The Canadian Light Source

Tom Ellis

CLS Director of Research

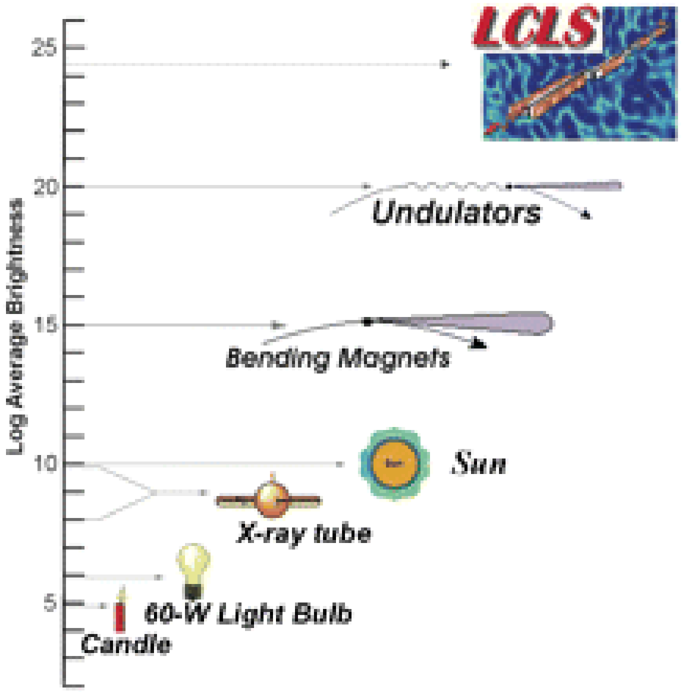
thomas.ellis@lightsource.ca

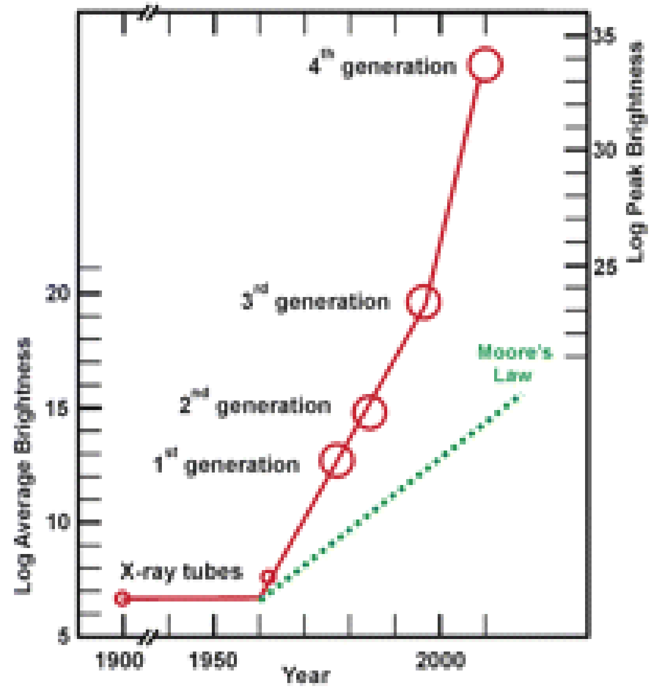
Surface Canada May 2013

A Brief History of Synchrotron Radiation Sources

Canadian Light Source
Centre canadien de rayonnement synchrotron

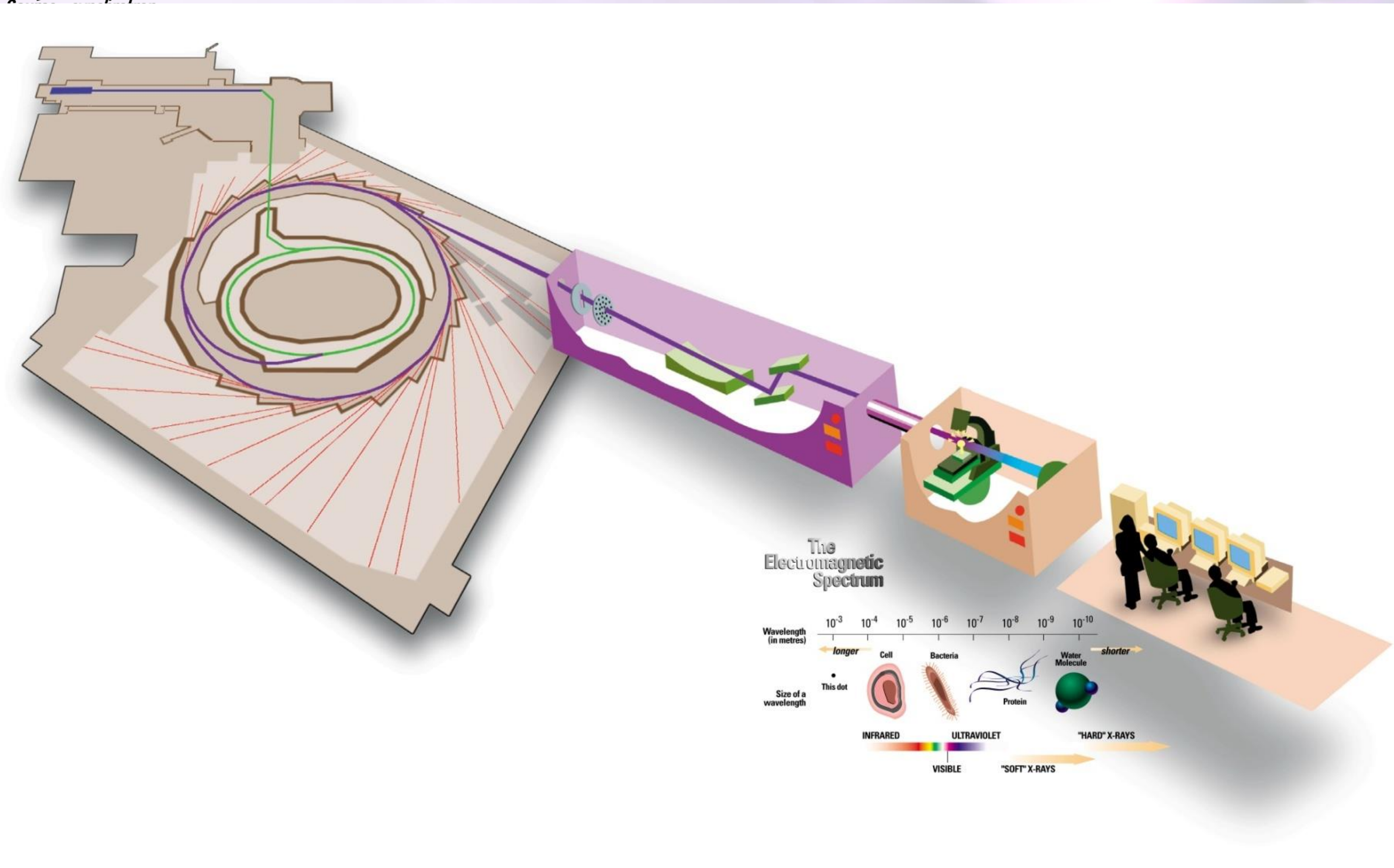
X-ray Brightness





Parise and Brown (2006)

How a synchrotron works



CLS Timeline

- **September 27, 1999** – Groundbreaking ceremony
- **February 26, 2001** – Building dedication ceremony
- **September 18, 2002** – Booster ring commissioning complete
- **December 9, 2003** – First synchrotron light detected
- **October 22, 2004** – Official opening
- **May 27, 2005** – First CLS user
- **June 30, 2005** – Official completion of the CFI project

Capital Investment to Date

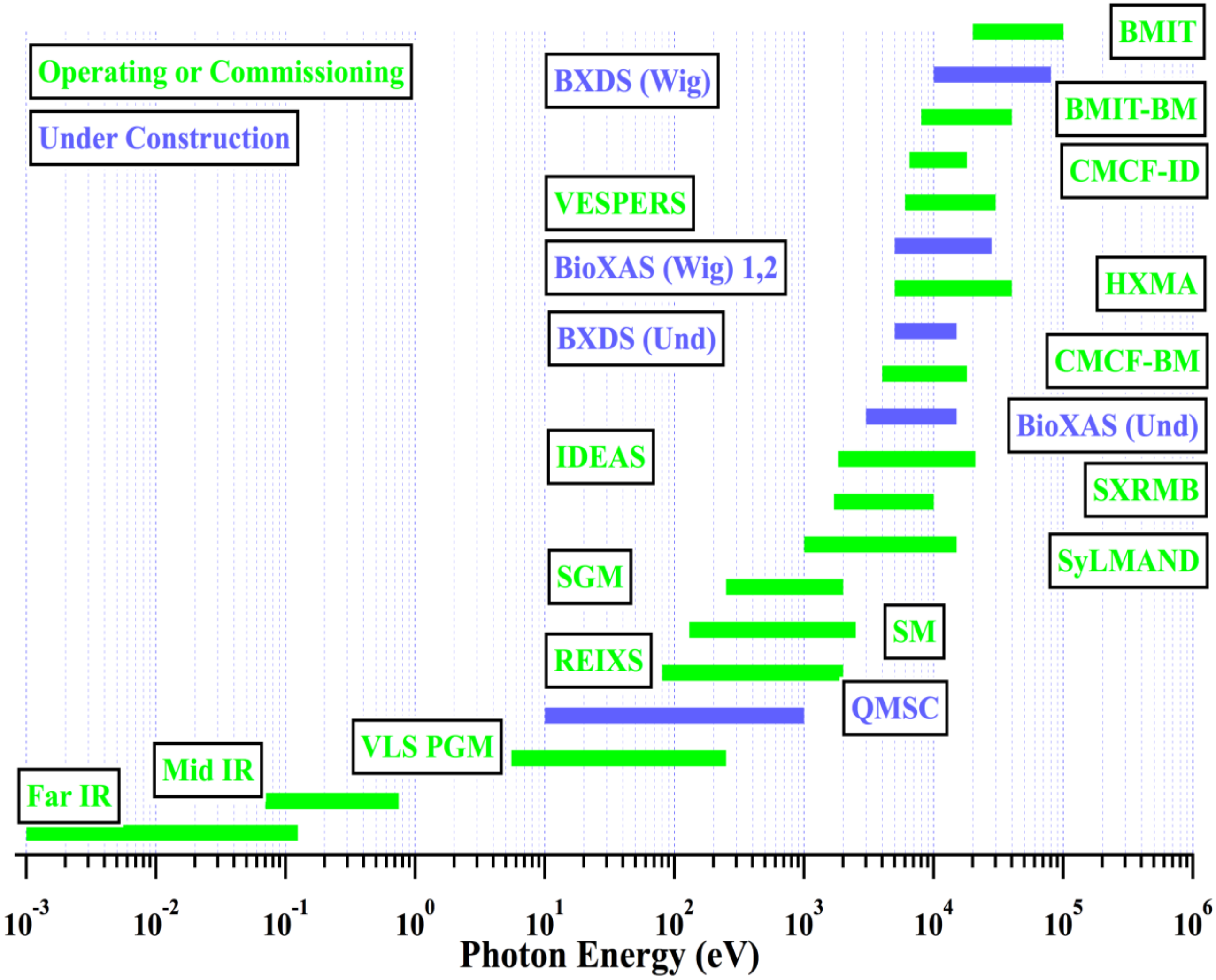
- Original Construction (7 beamlines) $141M
- Phase II (7 beamlines) 52M
- Phase III (7 beamlines & upgrade) 68M
- Isotopes Project 12M

CLS Features

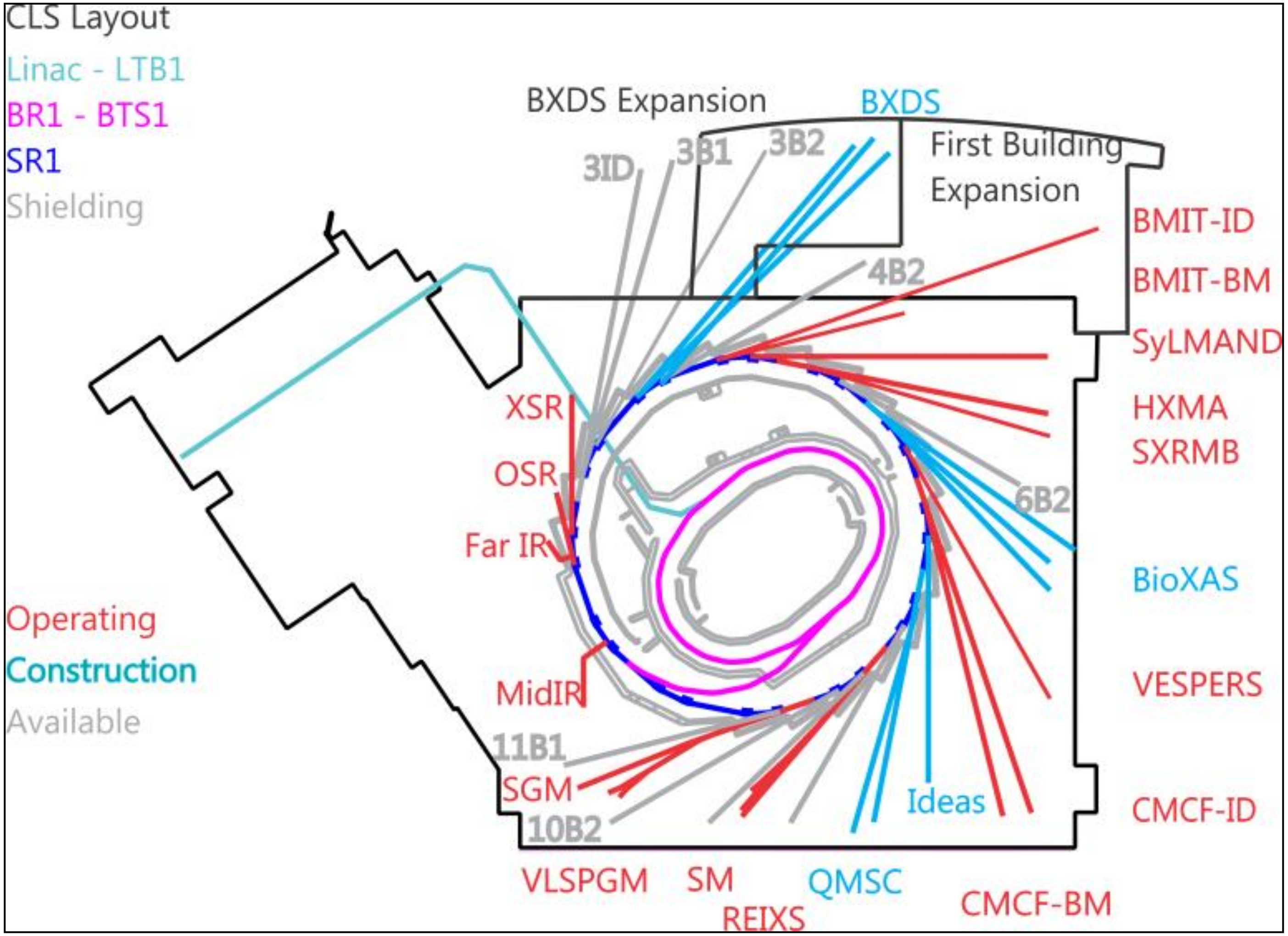
- Canada's national synchrotron facility
- One of the world's first ~3 GeV synchrotrons
  - Superconducting RF cavity
  - Canted insertion devices
  - Hard X-rays from superconducting wigglers
- Full spectrum of photon energies for spectroscopy (THz to hard X-rays)
- Other highlights: STXM, medical imaging, soft X-ray REIXS, soil science and mining applications


