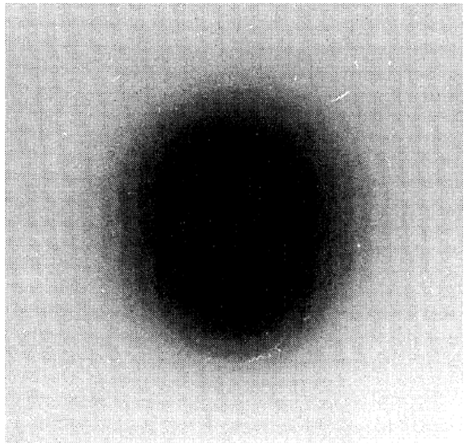
1980

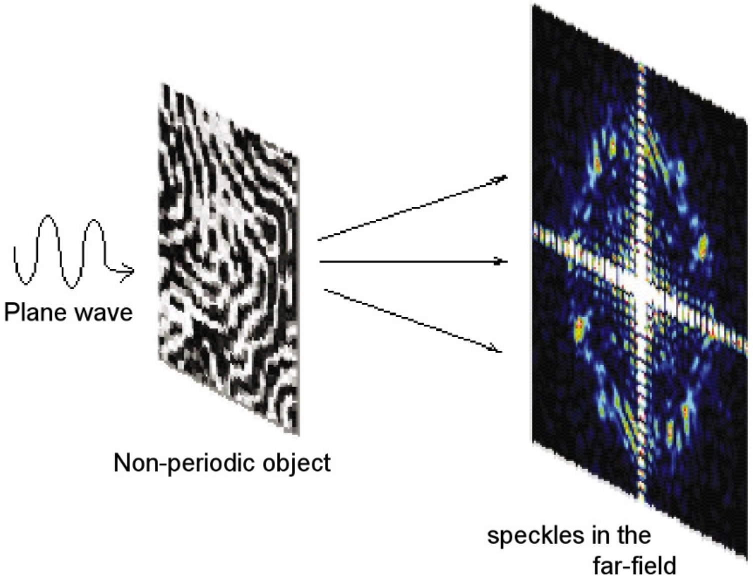
hologram. In column 6, soft x-ray diffraction patterns have been recorded[9] from samples composed of small polystyrene latex spheres, but no construction of images appears to have been done. This will require (as in crystallography) a method of phasing the diffraction pattern. In addition, in order to be useful in biological imaging, the experiment must be modified to collect the diffraction pattern of a single biological cell or organelle. Finally, in column 7, the require-

Journal of the Physical Society of Japan, Vol. 44, No. 4, April, 1978

Soft X-Ray Small-Angle Scattering
by Polystyrene Latexes Using Synchrotron Radiation

Katsuzo Wakabayashi, Akito Kakizaki,[†] Yasuo Siota,[†]
Keiichi Namba, Kimio Kurita,[††] Mamoru Yokata,[†††]
Hiroyuki Tagawa,[††] Yōji Inoko, Toshio Mitsui,
Eiichi Wada,[††] Tatzuo Ueki, Ichiro Nagakura[††††]
and Tokuo Matsukawa[†††††]





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JOURNAL OF THE PHYSICAL SOCIETY OF JAPAN, Vol. 44, No. 4, APRIL, 1978

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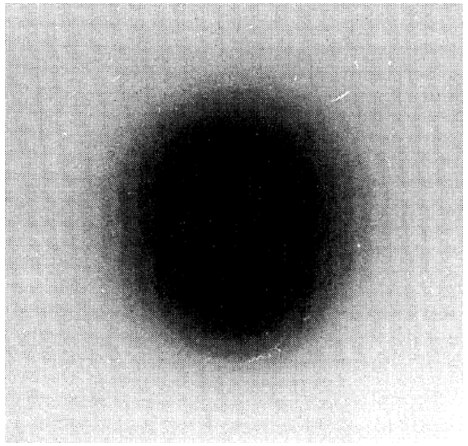
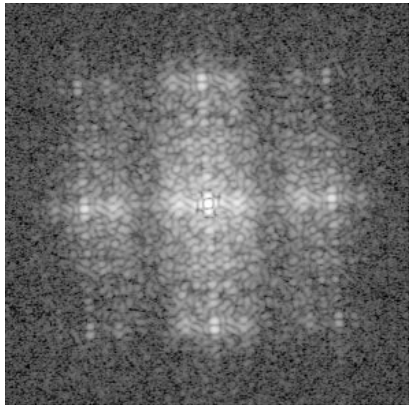
Eiichi WADA,†† Tatzuo UEKI, Ichiro NAGAKURA††††
and Tokuo MATSUKAWA†††††



Extending the methodology of X-ray crystallography to allow imaging of micrometre-sized non-crystalline specimens

Jianwei Miao*, Pambos Charalambous†, Janos Kirz*
& David Sayre*‡

* *Department of Physics and Astronomy, State University of New York, Stony Brook, New York 11794-3800, USA*
† *Kings College, Strand, London WC2R 2LS, UK*



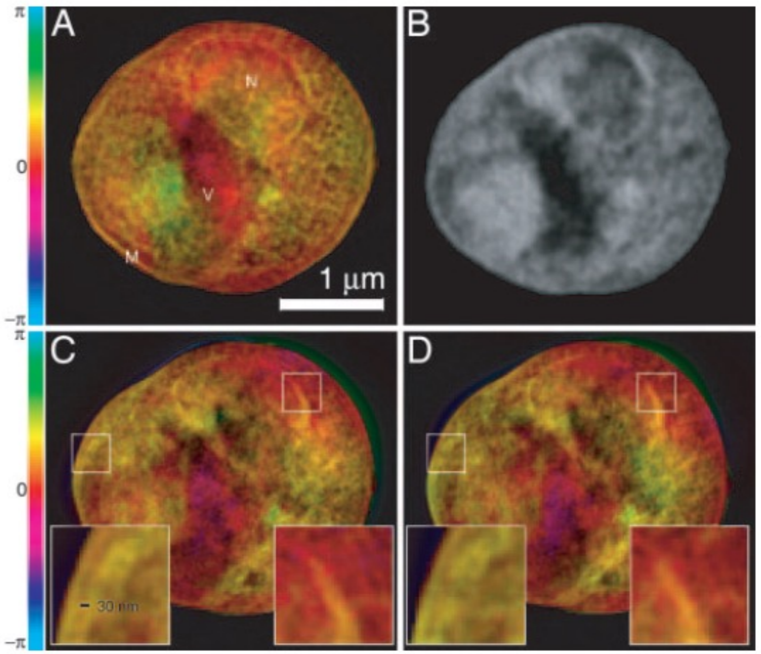
NATURE | VOL 400 | 22 JULY 1999 | www.nature.com

CDI: Soft matter, single cells, molecules

Elettra Sincrotrone Trieste

Biological imaging by soft x-ray diffraction microscopy

David Shapiro*, Pierre Thibault†, Tobias Beetz*‡, Veit Elser†, Malcolm Howells§, Chris Jacobsen*‡¶, Janos Kirz*§, Enju Lima*, Huijie Miao*, Aaron M. Neiman‖, and David Sayre*



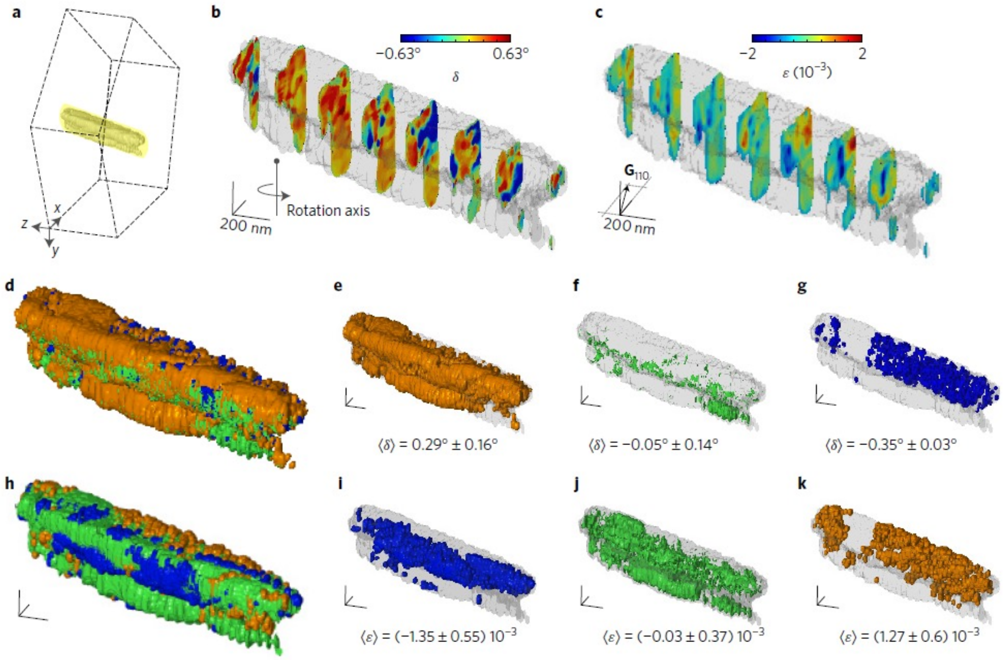
PNAS | October 25, 2005 | vol. 102 | no. 43 | 15343–15346

