Luz de Radiación Sincrotrón, su uso y algo más

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UNACH
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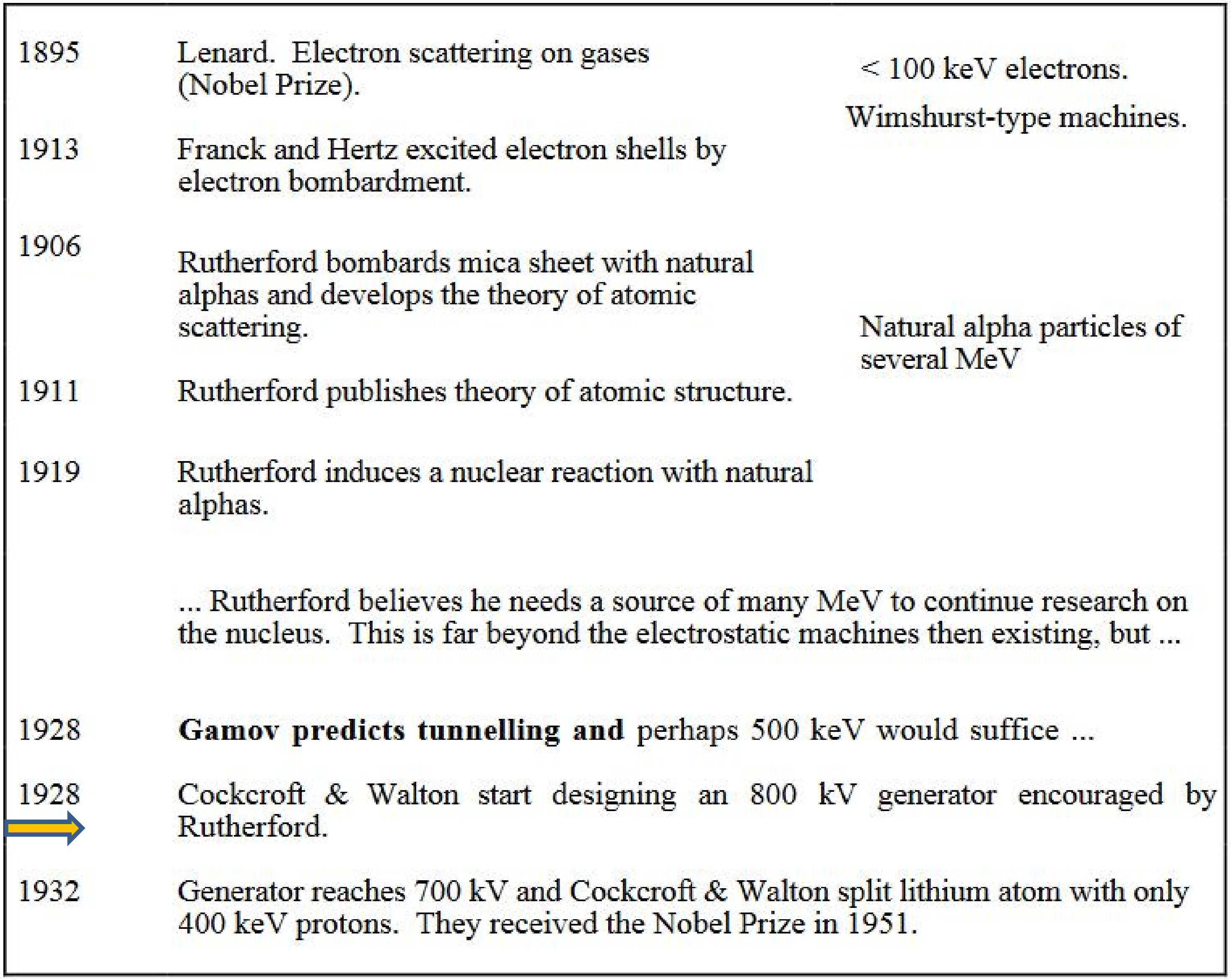
Los aceleradores de partículas en el mundo