Western
The University of Western Ontario
Boehringer Ingelheim
SaskPower

Energy Range

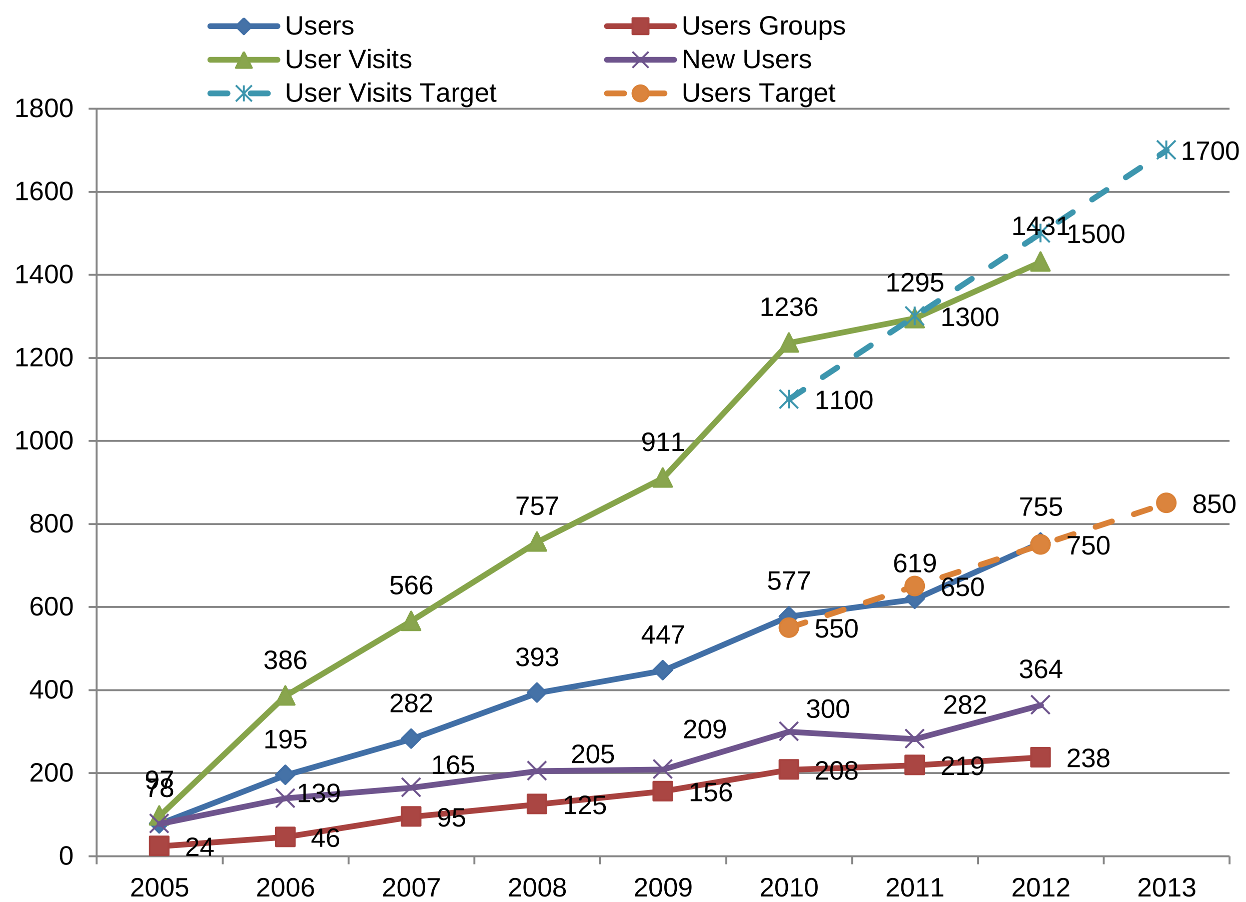


CLS Layout



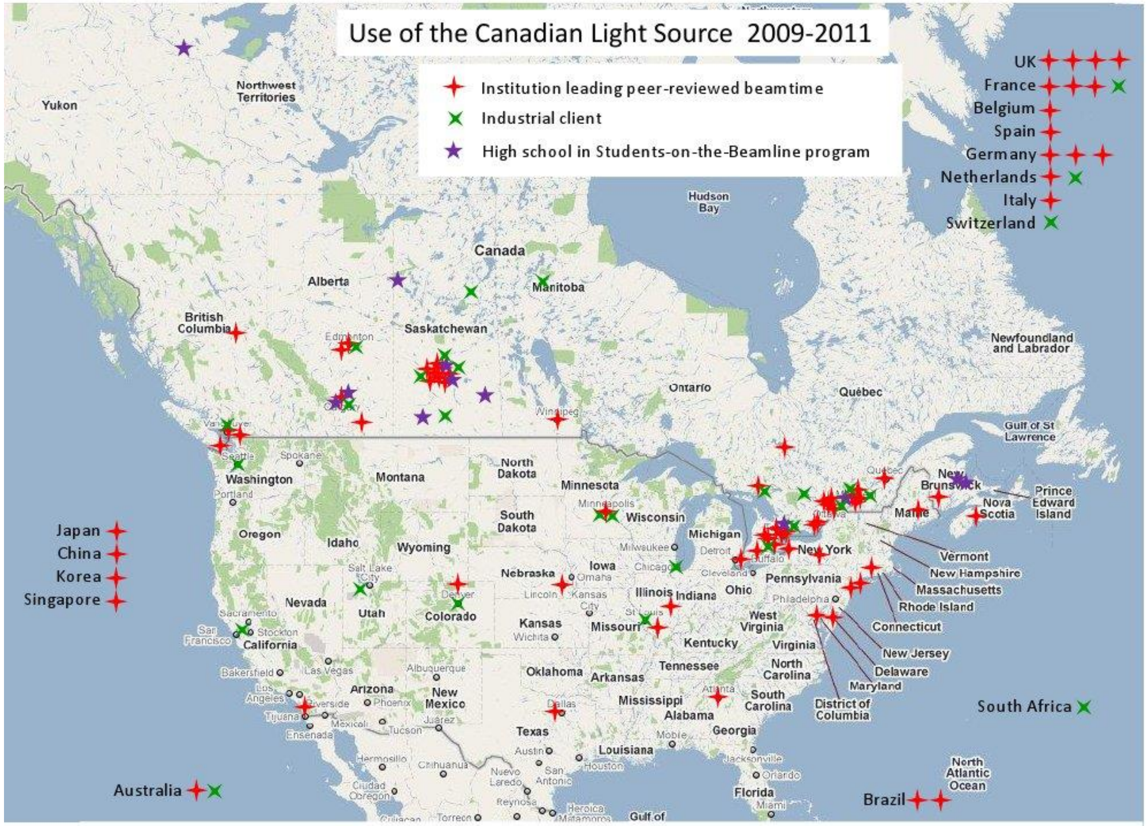
CLS Layout
Linac - LTB1
BR1 - BTS1
SR1
Shielding
BXDS Expansion
BXDS
First Building
Expansion
3ID
3B1
3B2
4B2
BMIT-ID
BMIT-BM
SyLMAND
HXMA
SXRMB
6B2
BioXAS
VESPERS
CMCF-ID
CMCF-BM
Ideas
QMSC
REIXS
SM
VLSPGM
10B2
SGM
11B1
MidIR
Far IR
OSR
XSR
Operating
Construction
Available

Users and User Visits



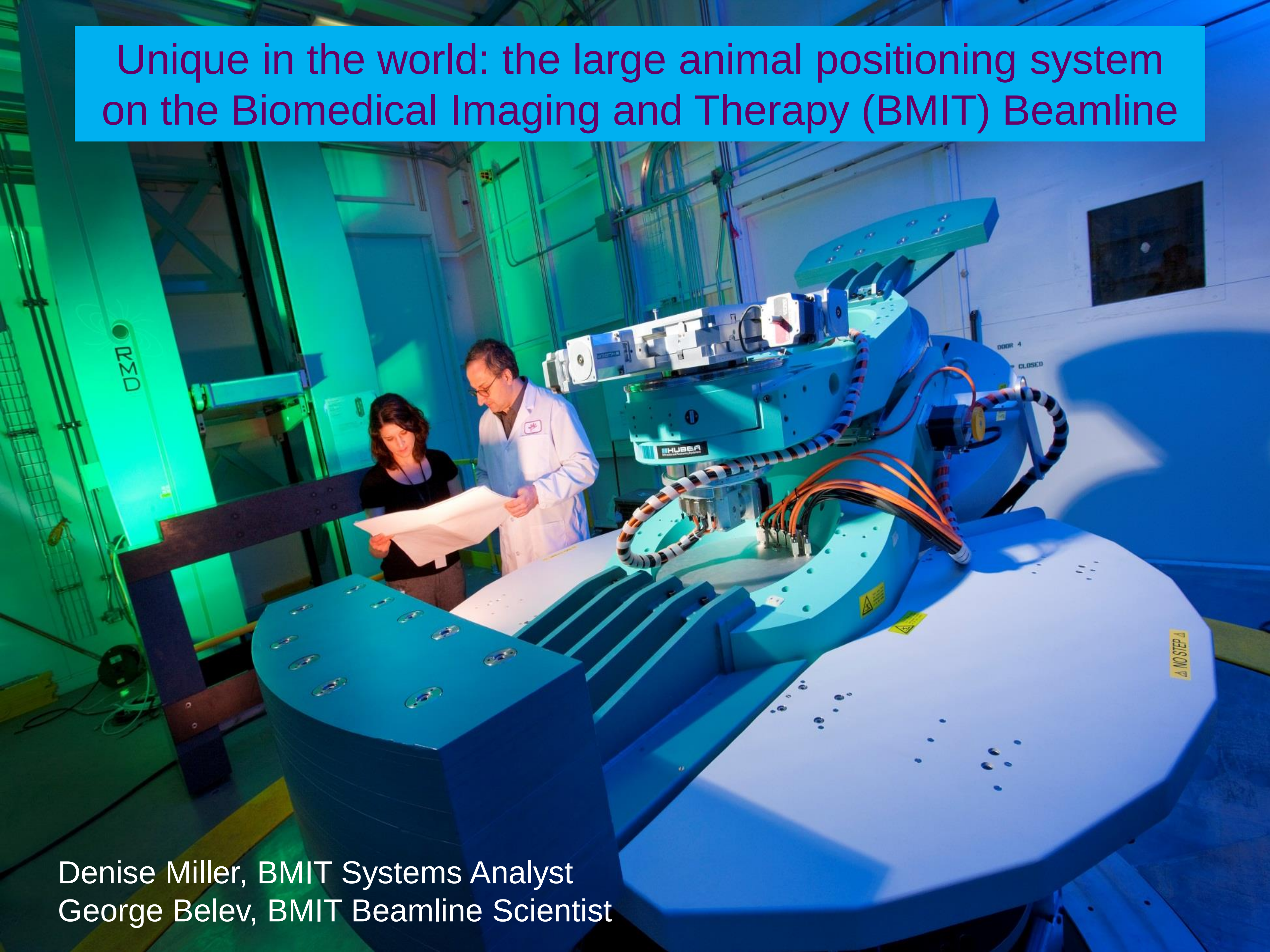
Prepared by Lavina Carter

The nature of our user base



Geographic distribution of shifts	2008	2009	2010
Canada – SK	560 (46%)	590 (35%)	716 (30%)
Canada – other provinces	554 (45%)	828 (49%)	1233 (52%)
International	114 (9%)	275 (16%)	406 (17%)

Unique in the world: the large animal positioning system on the Biomedical Imaging and Therapy (BMIT) Beamline



Denise Miller, BMIT Systems Analyst
George Belev, BMIT Beamline Scientist

Call for Proposals

Canadian Light Source | Centre canadien de rayonnement synchrotron

A call for proposals is issued twice per year for experimental beam time

Call Open	Proposal Deadline	Review Date (Safety, Technical, Peer Review)	Peer Review Meeting (week of)	Results Announced (week of)	Scheduling Period Begins	Scheduling Period Ends	Cycle
Jan.30/13	Feb.27/13	Apr. 8/13	Apr.29/13	May 13/13	July 1/13	Dec. 31/13	18
Aug.1/12	Sept.5/12	Oct.15/12	Nov. 5/12	Nov.19/12	Jan. 1/13	June 30/13	17

Submit a Proposal:

Step 1: Contact the appropriate CLSI beamline scientist to discuss your research.

Step 2: Logon to https://user.lightsource.ca.

If you have not previously registered you will be required to register and you will receive a username prior to submitting a proposal.

Peer Review

Evaluation Criteria

Each proposal is reviewed and scored by at least three external reviewers and at least one member of the Peer Review Committee. Reviewers are asked to provide an integer score in each of the three Evaluation Criteria, as described below

Quality of scientific research in the context of the field

Does the proposal describe what is to be studied and the importance of it? What hypothesis would be tested, how will the results impact the field, and what is the likelihood of success?