ALS, 750 eV, resolution **30 nm**, acquisition time **4 hours**

ARTICLES
PUBLISHED ONLINE: 10 JULY 2017 | DOI: 10.1038/NMAT4937
nature materials

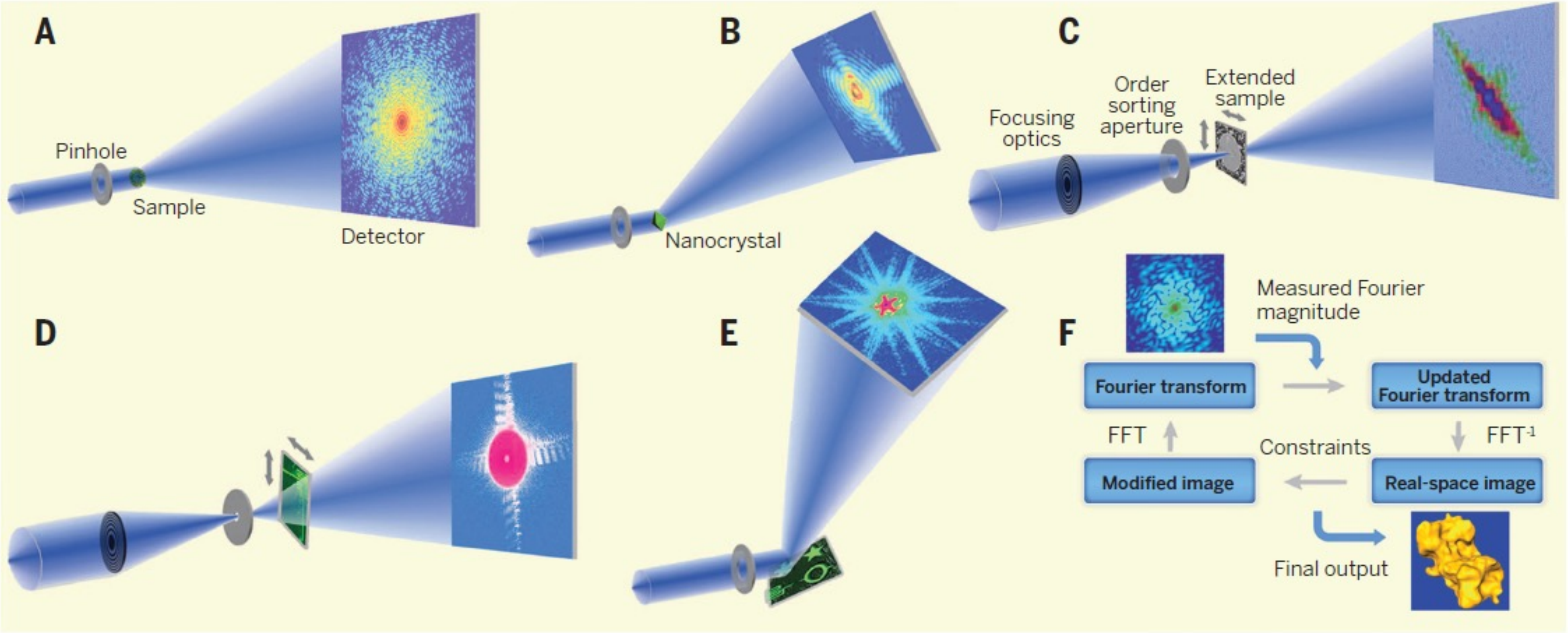
Revealing crystalline domains in a mollusc shell single-crystalline prism

F. Mastropietro[1], P. Godard[1†], M. Burghammer[2], C. Chevallard[3], J. Daillant[4], J. Duboisset[1], M. Allain[1], P. Guenoun[3], J. Nouet[5] and V. Chamard[1*]



ESRF, 15 keV, resolution **40 nm**, acquisition time **9 hours**

‘Lensless’ Imaging

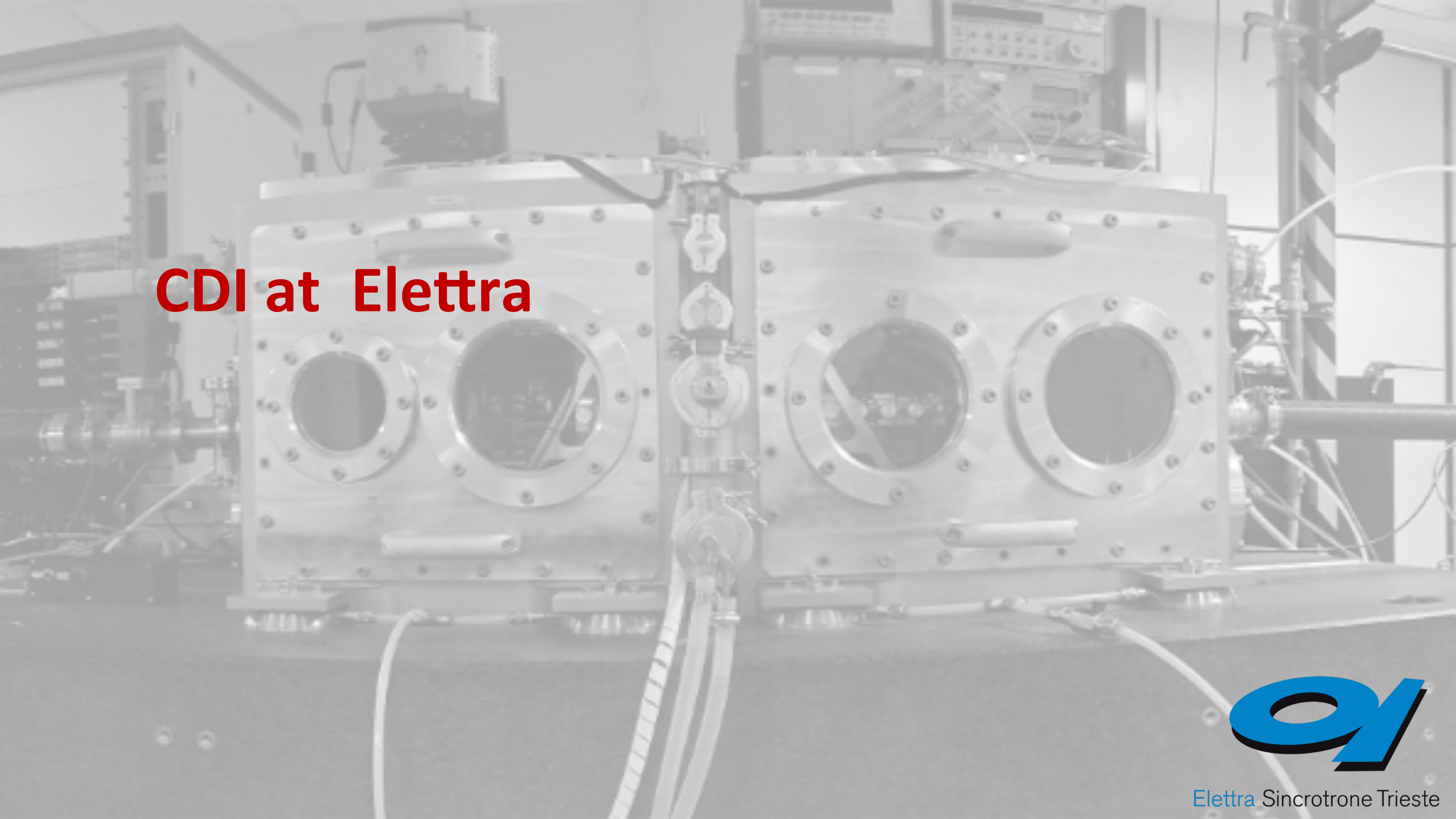


J. Miao et al., Science **348**, 530 (2015)

<u>In the diffraction-limited SR:</u>

- Truly ‘lensless’
- Suppress unwanted incoherent portion (higher S/N, lower radiation damage)
- Faster acquisition