Suitability of CLS resources being allocated relative to the proposed research

Is this a good use of CLS resources? Does the experiment require the resources being requested? Reviewers are also asked to comment on the appropriateness of the number of shifts that have been requested.

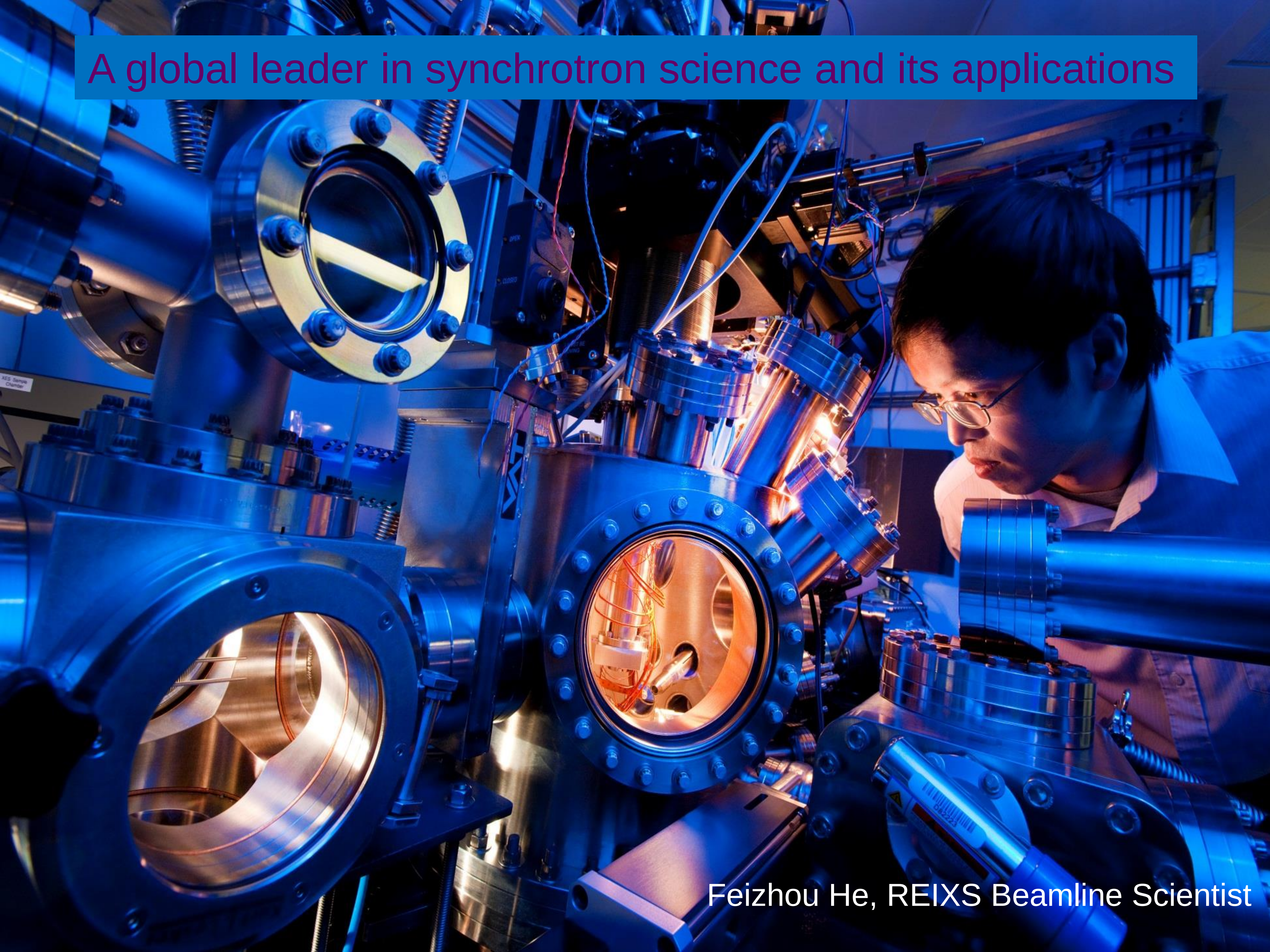
Quality and capability of the researchers based on their track record

Does the research team have recent synchrotron and/or other relevant experience? If they are a past user they should have clearly demonstrated their track record and productivity in the proposal.

Peer Review Access

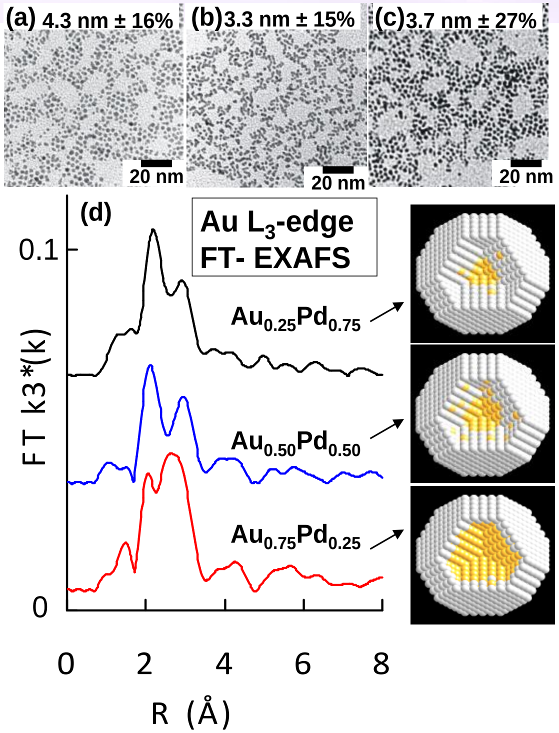
	2009	2010	2011
Number of shifts requested	1768	2675	3456
Number of shifts allocated	1252	1816	2203
Oversubscription	41%	47%	57%

A global leader in synchrotron science and its applications



Feizhou He, REIXS Beamline Scientist

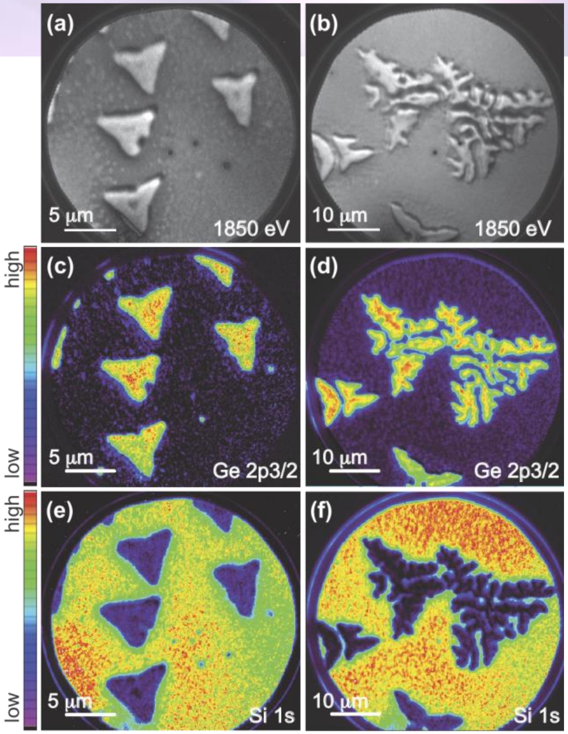
Nanoscience



The local structure of Au-Pd nanoparticles capped with mixed amine and bromide ligands: An EXAFS Study

F. Liu and P. Zhang

Department of Chemistry, Dalhousie University



Si/Ge Intermixing in Very Large Ge Islands on Si(111)

J. M. MacLeod (1, 2), J. A. Lipton-Duffin (1, 2), F. Rosei (1)

(1) INRS-EMT, Université du Québec, 1650 Boul. Lionel Boulet J3X 1S2 Varennes (QC), Canada

(2) Current address: Dipartimento di Fisica, Università degli Studi di Trieste, Trieste (TS), Italy

Nanoscale Chemical Imaging of the Reduction Behaviour of a Single Catalyst Particle

E. de Smit (1), I. Swart (1), J. F. Creemer (2), C. Karunakaran (3), D. Bertwistle (3), H. W. Zandbergen (2), B.M. Weckhuysen (1) and F. M. F. de Groot (1)

(1) Utrecht University, The Netherlands

(2) Delft University of Technology, The Netherlands

(3) Canadian Light Source, Inc.

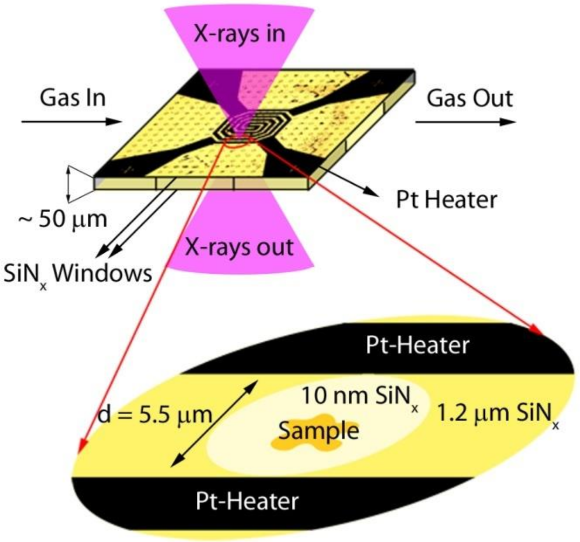


Figure 1: Description and relevant dimensions of the nanoreactor chamber.

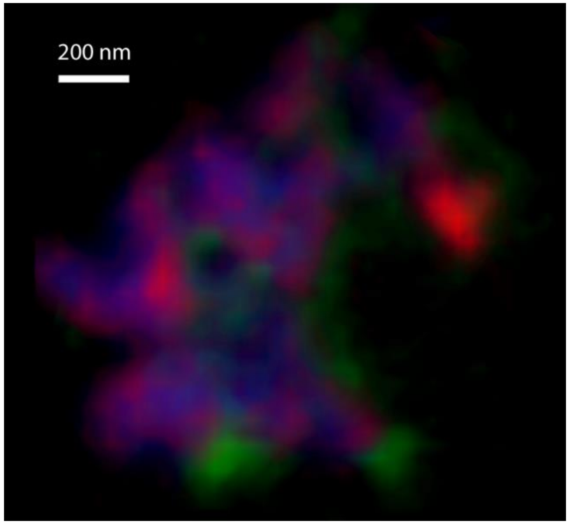
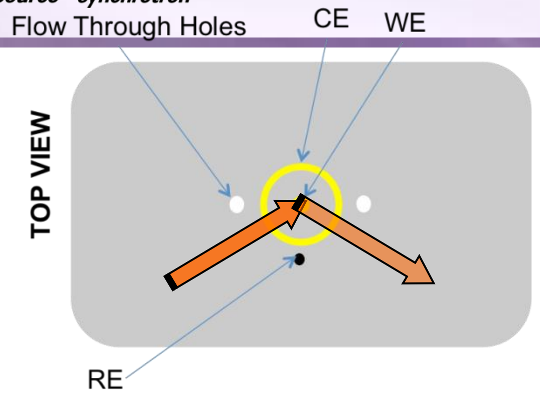
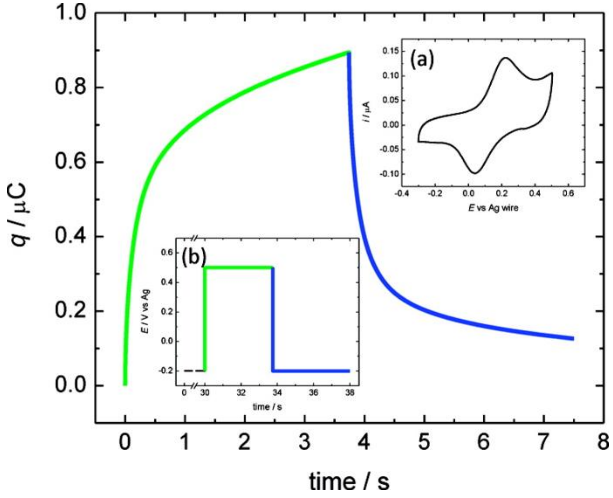
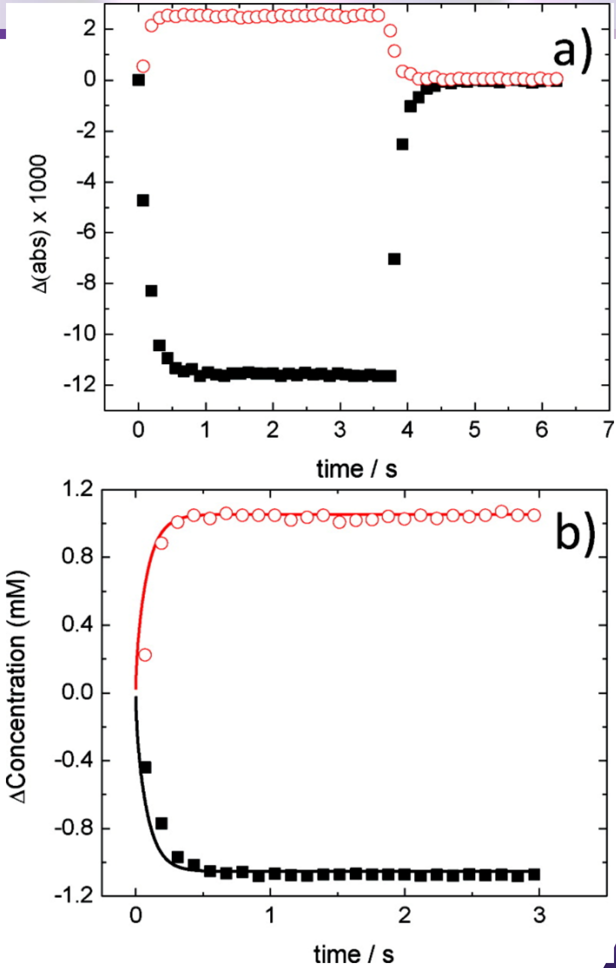


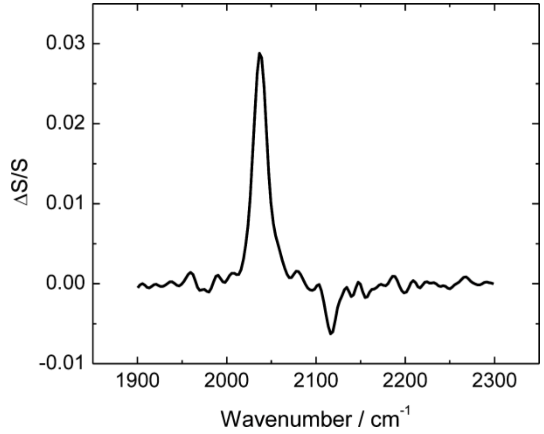
Figure 2: Chemical species contour map showing the distribution of Fe-species of different valence after treatment at 250°C in H_2. Blue: mixed $Fe^{2+/3+}$ (Fe_3O_4), green: pure Fe^{2+}, red: Fe^0.

Electrochemical external reflection IR spectroscopy



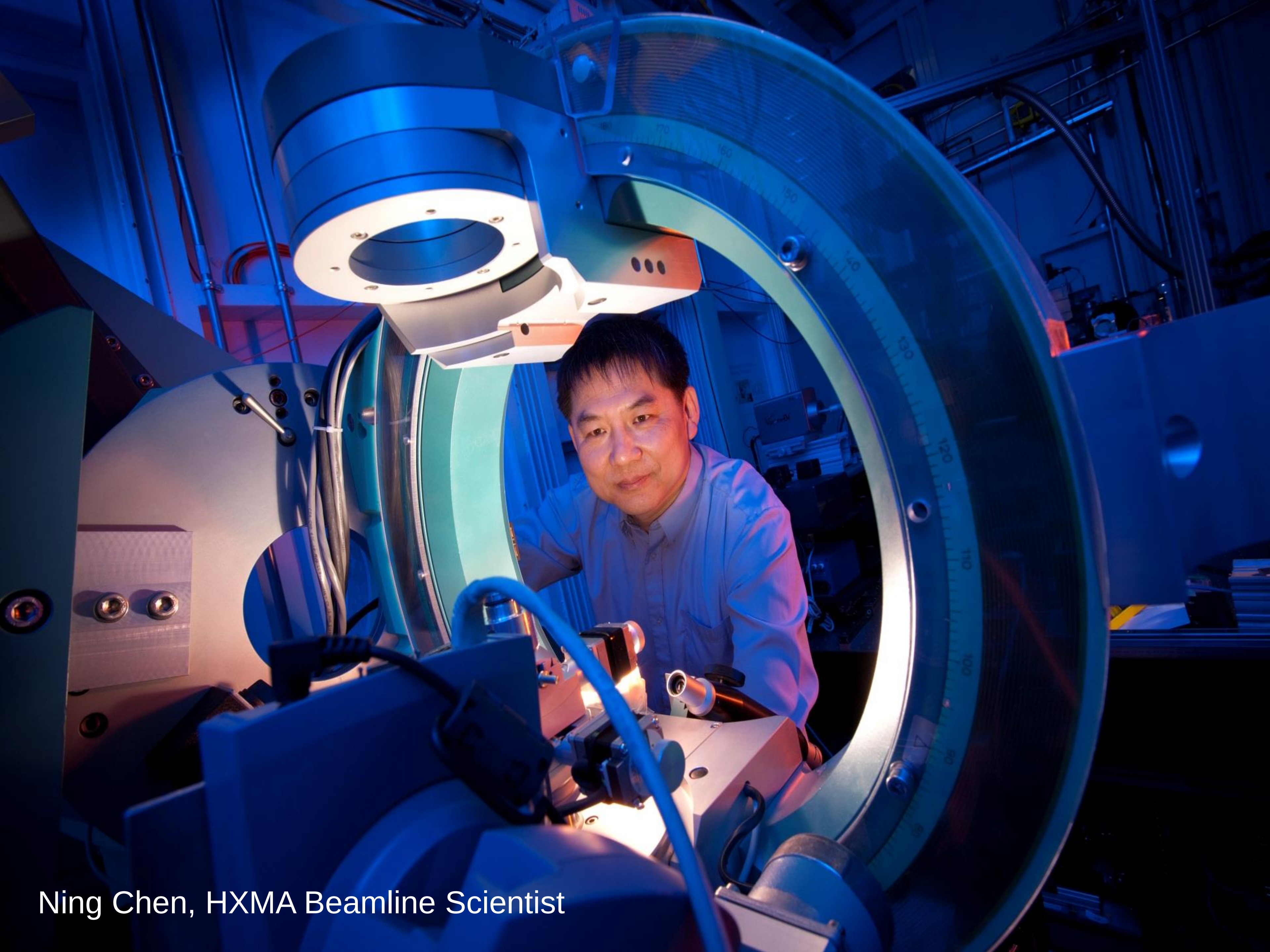






Rosendahl et al., Anal. Chem. (2011)

Ian Burgess, Chemistry, University of Saskatchewan

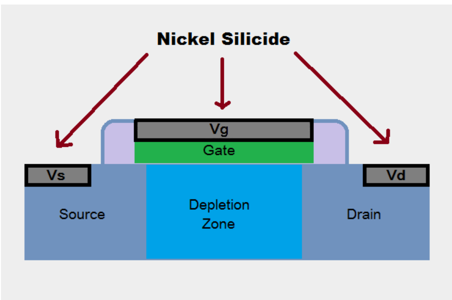


Ning Chen, HXMA Beamline Scientist

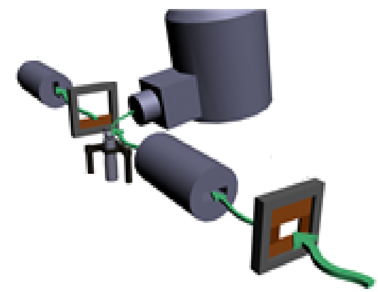
GI-XAFS Thin Film Studies at CLS HXMA

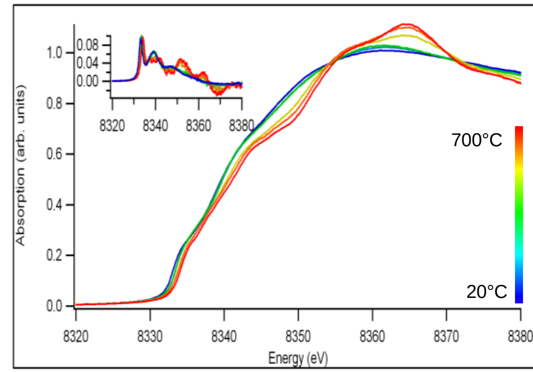
Z. Arthur[1], K. Miller[1], N. Chen[2], C. Lavoie[3], Y. Joly[4] , D.T. Jiang[1]
[1]U of Guelph, Canada; [2] CLS, Canada; [3]IBM T.J. Watson Research Ctr., USA; [4]CNRS Grenoble, France

Material applications



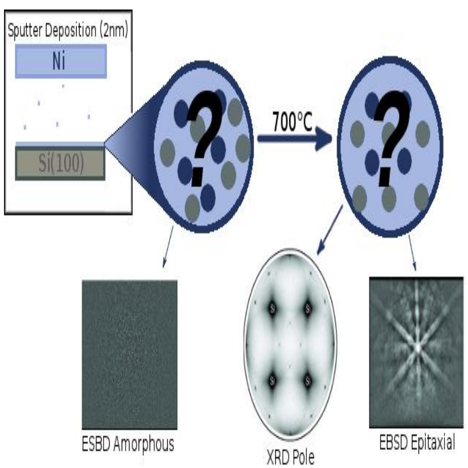
CLS HXMA BL
GI-XANES schematic



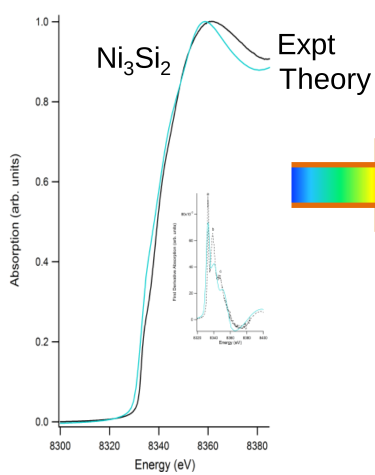


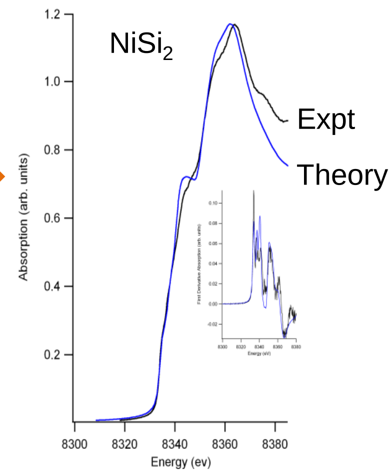
More detail in presentation: MDPEZ3

Ultrathin epitaxial Ni-Si film on Si(001):



FDMNES Simulation

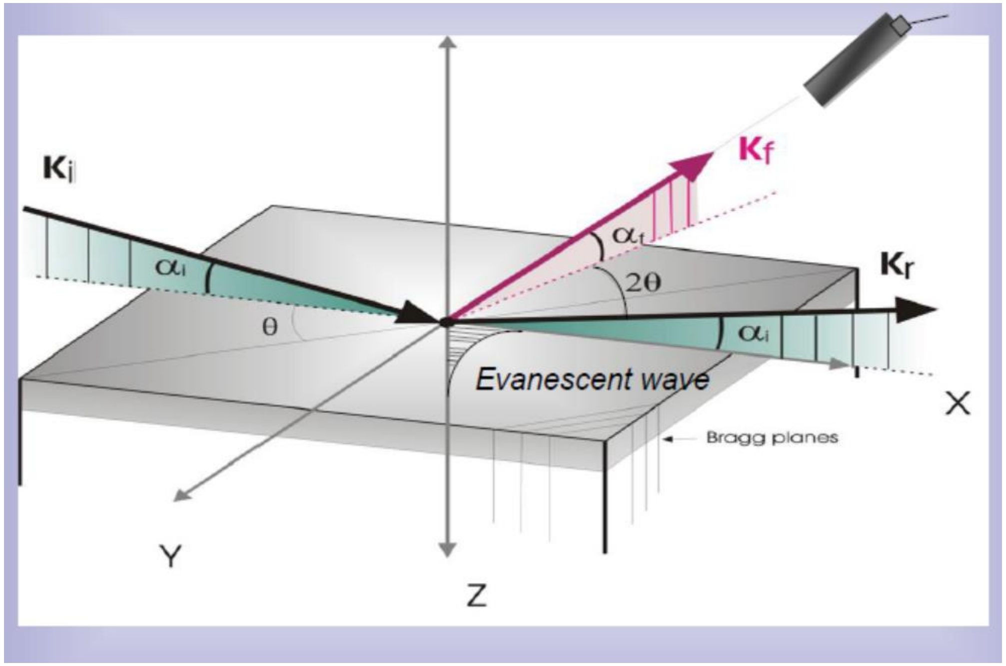


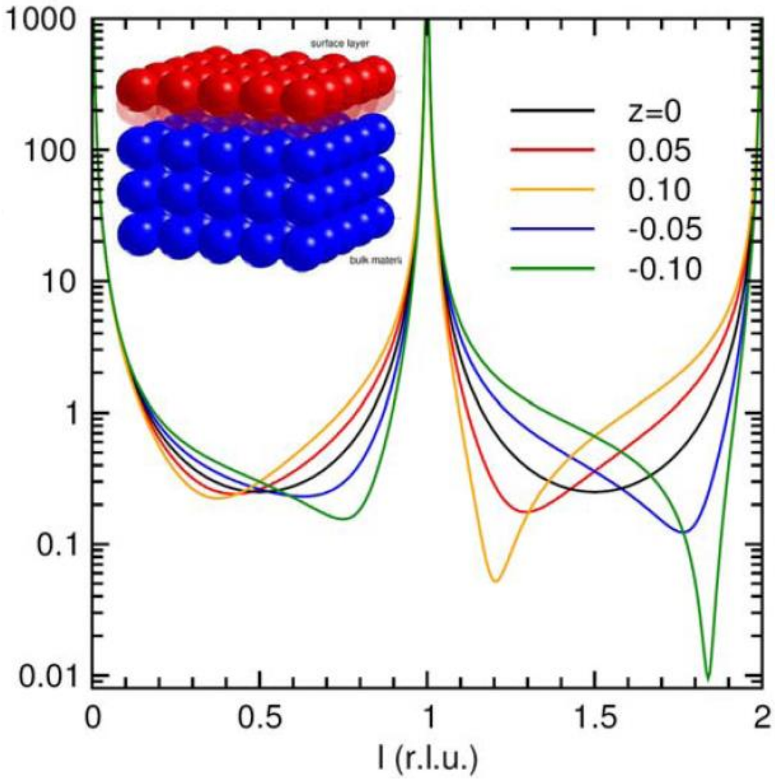


- Epitaxial phase is $NiSi_2$
- As-deposited is mostly Ni_3Si_2
- Surface/interface effects dominate the phase formation sequence – seems NiSi phase is bypassed, different from thicker film cases.

Surface X-ray Scattering

X-ray scattering from an infinite crystal → Bragg peaks.
Presence of crystalline surfaces → truncation rods (normal to the surface).
Crystal Truncation Rod (CTR) measurements allow detailed determination of atomic structure at the surface.