CDI at Elettra



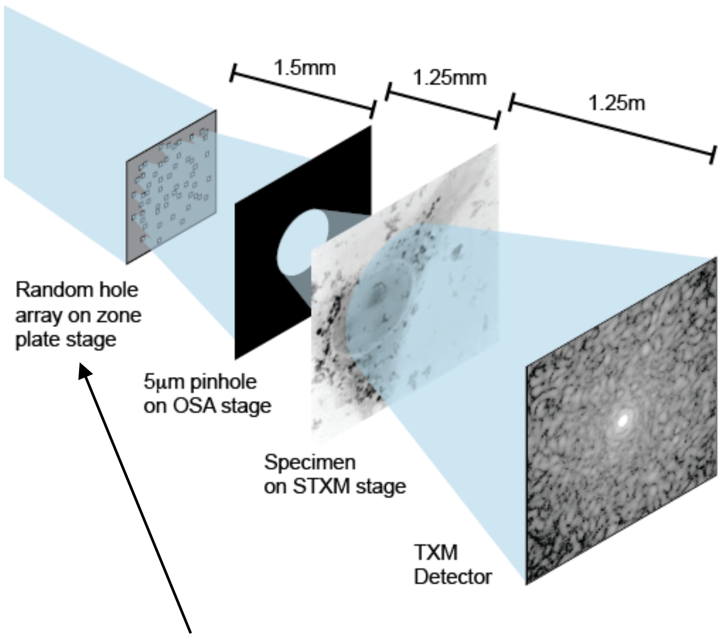
Elettra Sincrotrone Trieste

Ptychography @ TWINMIC Beamline

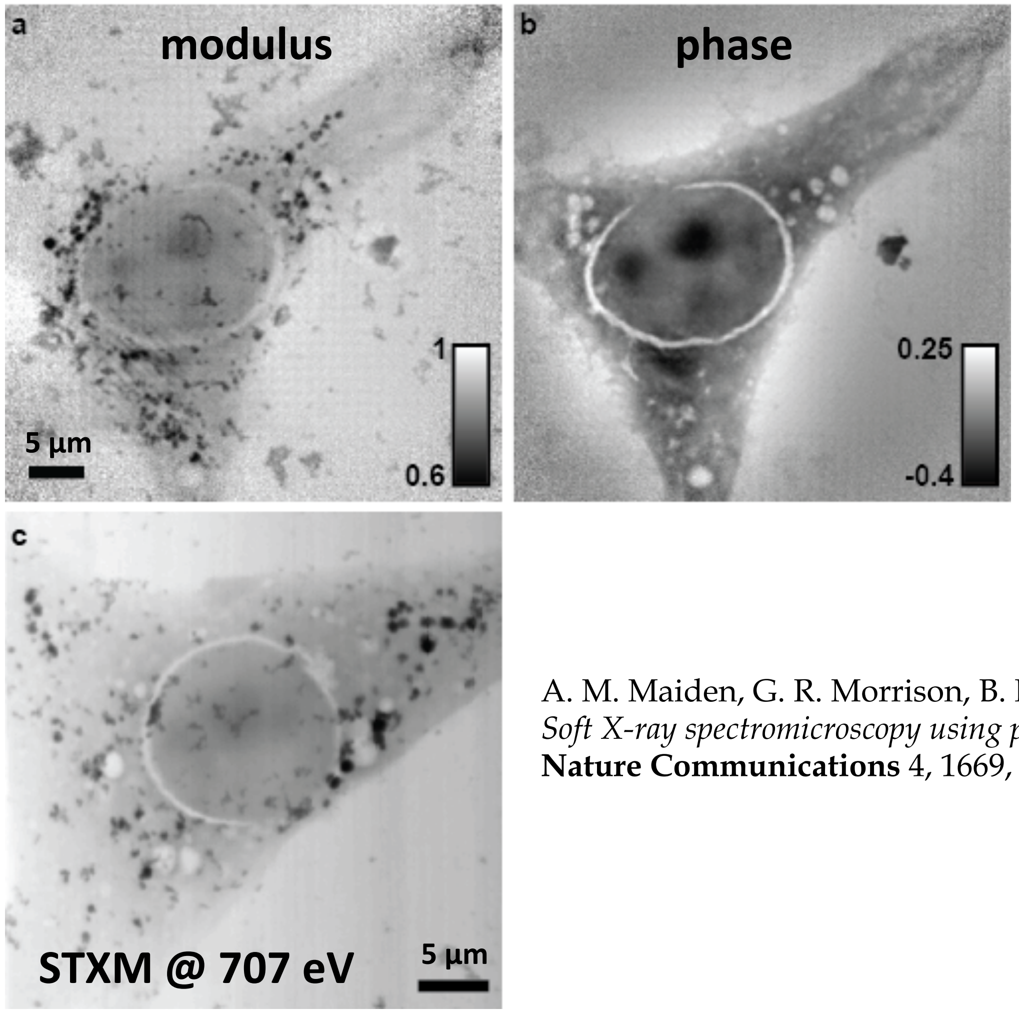
Elettra Sincrotrone Trieste

Balb/3T3 mouse fibroblast cells exposed to cobalt ferrite ($CoFe_2O_4$) nanoparticles

- Illuminated area defined by a 5 µm pinhole
- Sample was scanned with raster steps ~1 µm



To spread the illumination and the phases across the detector



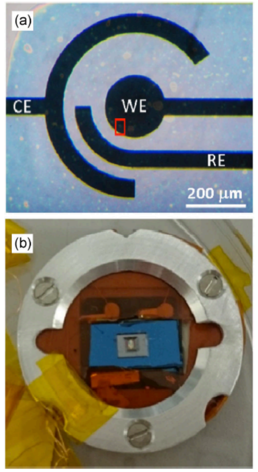
Ptychography reconstruction using the ePIE algorithm (Uni of Sheffiled)
Photon energy = 708.8 eV

A. M. Maiden, G. R. Morrison, B. Kaulich, **A. Gianoncelli**, J. M. Rodenburg, *Soft X-ray spectromicroscopy using ptychography with randomly phased illumination* **Nature Communications** 4, 1669, (2013)

Ptychography @ TWINMIC Beamline

Elettra Sincrotrone Trieste

Chemical imaging: Ptychography at the Mn L edge



Electrochemical cell biased *in situ*

The cell was monitored in its pristine state and after biasing, across Mn and Co edge, elements present in the electrolyte solution

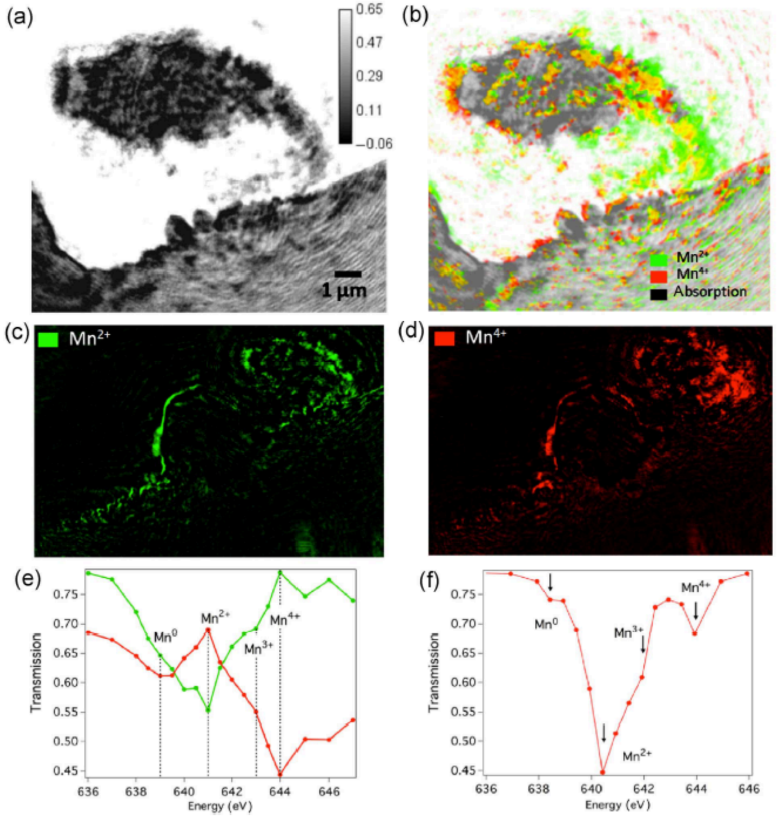


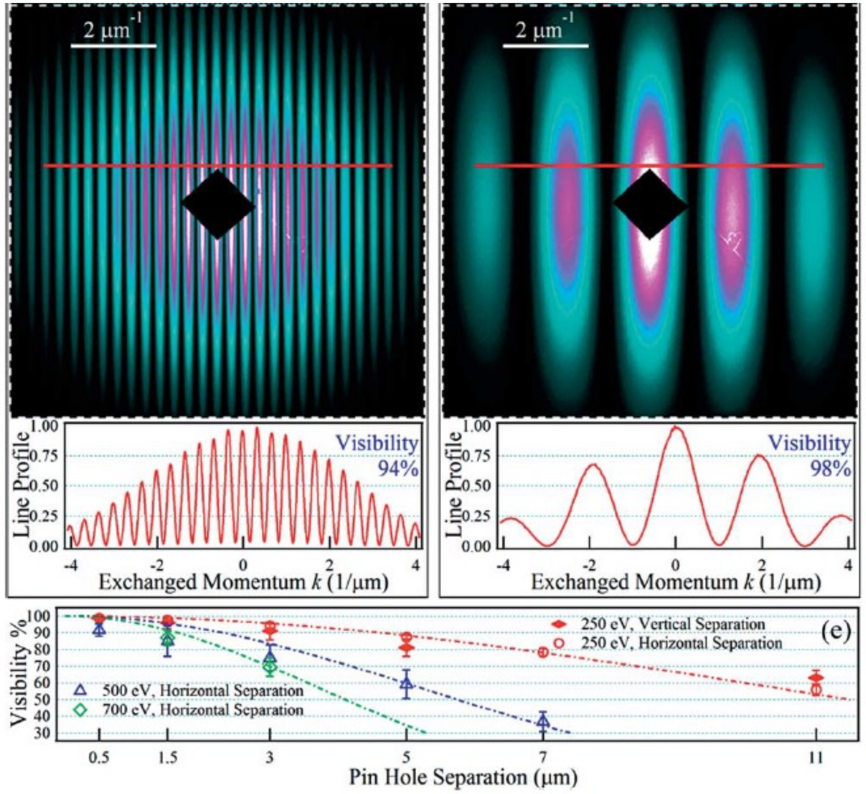
Figure 6 Spectroscopic analysis of the WE/electrolyte interface highlights the spatially resolved Mn species. (a) Absorption image acquired at 636 eV (below the Mn L absorption edge) for a sub-region of the WE electrode. (b) The same area where the distribution of the Mn^{2+} and Mn^{4+} states are indicated by red and green, overlapping the absorption contrast dominated by Mn species. The results are based on scans at 18 different energies, ranging from 636 to 647 eV. (c) and (d) show the same information as (b) over a larger electrode area. (e) shows the average absorption spectra for the region where the Mn^{2+} state dominated (green plot) compared with that where Mn^{4+} state dominated (red plot), and (f) shows the average absorption spectrum collected over the entire area shown in (a).

Kourousias G, Bozzini B, **Gianoncelli A**, Jones MWM, Junker M, van Riessen G, **Kiskinova M**
Shedding light on electrodeposition dynamics tracked in situ via soft X-ray coherent diffraction imaging
Nano Research, Vol. 9 - 7, pp. 2046-2056 (2016)

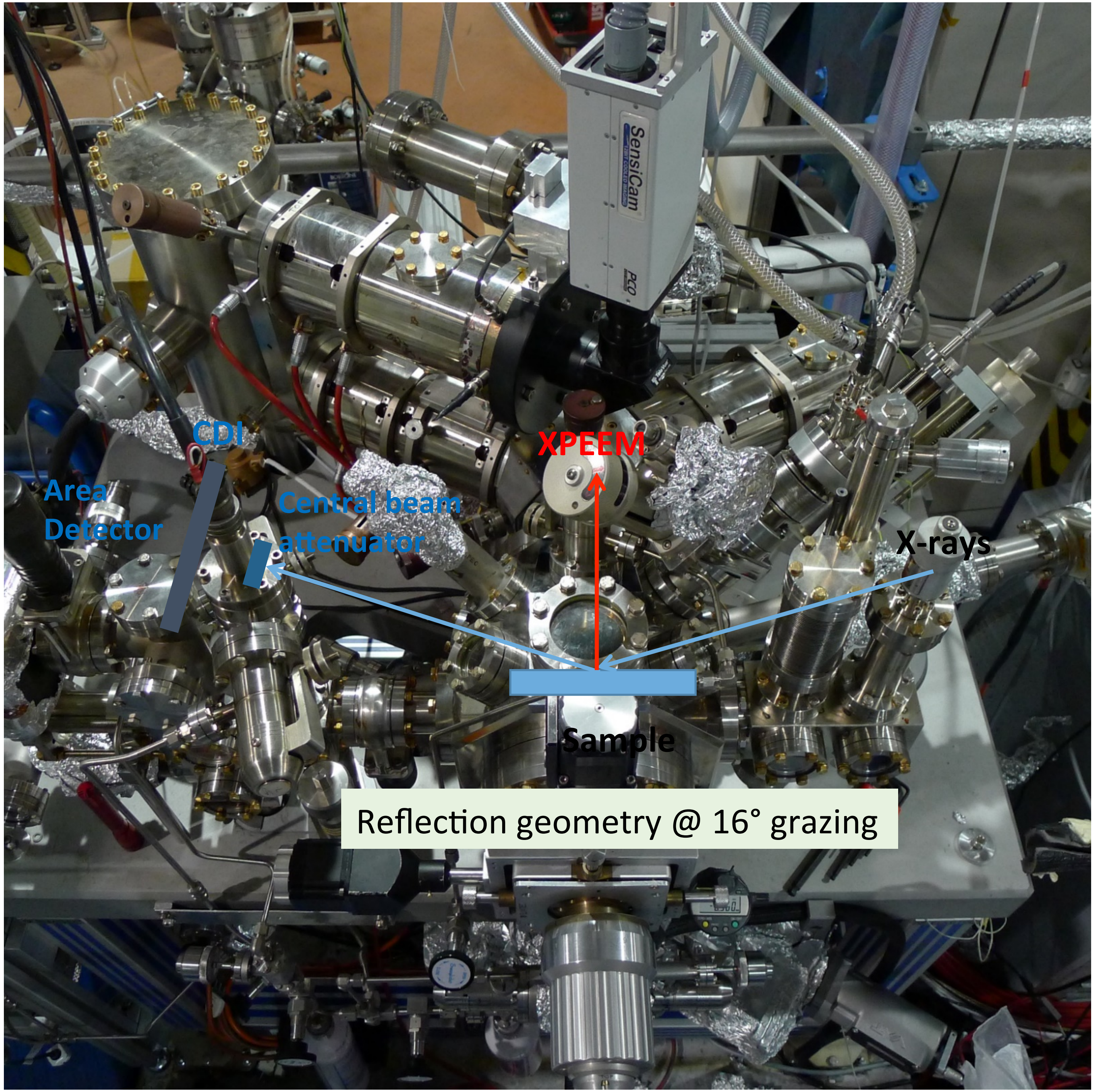
Implement CDI @ Nanospectroscopy

DiPRoi @ Nanospectroscopy (now@FERMI!)

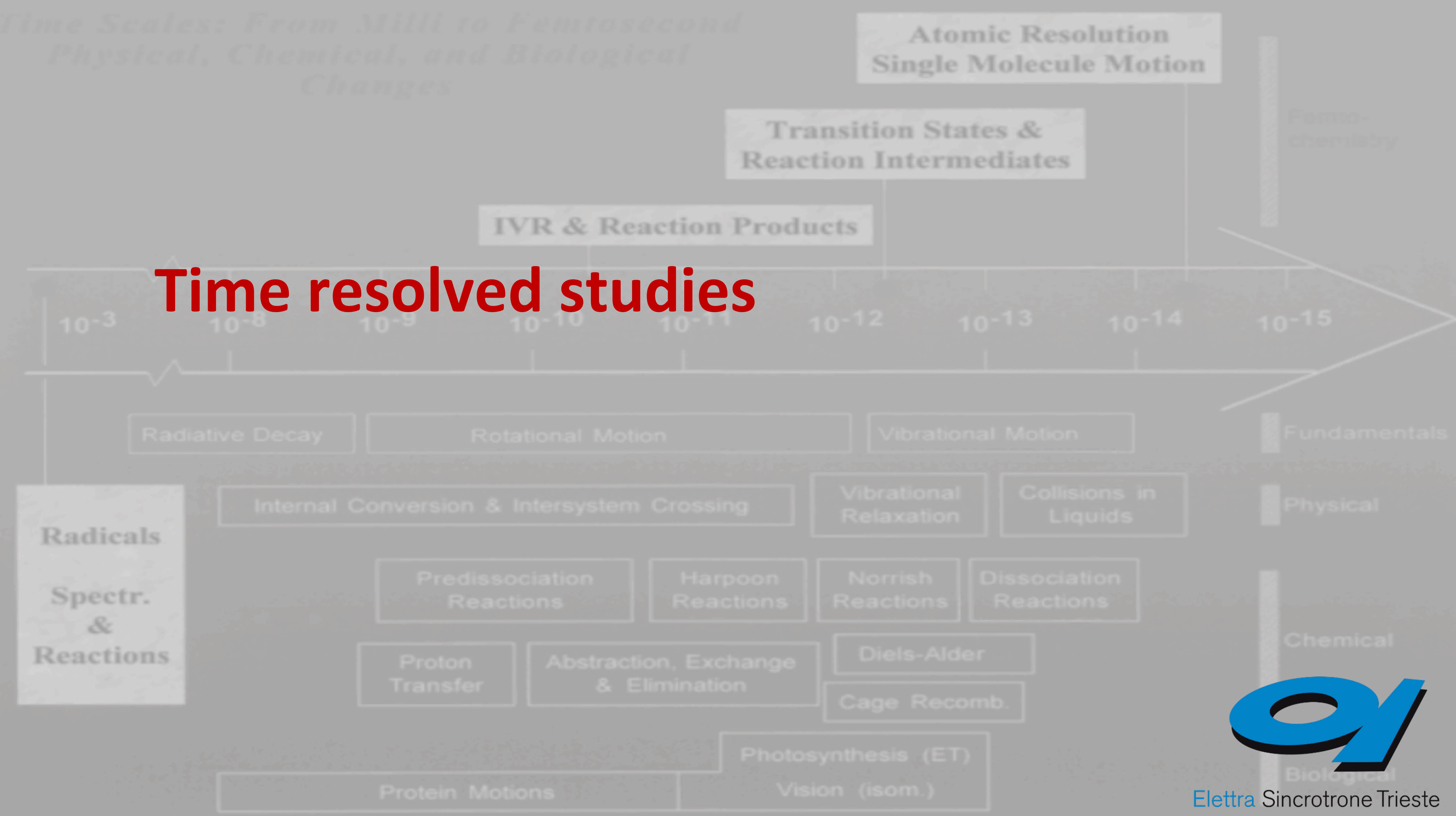
Pinhole separation **3 µm** Pinhole separation **0.5 µm**