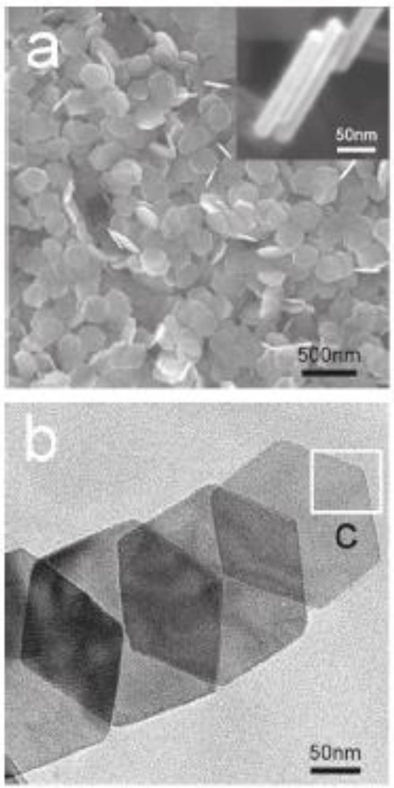
P. Willmott, Zuoz Summer School, 2008

Applying Surface X-ray diffraction technique

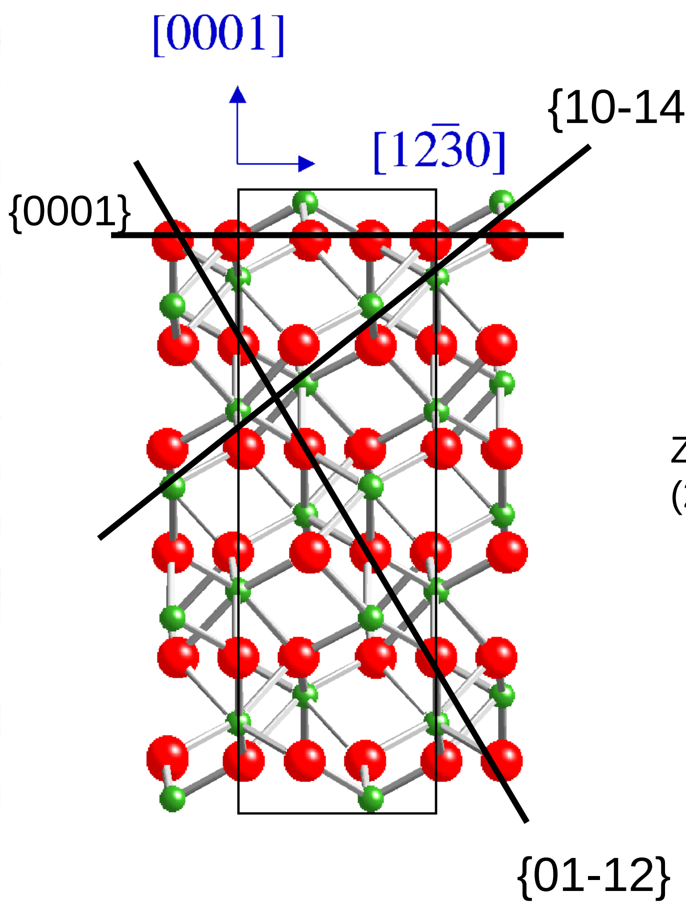
to uniform shape, mono-dispersive single crystalline nanoparticle →

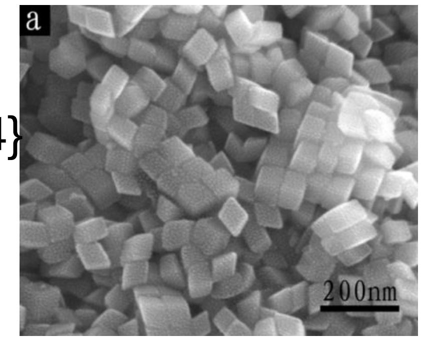
Correlation of enhanced performance of nanoparticle to its surface structure

Shape control of α-Fe_2O_3 nanoparticles

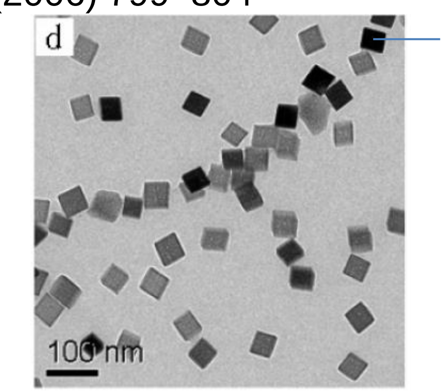


α-Fe_2O_3 nanoplate,
L. Chen et al, Inorg. Chem. 2010, 49, 8411–8420



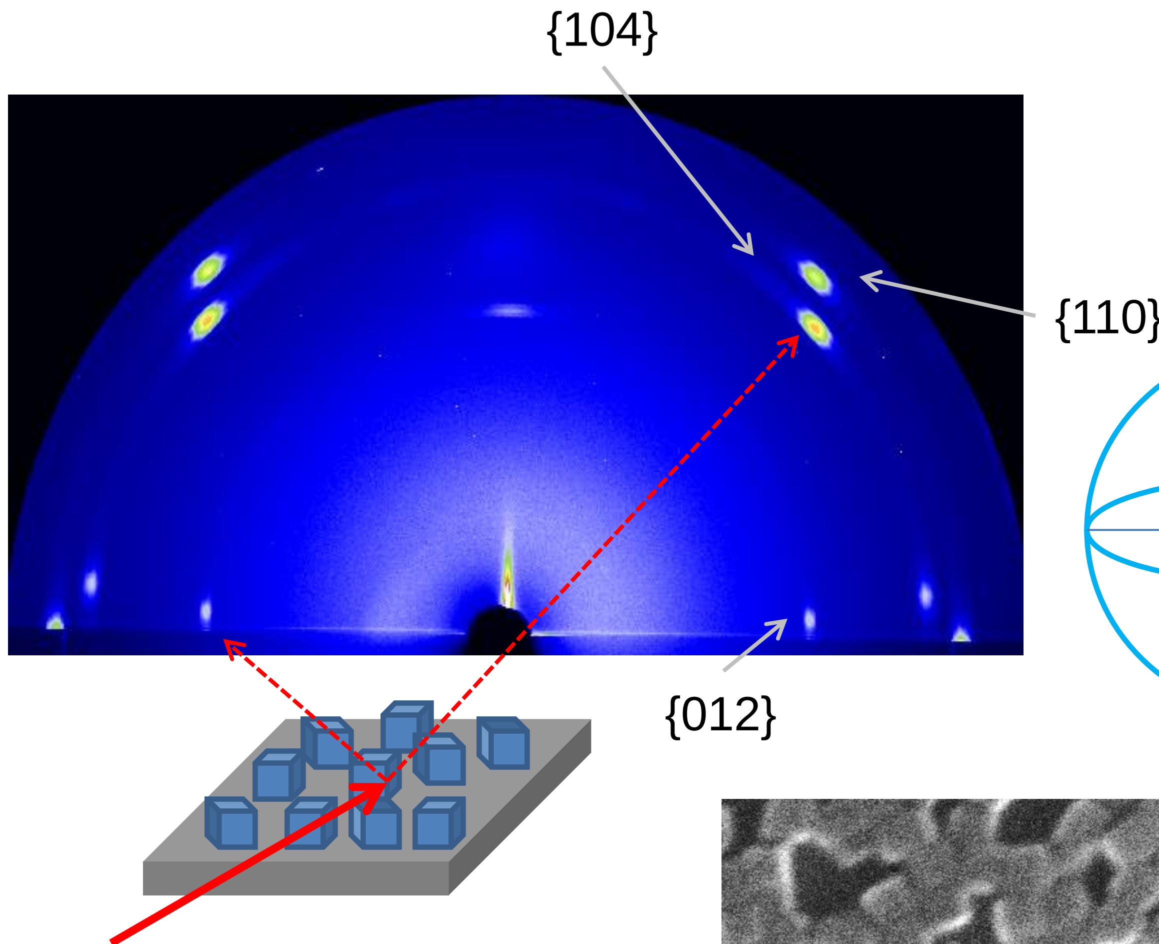


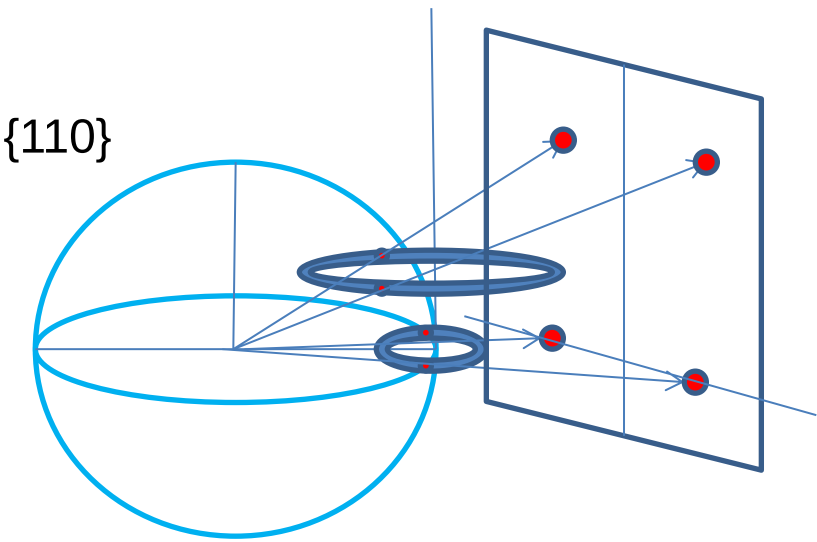
α-Fe_2O_3 nanorhombohedra
Z. Pu et al, Nanotechnology 17 (2006) 799–804

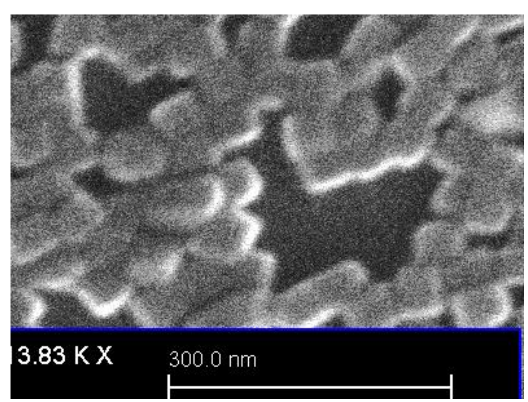


α-Fe_2O_3 nanocube
Y. Zheng et al, J. Phys. Chem. B 2006, 110, 3093

Grazing incidence X-ray diffraction (GIXRD)
from dip-coated hematite (α-Fe_2O_3) nano-cubes

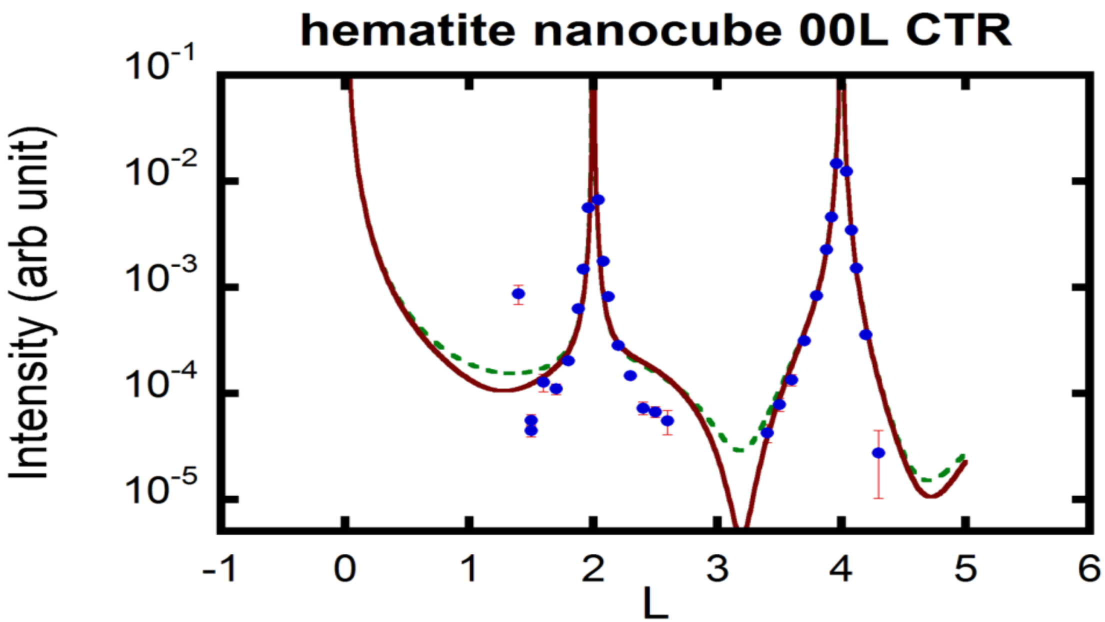


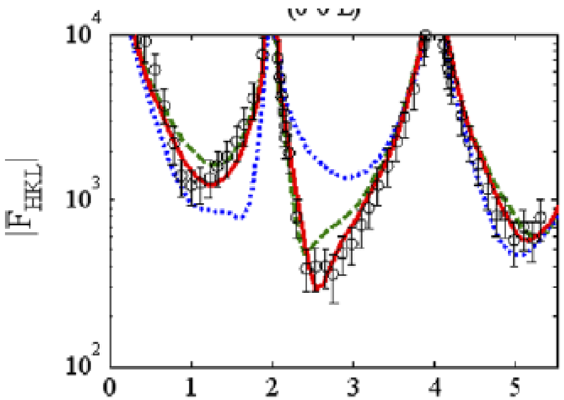




SEM image (CLS SyLMAND)

Crystal truncation rod (CTR) from **α-Fe_2O_3(012) nanocube**

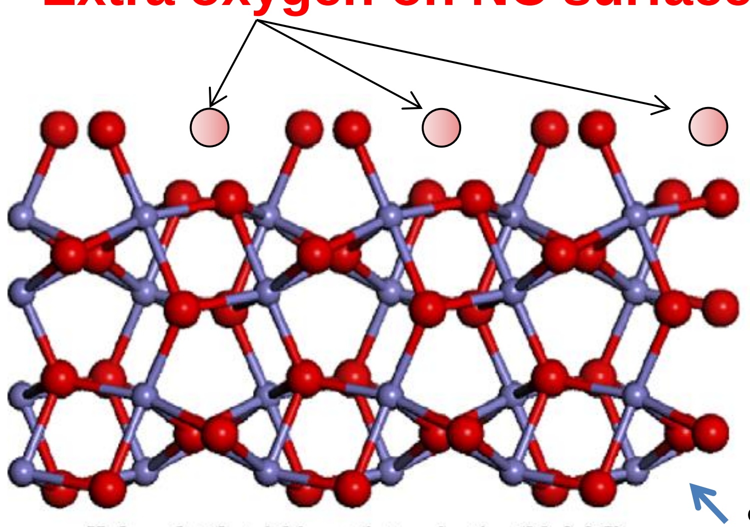




CTR from single crystal

K.S. Tanwar et al. / Surface Science 601 (2007) L59–L64

Extra oxygen on NC surface



Hydroxylated stoichiometric termination (Model C)