E. Pedersoli et al. Rev. Sci. Inst. **82**, 043711 (2011)



Time resolved studies



X-Ray Photon Correlation Spectroscopy

Elettra Sincrotrone Trieste

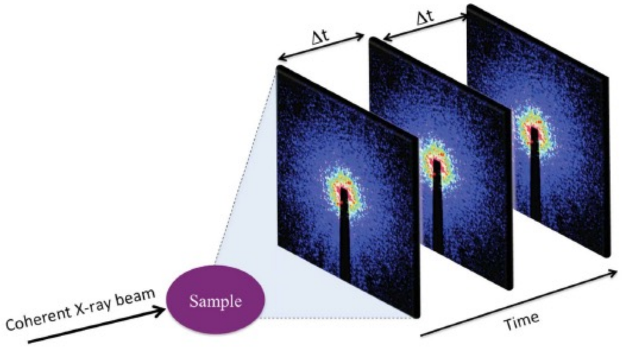


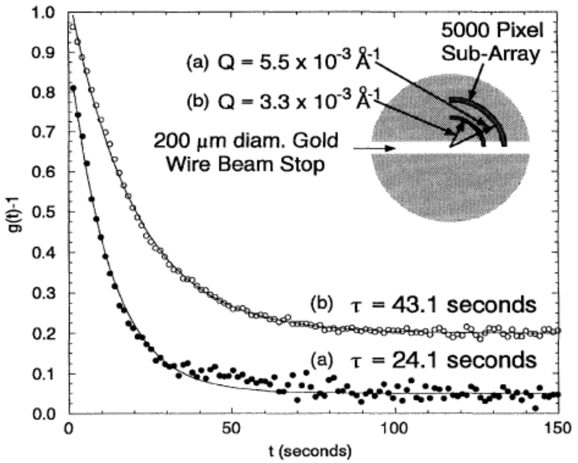
Figure 1
Schematic measurement procedure for XPCS measurements.

J. Synchrotron Rad. (2014). **21**, 1057–1064 O. G. Shpyrko

VOLUME 75, NUMBER 3 PHYSICAL REVIEW LETTERS 17 JULY 1995

X-Ray Photon Correlation Spectroscopy Study of Brownian Motion of Gold Colloids in Glycerol

S. B. Dierker,[1] R. Pindak,[2] R. M. Fleming,[2] I. K. Robinson,[3] and L. Berman[4]

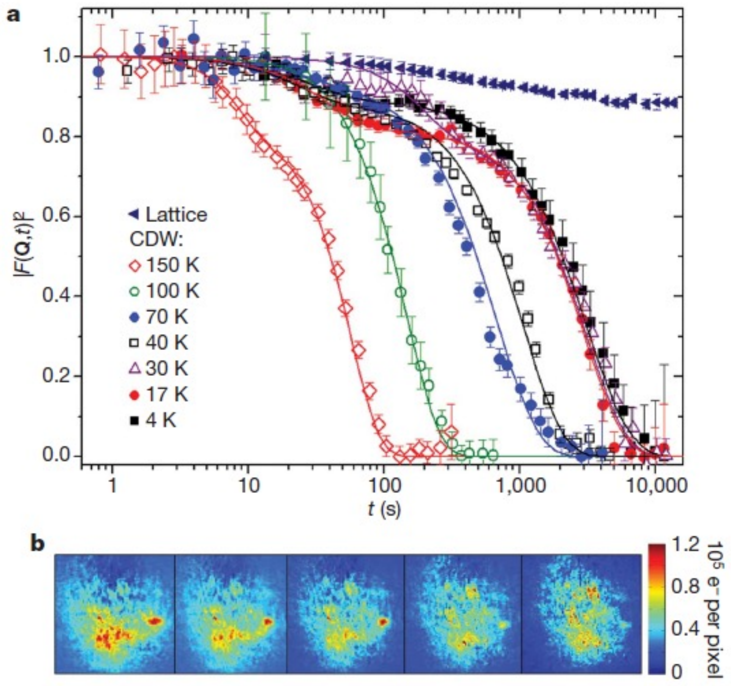


NSLS, 8 keV, X25 Wiggler Beamline

NATURE | Vol 447 | 3 May 2007

Direct measurement of antiferromagnetic domain fluctuations

O. G. Shpyrko[1], E. D. Isaacs[1,3], J. M. Logan[3], Yejun Feng[3], G. Aeppli[4], R. Jaramillo[3], H. C. Kim[3], T. F. Rosenbaum[3], P. Zschack[2], M. Sprung[2], S. Narayanan[2] & A. R. Sandy[2]



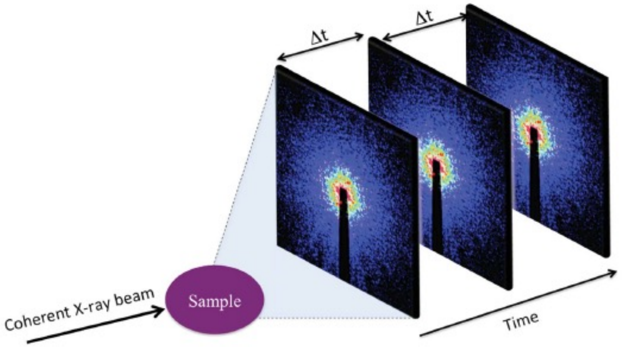
APS, 7.35 keV, Cr(111)

- Current time scale ≈ **msec**
- For given S/N, $\tau \propto (I_{coh})^{-2}$

PHANGS Photons at the Next Generation Synchrotron Facilities: from Production to Delivery

X-Ray Photon Correlation Spectroscopy

Elettra Sincrotrone Trieste



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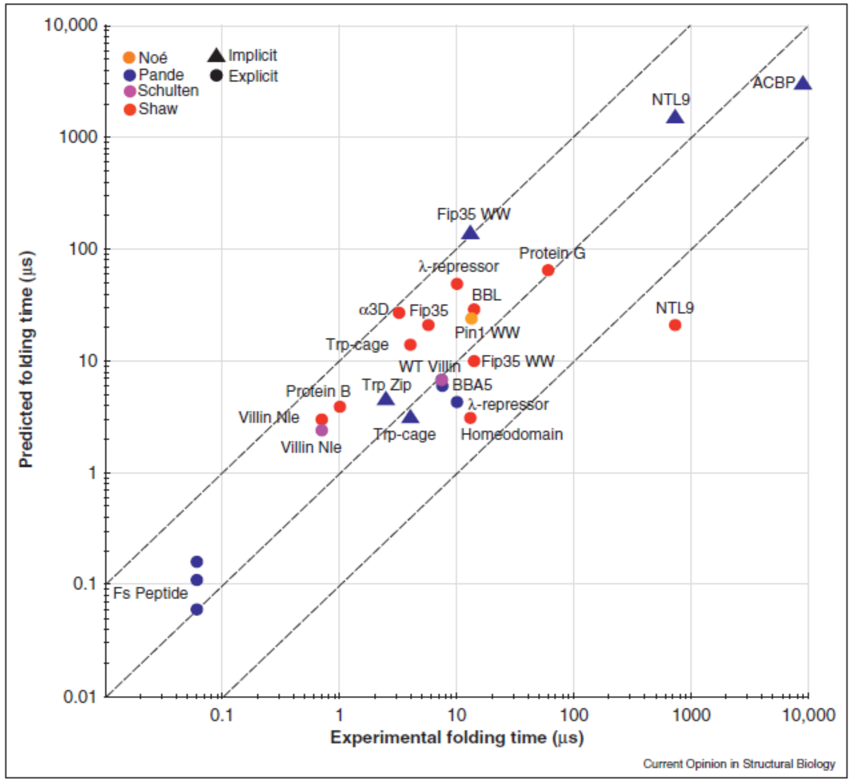
- For given S/N, $\tau \propto (I_{coh})^{-2}$

Available online at www.sciencedirect.com
SciVerse ScienceDirect
ELSEVIER
Current Opinion in Structural Biology

To milliseconds and beyond: challenges in the simulation of protein folding

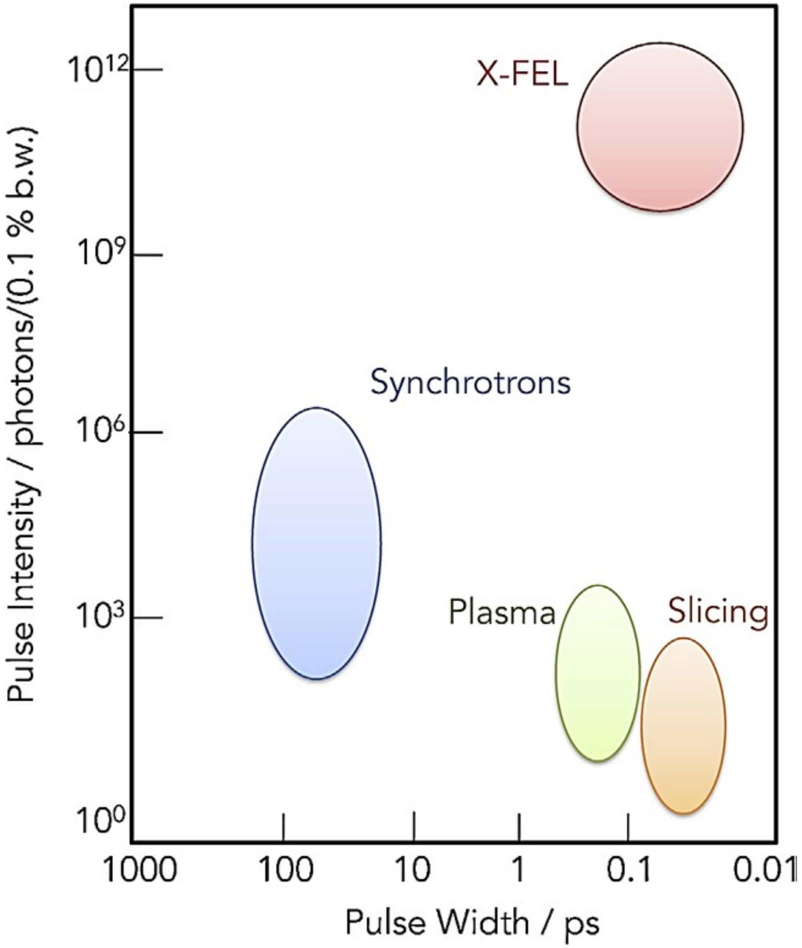
Thomas J Lane[1], Diwakar Shukla[1,2], Kyle A Beauchamp[3] and Vijay S Pande[1,3,4]



Current Opinion in Structural Biology 2013, 23:58–65

The entire time scale spanning **ps** to **ms**.

Temporal resolution



Schemes for the generation of stable short x-ray pulses in 3rd generation SRLS.

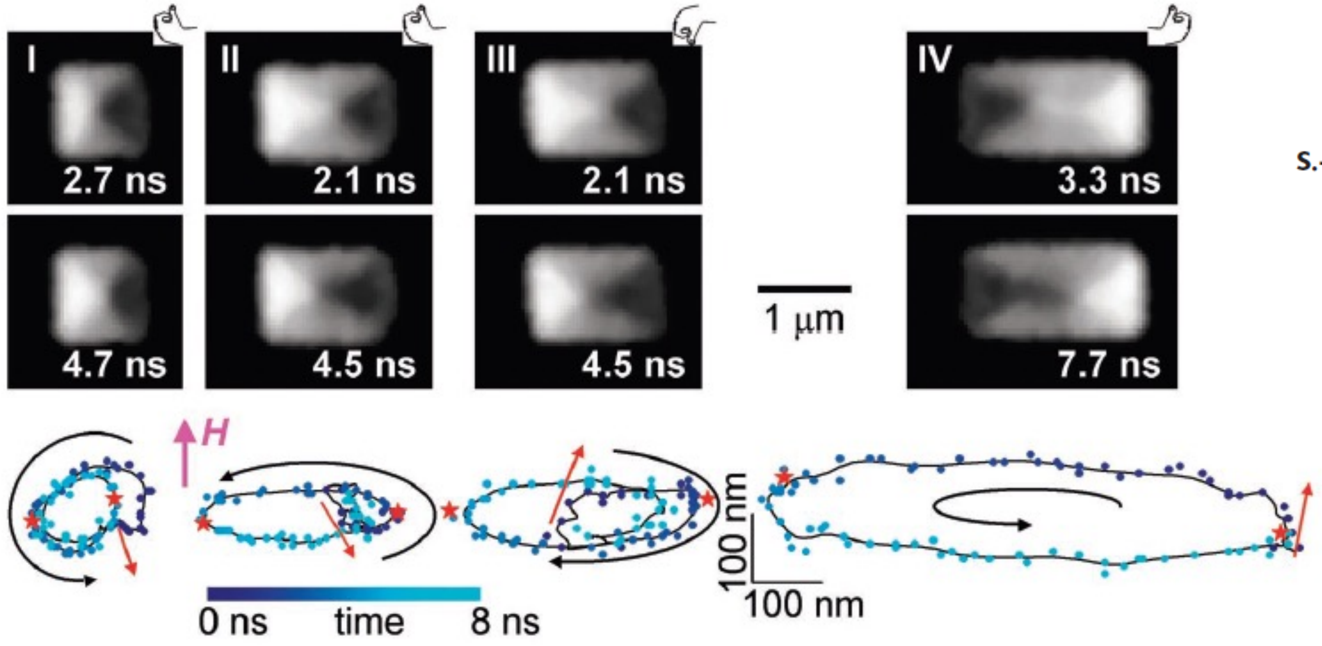
	Min pulse duration (FWHM) [ps]	Intensity relative to SUM	Rep. Rate [MHz]	Layout invasive	Compatible with SUM	Compatible with DLO
Low-alpha	~2	~10^{-2}	< 500	No	No	No
Voltage beating	**~1**	**~10^{-2}–10^{-1}**	**< 500**	**Yes**	**Yes**	**Maybe***
Deflecting cavity	**~1**	**~10^{-5}–10^{-1}**	**< 500**	**Yes**	**Yes**	**Unlikely**
Femto-slicing	~0.1	~10^{-8}–10^{-6}	~0.1	Yes	Yes	Unlikely

* for SRLS at beam energies lower than ~3 GeV.

Time resolved studies

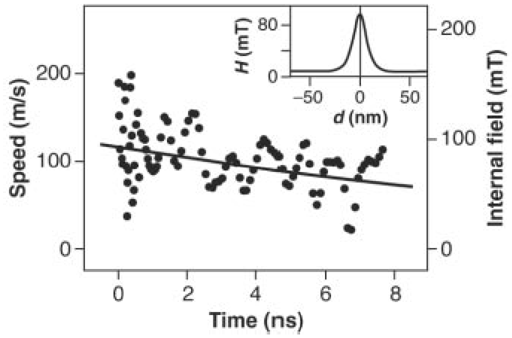
nanosecond	picosecond	femtosecond

Magnetization dynamics **Lattice dynamics** **Electron dynamics**



Vortex Core–Driven Magnetization Dynamics

S.-B. Choe,[1*] Y. Acremann,[2] A. Scholl,[1] A. Bauer,[1,2,3] A. Doran,[1] J. Stöhr,[2] H. A. Padmore[1]



SCIENCE VOL 304 16 APRIL 2004

ALS, XMCD-PEEM Co L edge, electrical pump pulse **300 ps**, photon pulse **70 ps,** CoFe on Cu waveguide

Time resolved studies

nanosecond	picosecond	femtosecond
Magnetization dynamics	Lattice dynamics	Electron dynamics

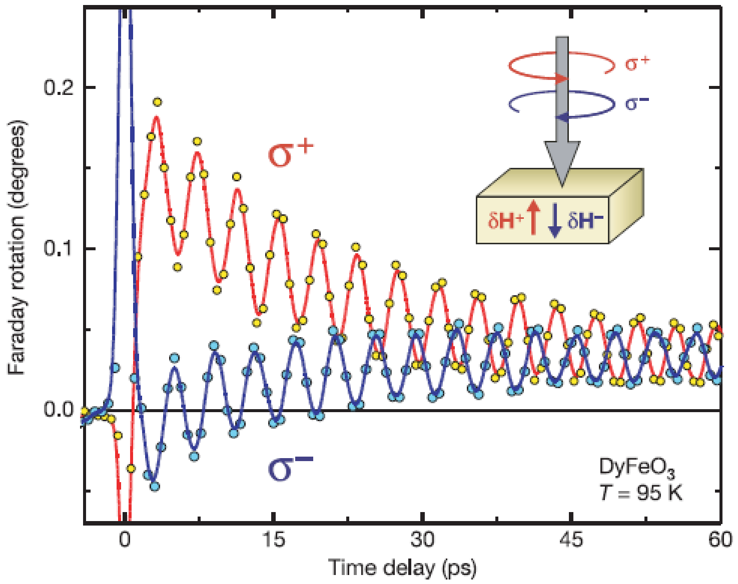


Figure 1 | Magnetic excitations in $DyFeO_3$ probed by the magneto-optical Faraday effect. Two processes can be distinguished: (1) instantaneous changes of the Faraday effect due to the photoexcitation of Fe ions and relaxation back to the high spin ground state $S = 5/2$; (2) oscillations of the Fe spins around their equilibrium direction with an approximately 5 ps period. The circularly polarized pumps of opposite helicities excite oscillations of opposite phase. Inset shows the geometry of the experiment. Vectors δH^+ and δH^- represent the effective magnetic fields induced by right-handed σ^+ and left-handed σ^- circularly polarized pumps, respectively.