Single crystal model

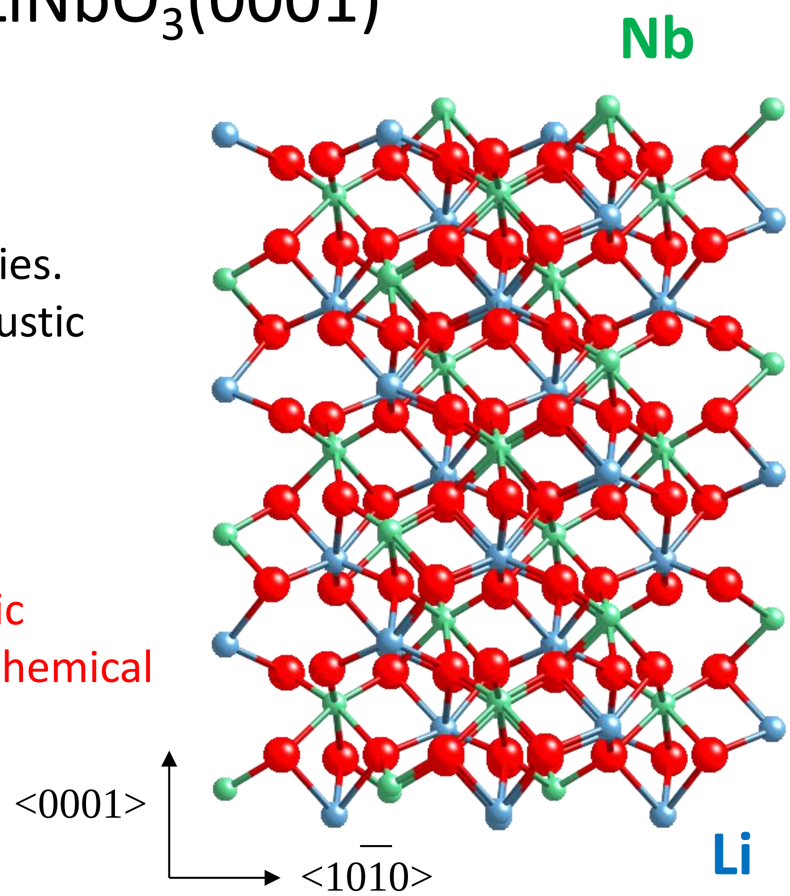
Existence of extra oxygen on hydroxylated nanocube surface agrees well with observations that nanoparticle can be easily hydroxylated

Surface X-ray Scattering Study of Polarization Dependent Surface Structure and Stoichiometry of $LiNbO_3(0001)$

Lithium Niobate (LiNbO3)

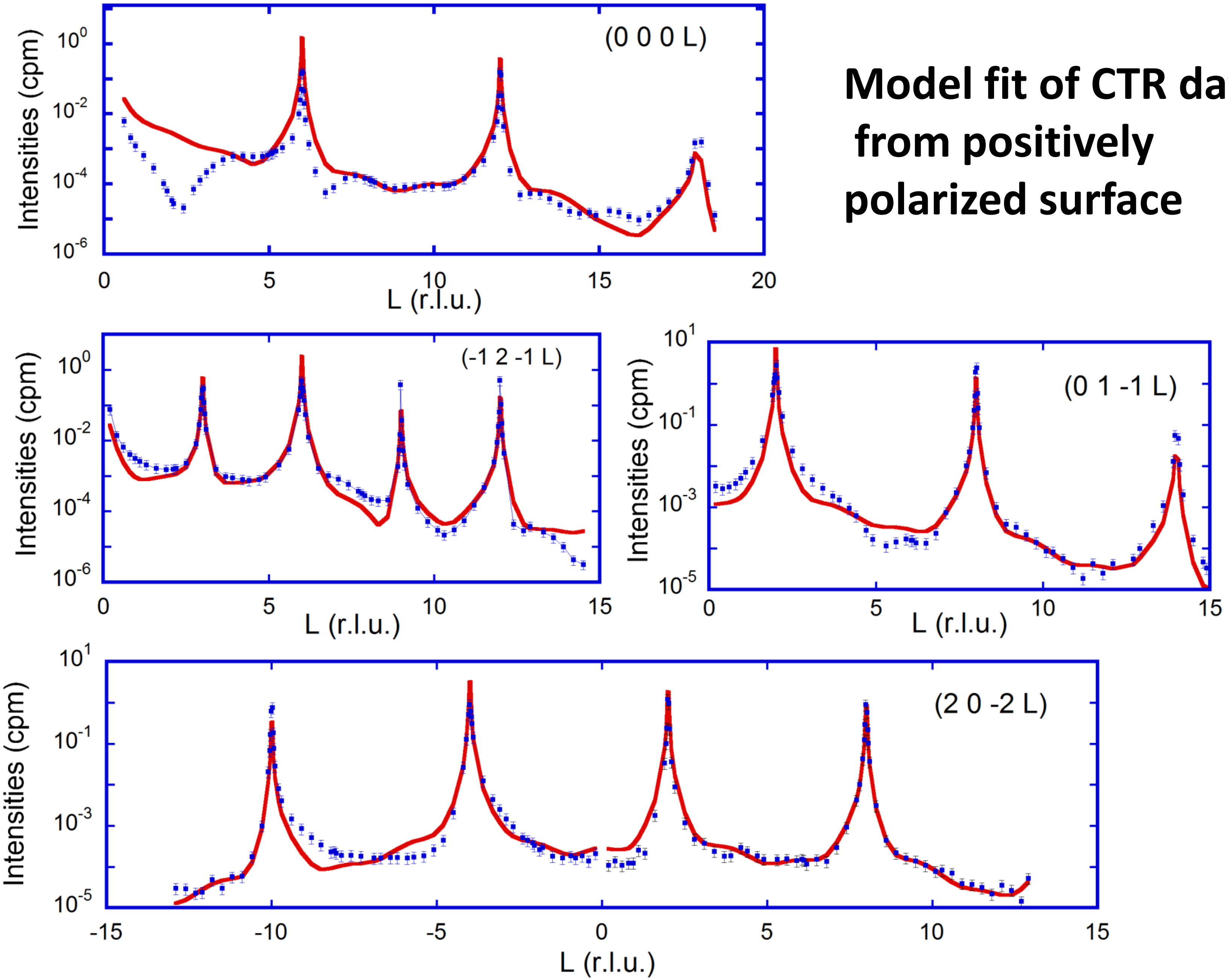
- Ferroelectric material with pyroelectric, piezoelectric and nonlinear optical properties.
- Widely used for electro-optic, surface acoustic wave generation, and second harmonic generation.

Oppositely poled LNO(0001) surfaces have different stoichiometries , atomic/electronic structures, photo-catalytic activities , and chemical reactions.

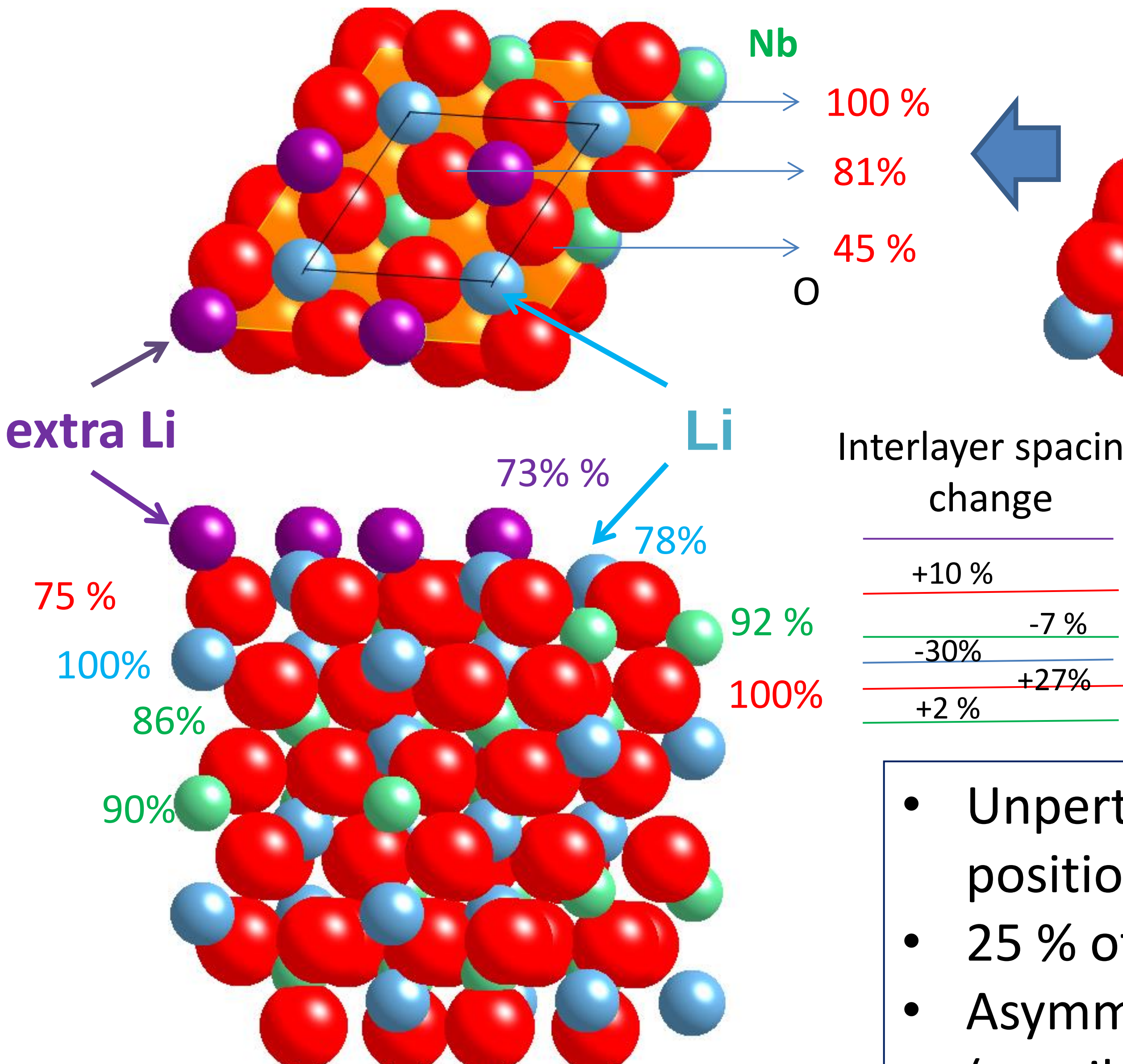


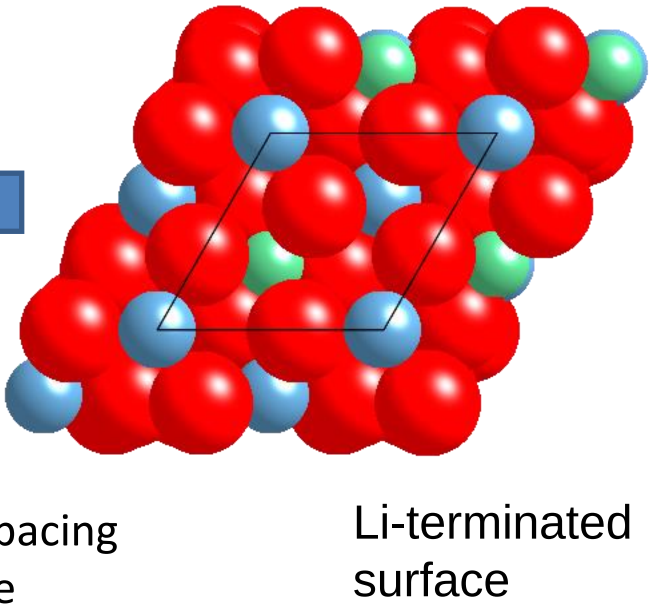
Surface structure characterization is essential for further study of the polarization dependent properties.

Model fit of CTR data from positively polarized surface



Best fit model of positively polarized surface

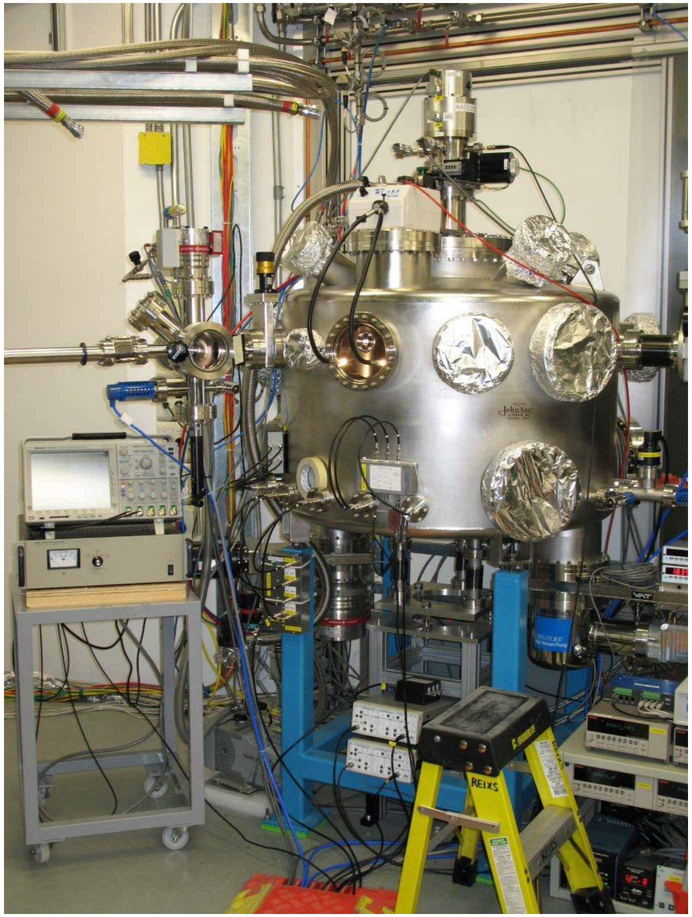


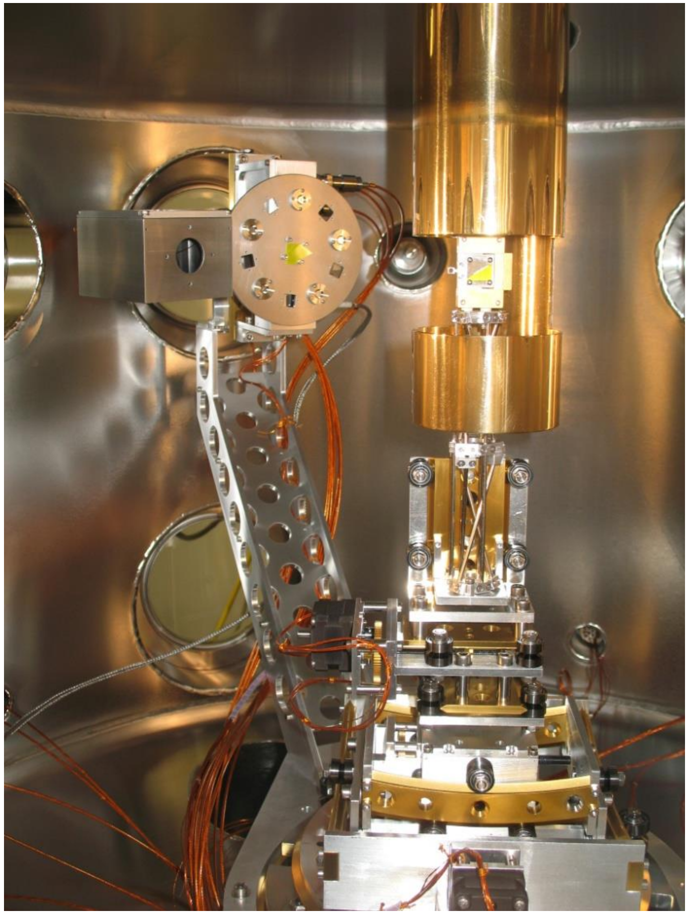


- Unperturbed oxygen layer positions
- 25 % of Li_2O_3 unit is vacant
- Asymmetric vacancy of O (possibly by step structure)