Ultrafast non-thermal control of magnetization by instantaneous photomagnetic pulses

A. V. Kimel[1], A. Kirilyuk[1], P. A. Usachev[2], R. V. Pisarev[2], A. M. Balbashov[3] & Th. Rasing[1]

NATURE|Vol 435|2 June 2005

Laser pump (Circular Pol), **laser probe** (Linear Pol), pulse width **200 fs**

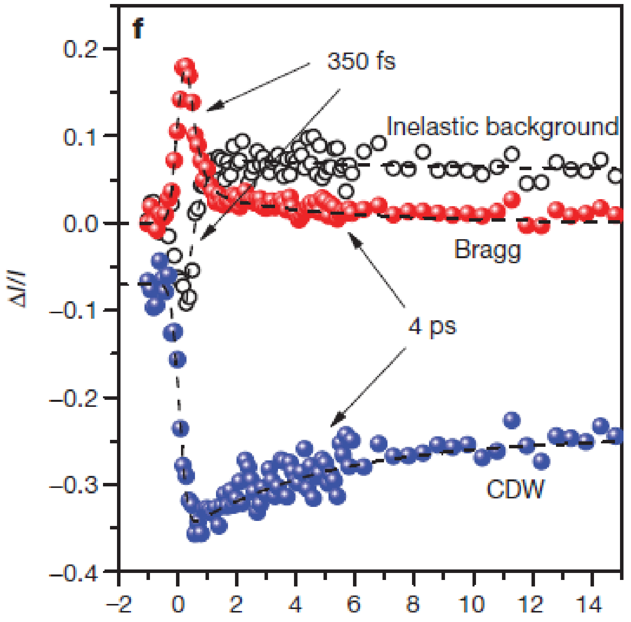
Time resolved studies

nanosecond	picosecond	femtosecond

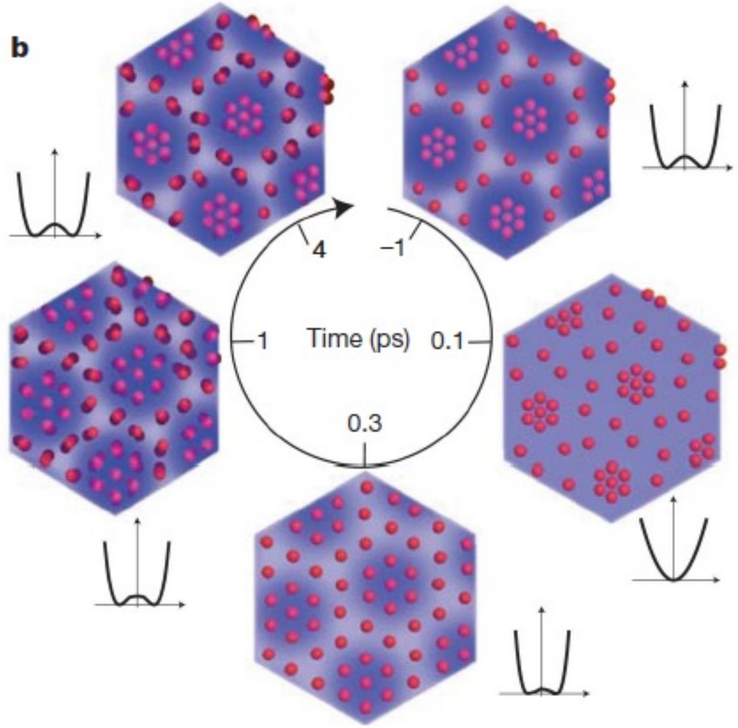
Magnetization dynamics

Lattice dynamics

Electron dynamics



time delay (ps)



Snapshots of cooperative atomic motions in the optical suppression of charge density waves

Maximilian Eichberger[1]*, Hanjo Schäfer[1]*, Marina Krumova[2], Markus Beyer[1], Jure Demsar[1,3], Helmuth Berger[4], Gustavo Moriena[5,6], Germán Sciaini[5,6]* & R. J. Dwayne Miller[5,6]

9 DECEMBER 2010 | VOL 468 | NATURE | 799

1T – TaS_2

Laser pump with pulse width 140 fs, **electron probe** at 50 keV pulse width **250 fs**

Summary

- **Coherence** is a keyword for the next generation synchrotrons including Elettra 2.0.
- **Time structure** of the new synchrotron may introduce new science at Elettra.
- **Dedicated endstation** development along with the upgrade to be considered.

Nanospectroscopy
Andrea Locatelli

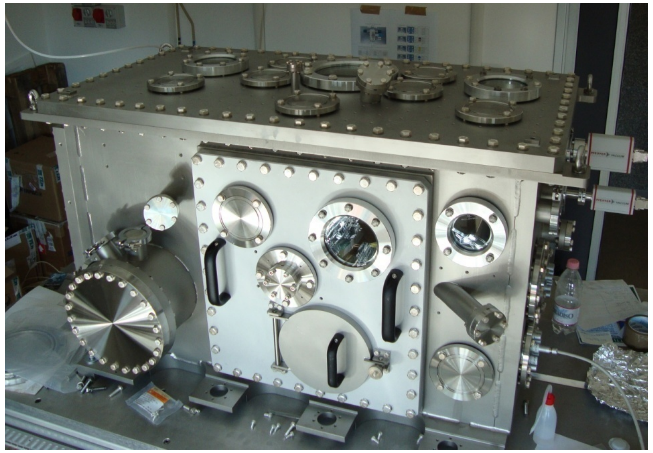
Elettra Optics group
Anna Bianco
Luca Rebuffi
Edoardo Busetto

Thanks for your attention

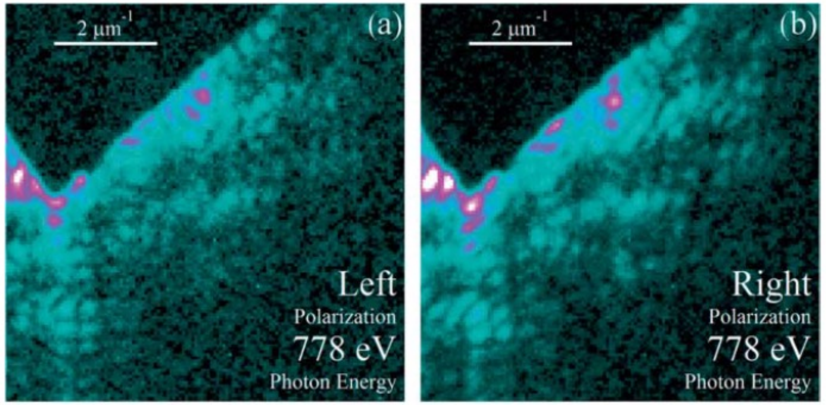
Coherent Diffraction Imaging @ Nanospectroscopy

Elettra Sincrotrone Trieste

DiPRoi @ FERMI, before FERMI

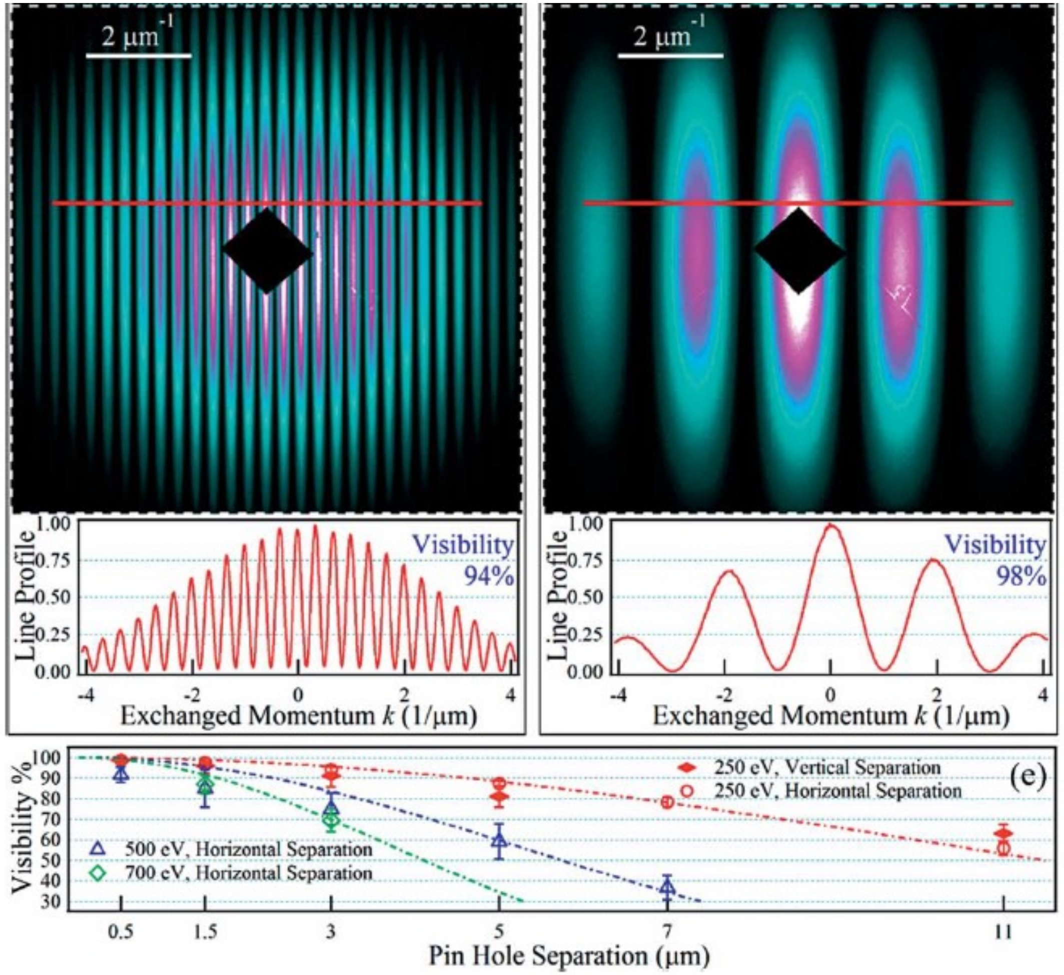


XMCD in CDI: Cobalt islands



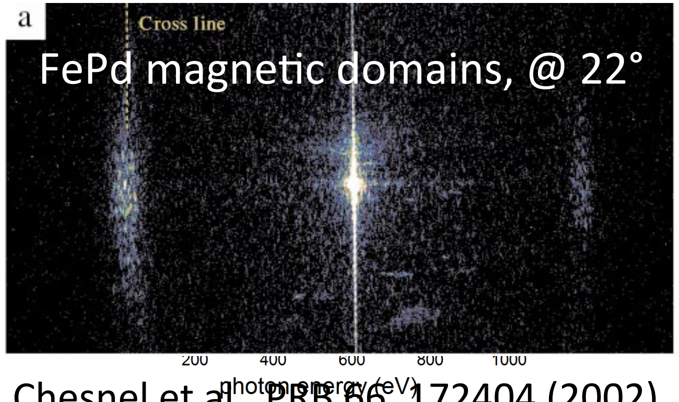
E. Pedersoli et al. Rev. Sci. Inst. **82**, 043711 (2011)