RSXS Endstation

- Resonant Soft X-ray Scattering (RSXS)
- X-ray Absorption Spectroscopy (XAS) by TEY and TFY
- Magnetic Circular Dichroism (MCD)
- X-ray Reflectivity





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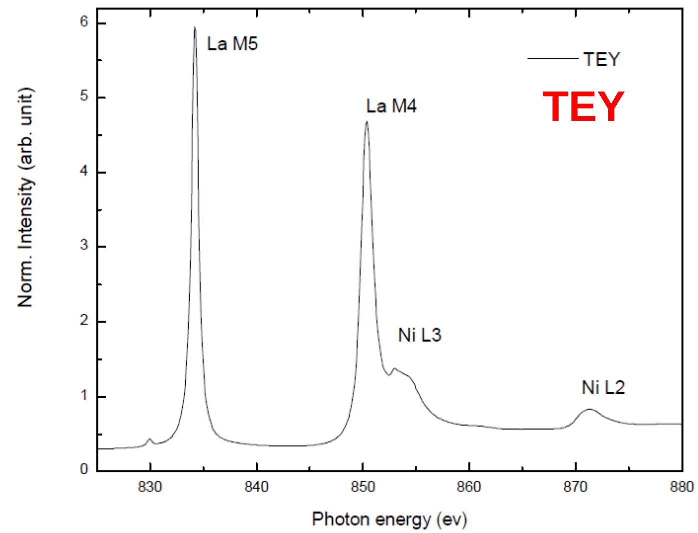
Experimental Techniques

- X-ray Absorption Spectroscopy
  - TEY – sample current
  - TFY – Photodiode, Channeltron, Microchannel Plate (MCP)
- XMCD – X-ray Magnetic Circular Dichroism

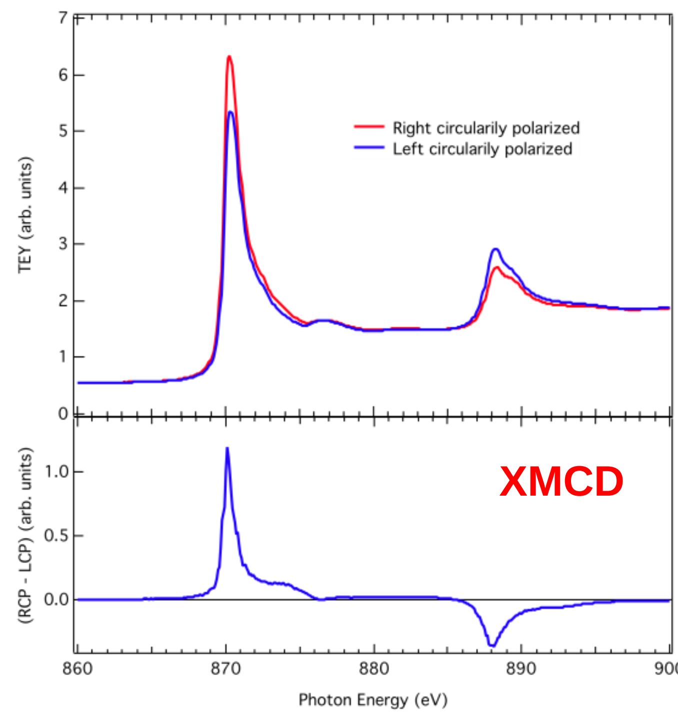
  High energy resolution

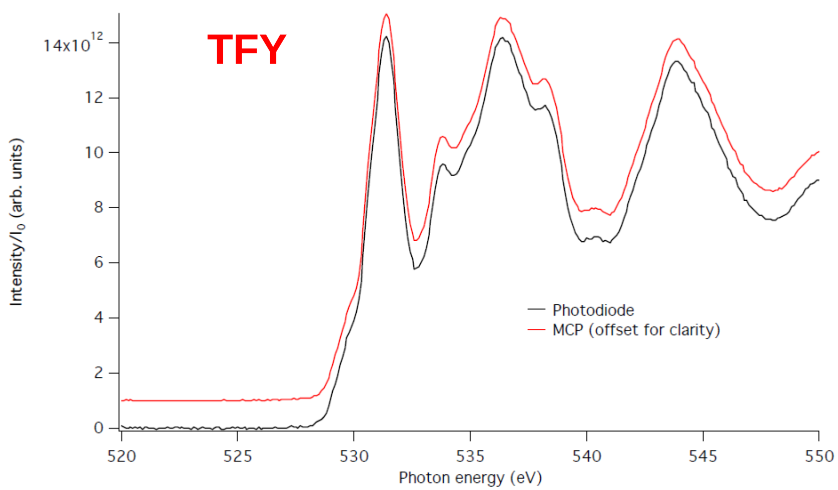
  Polarized incoming beam

  Measure TEY, specular reflection, fluorescence yield simultaneously



REIXS Data by D. Hawthorn





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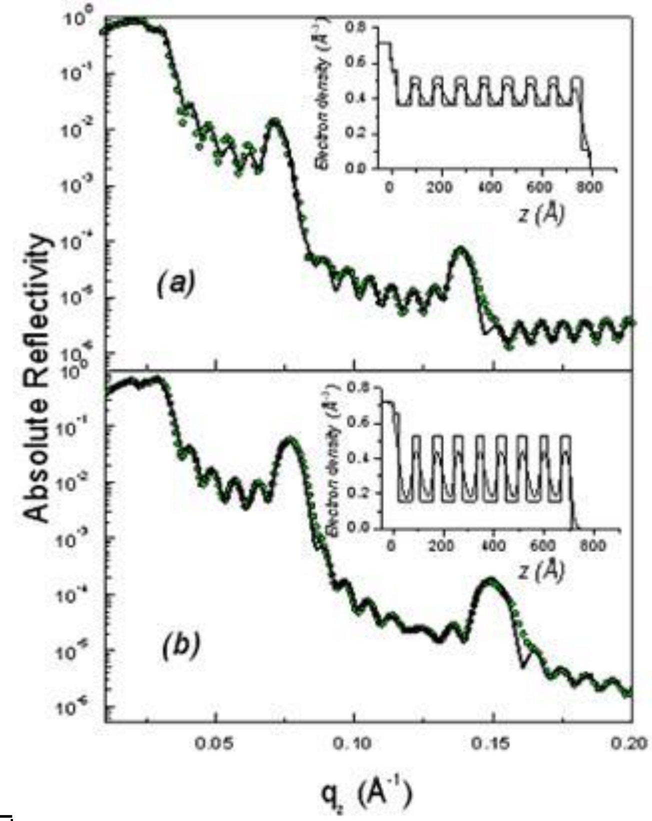
Experimental Techniques

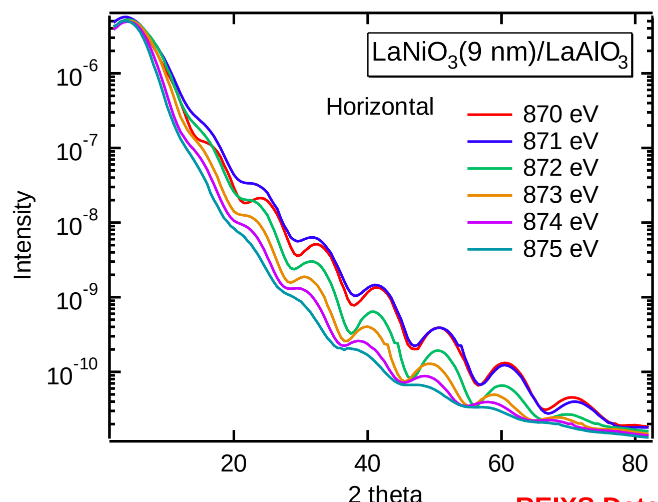
➢ X-ray Reflectivity

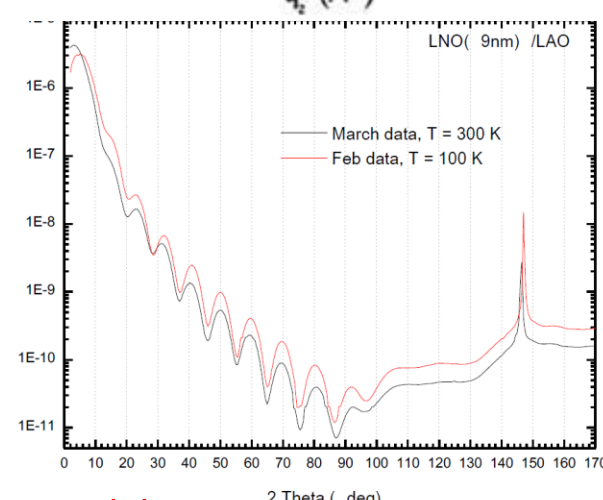
- Wide 2θ and θ range (maximum 2θ: 172°)
- Energy dependence, temperature dependence, polarization dependence

Information on:

- Electron density profile in thin films, multilayers, interface
- Film thickness, multilayer periodicity
- Roughness of surface and interface







REIXS Data by H. Wadati

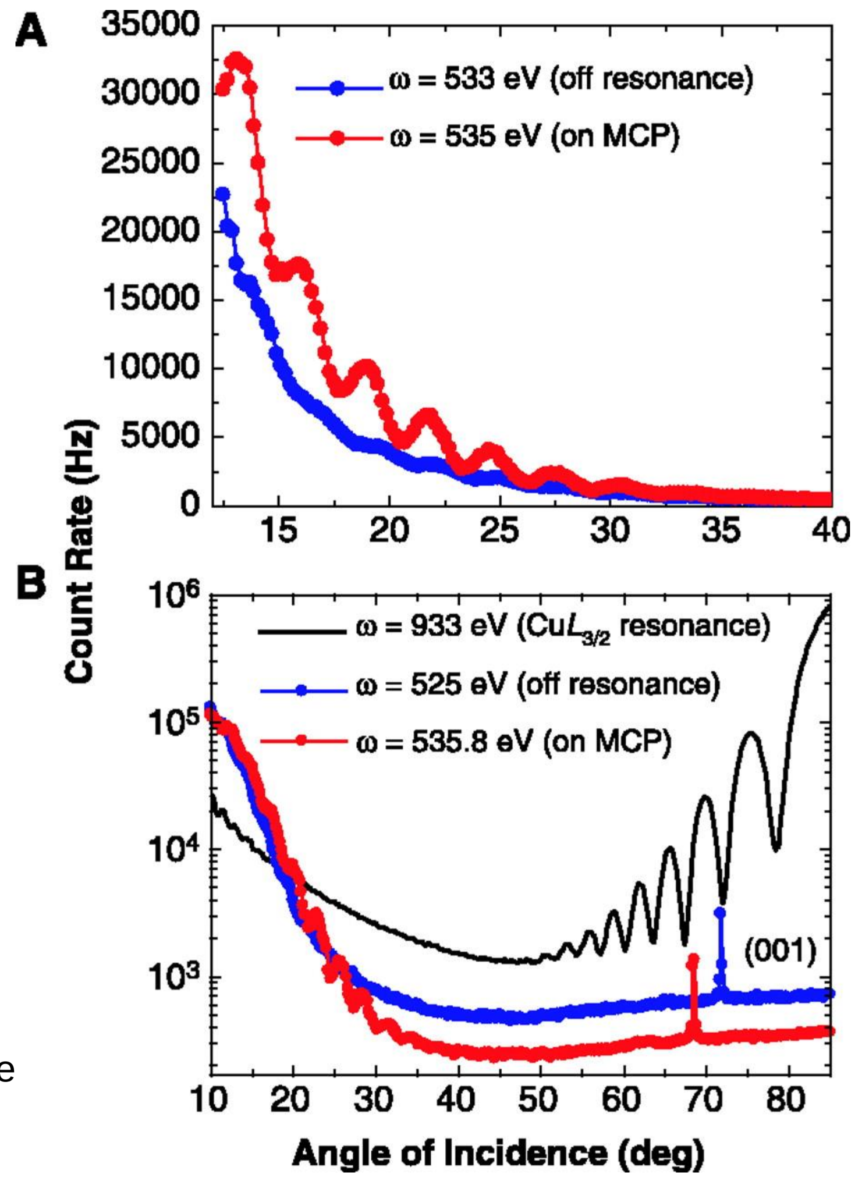
Feizhou He

Resonant Soft X-Ray Scattering

P. Abbamonte et al, Science 297, 581 (2002).

At resonance we have contrast for:

- Elements – each element has specific resonant energy → element selective
- Valence electron density
- Bond orientation; orbital ordering quadrupole moment orientation [linear pol. light]
- Spin density [circular pol. light and *p* or *d* core level]



$La_2CuO_{4+\delta}$ film
O *K* edge
Cu *L* edge

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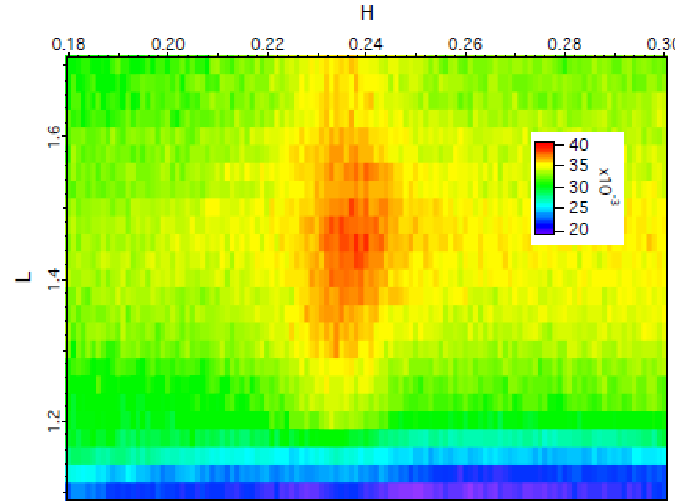
Resonant Soft X-Ray Scattering

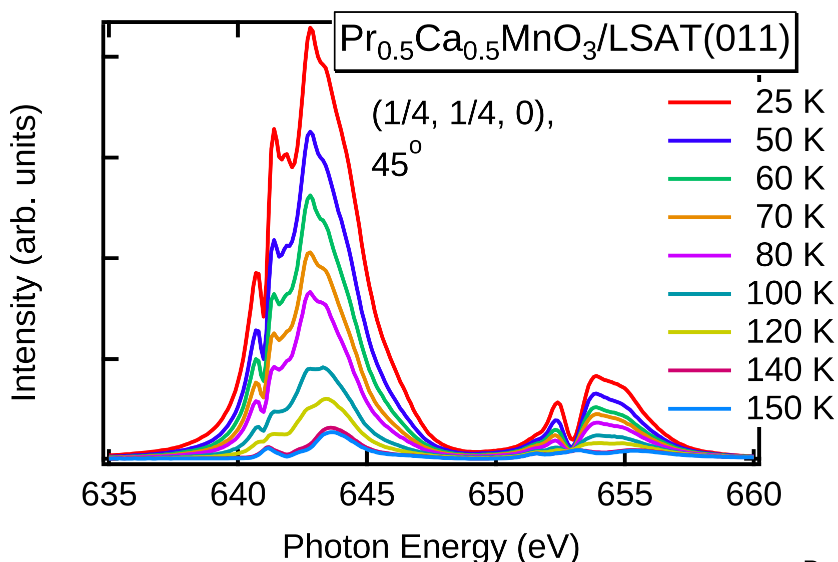
- REIXS RSXS
  - Temperature 18K – 400K
  - Energy 100 eV – 2500 eV
  - Arbitrary Polarization

  - FixQ energy scan
  - Reciprocal space mapping

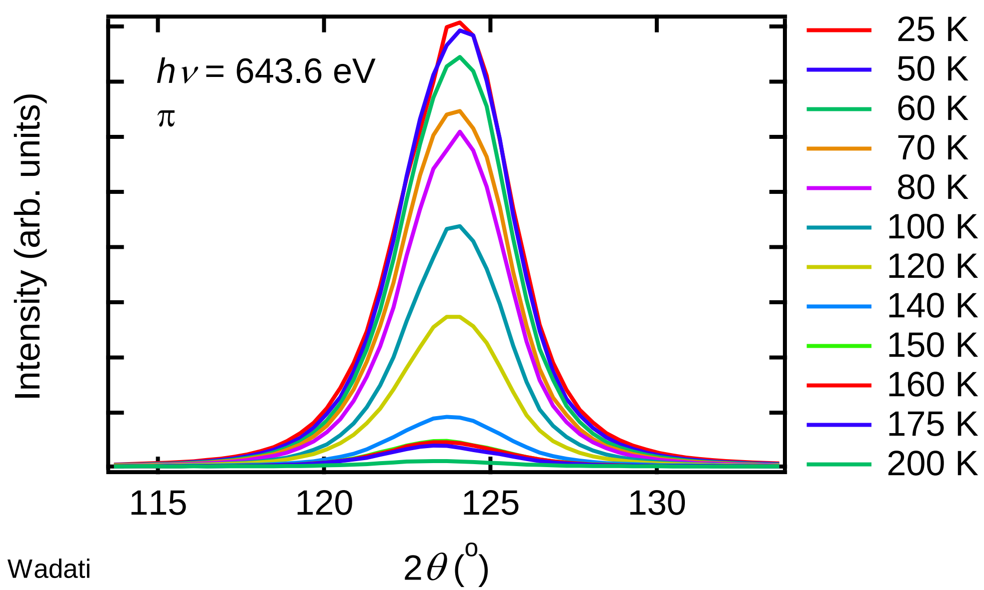
[H 0 L] mesh at 931.1 eV



By D. Hawthorn



By H. Wadati



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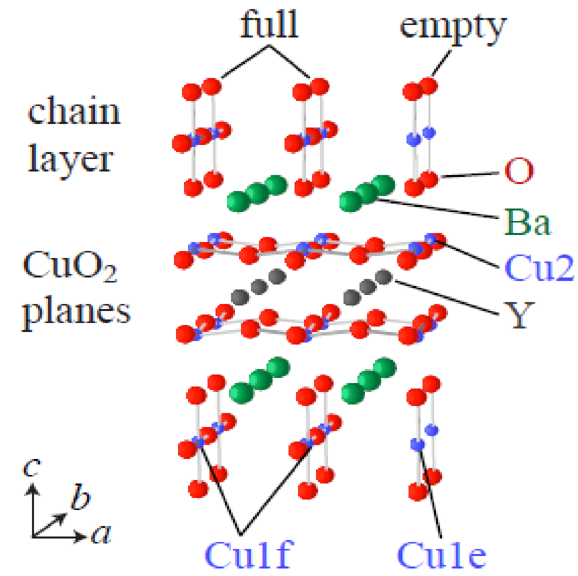
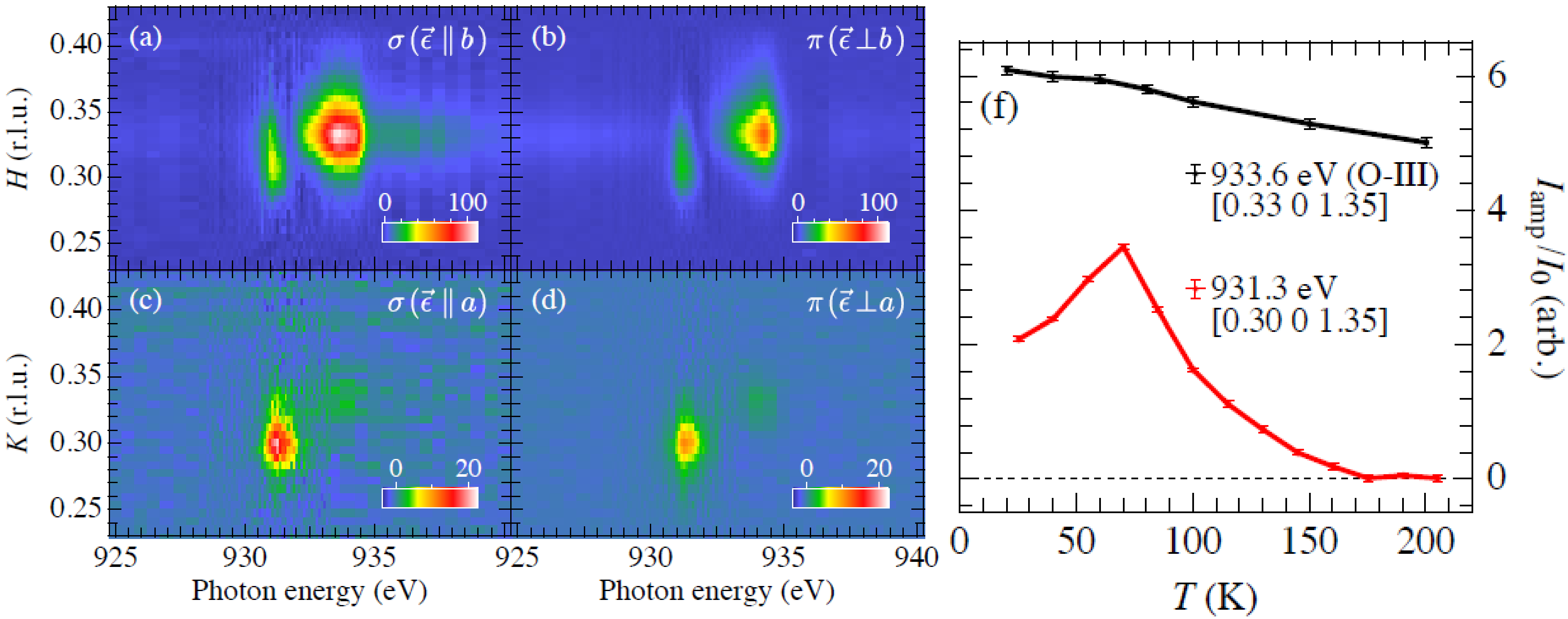
Charge ordering in chain layer and plane layer in YBCO



A. Achkar et al, PRL (2012)



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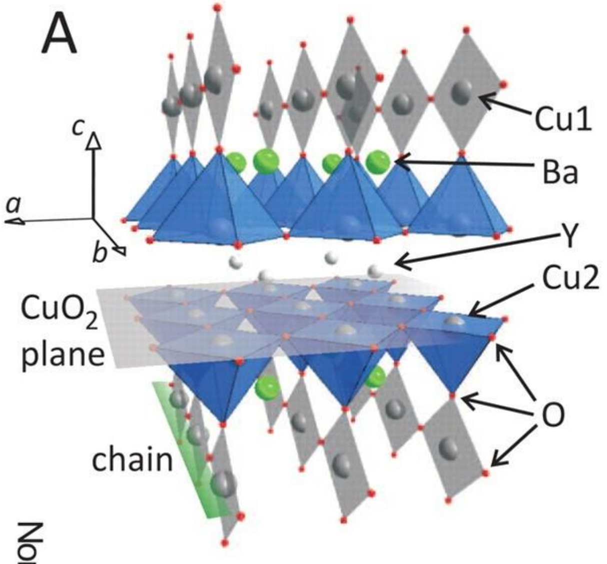
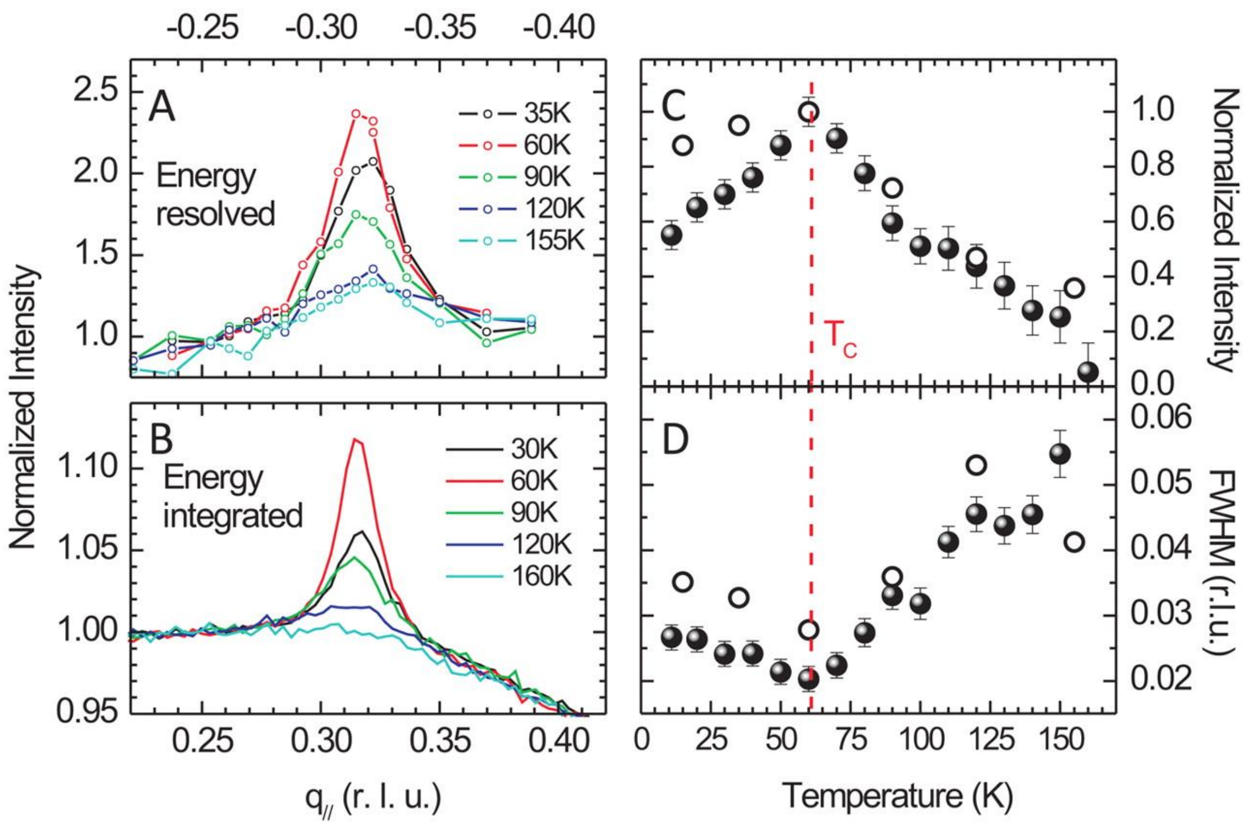
Charge density wave in YBCO



G. Ghiringhelli et al, Science (2012).



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Thank you!