Pinhole separation **3 µm** | Pinhole separation **0.5 µm**



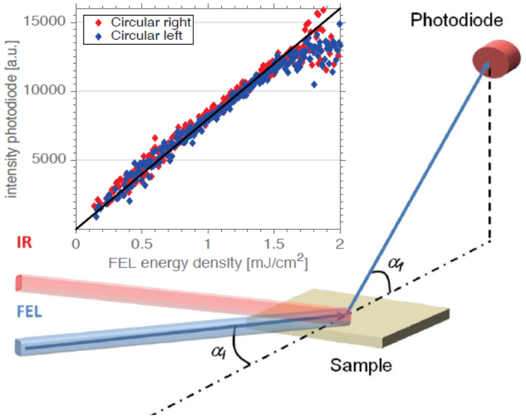
Implement CDI @ Nanospectroscopy

Reflection geometry @ 16° grazing

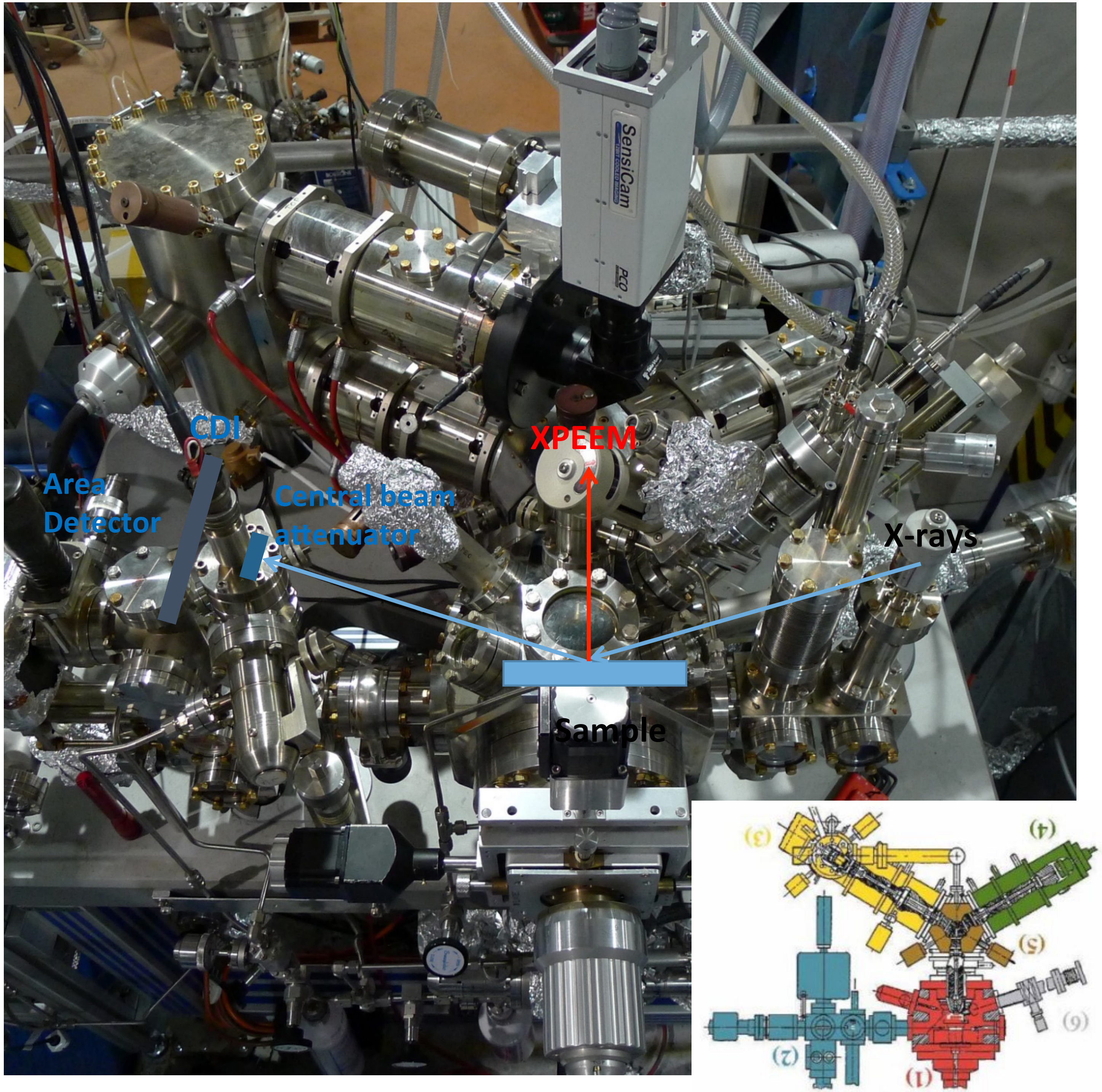


Chesnel et al., PRB 66, 172404 (2002)

Experience from DiPRoi @ FERMI



C. Gutt et al., to be published.



Improvement in numbers

Now **Elettra 2.0**

- **Reduced size of the e-beam in the ring**
  - σ_x from **253 µm** to **55 µm** (gain 4.6)
  - σ_y from **18 µm** to **3 µm** (gain 6)
  - $\sigma_{x'}$ from **29 µrad** to **5 µrad** (gain 6)
  - $\sigma_{y'}$ from **5 µrad** to **1 µrad** (gain 5)

  Long straight section

- **Contraction of the volume occupied by the radiation cone**
  - Σ_x from **253 µm** to **56.8 µm** (gain 4.5)
  - Σ_y from **22.3 µm** to **12.8 µm** (gain 1.7)
  - $\Sigma_{x'}$ from **35.5 µrad** to **21 µrad** (gain 1.7)
  - $\Sigma_{y'}$ from **21.5 µrad** to **20.6 µrad** (gain 1.0)

  EU10, Horiz. Pol, 400 eV on axis

- **Increased brilliance**
  - From $2.1 \cdot 10^{18}$ to $3.7 \cdot 10^{19}$ ph s^{-1} mm^{-2} $mrad^{-2}$ 0.1%BW (gain 18)

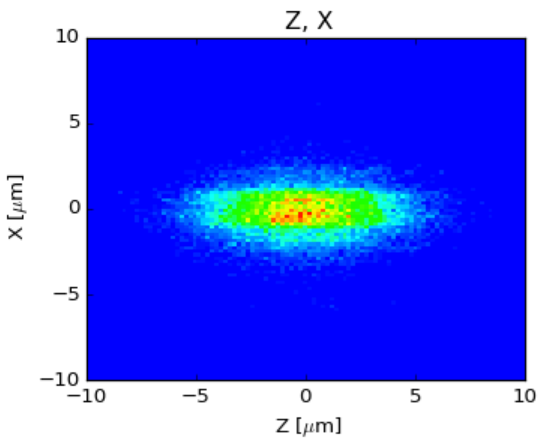
Calculations by: Anna Bianco, Elettra Optics Group

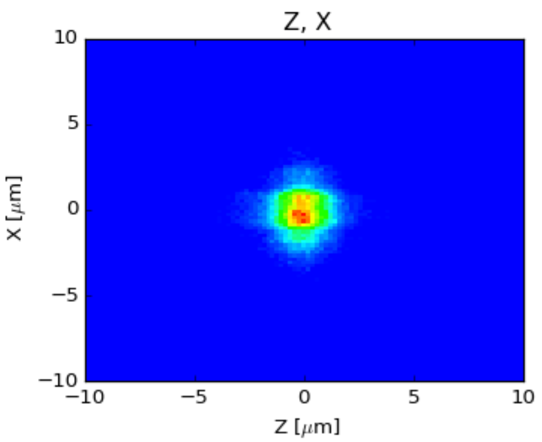
Improvement in numbers

- **Increase of the spectral photon flux through the beam defining aperture**
  - From $1.9 \cdot 10^{14}$ to $4.7 \cdot 10^{14}$ ph s^{-1} mm^{-2} $mrad^{-2}$ 0.1%BW (gain 2.5)

(with present settings of the aperture: 56 µrad x 63 µrad, 400 eV)

- **decrease of beam-spot size**
  - Calculated beam spot size from 6.2 µm x 2.0 µm to 1.6 µm x 2.0 µm





Calculations by: Anna Bianco, Elettra Optics Group

Time resolved studies

nanosecond	picosecond	femtosecond
Spin dynamics	Lattice dynamics	Electron dynamics