CICLOTRON, BEVATRON,
SINCROTRON, LINAC,… XFEL

Los aceleradores y nuestro quehacer científico

AREAS DE LA MATERIAL											
Física del estado solido	Ciencia de los materiales	Física Atómica	Física molecular	Química	Foto-química	Física nuclear	Estructura biomolecular	Biología celular	Geología	Fabricación industrial	TÉCNICAS UTILIZADAS
X	X	X	X		X		X		X		Espectroscopia absorción/reflexión
X	X	X	X		X		X		X		Espectroscopia de emisión
X	X			X				X			Espectromicroscopia
X	X	X	X	X	X		X		X		Espectroscopia de foto-electrones
X	X	X	X	X	X				X		Espectroscopia de fotoiones
X	X	X	X	X	X		X	X	X		EXAFS, XANES
X	X		X								Holografía
X	X		X								Difracción de foto-electrones
X	X		X								Desorción fotoestimulada
X	X		X	X				X			Dicroísmo circular
X	X	X	X	X	X		X	X	X		Análisis por fluorescencia de RX
X		X	X	X							Fotones inelásticamente dispersados
X	X			X	X		X		X		Difracción/dispersión de RX
X	X			X							Ondas estacionarias de RX
	X			X	X		X		X		Dispersión Difusa de RX
	X			X	X		X		X		Dispersión de RX de ángulo rasante
							X	X	X		Microscopia de rayos X suaves
	X									X	Litografía de RX
									X		Tomografía
				X				X			Microtomografía
X	X	X	X				X				Interferometría de RX
								X	X		Imageología de RX
					X					X	Procesamiento asistido por fotones
										X	Microfabricación
						X					Dispersión inversa de Compton

La historia

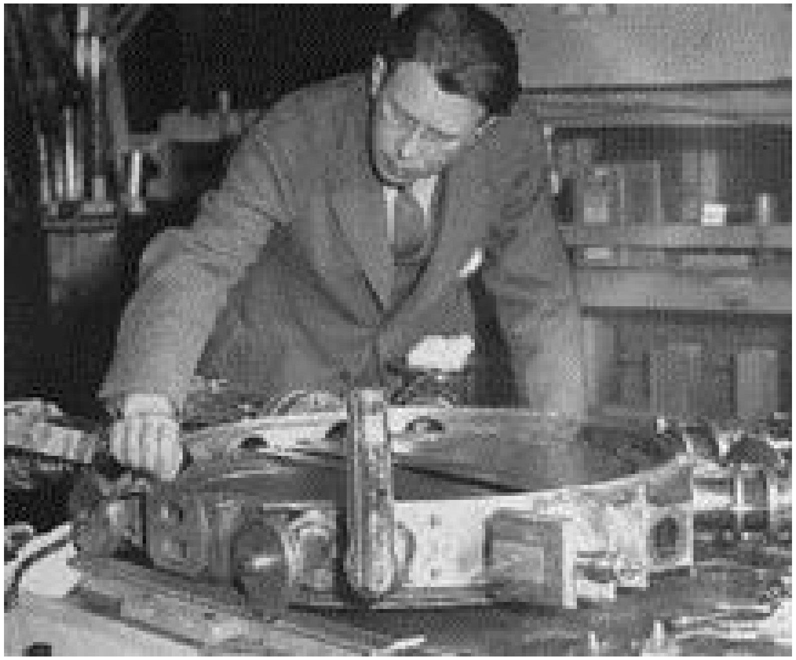


1895	Lenard. Electron scattering on gases (Nobel Prize).	< 100 keV electrons. Wimshurst-type machines.
1913	Franck and Hertz excited electron shells by electron bombardment.	
1906	Rutherford bombards mica sheet with natural alphas and develops the theory of atomic scattering.	Natural alpha particles of several MeV
1911	Rutherford publishes theory of atomic structure.	
1919	Rutherford induces a nuclear reaction with natural alphas.	
	... Rutherford believes he needs a source of many MeV to continue research on the nucleus. This is far beyond the electrostatic machines then existing, but ...	
1928	**Gamov predicts tunnelling and** perhaps 500 keV would suffice ...	
1928	Cockcroft & Walton start designing an 800 kV generator encouraged by Rutherford.	
1932	Generator reaches 700 kV and Cockcroft & Walton split lithium atom with only 400 keV protons. They received the Nobel Prize in 1951.	

http://www.afhalifax.ca/magazine/wp-content/sciences/lhc/HistoireDesAccelerateurs/histoire1.pdf

El ciclotrón (~1930´s)

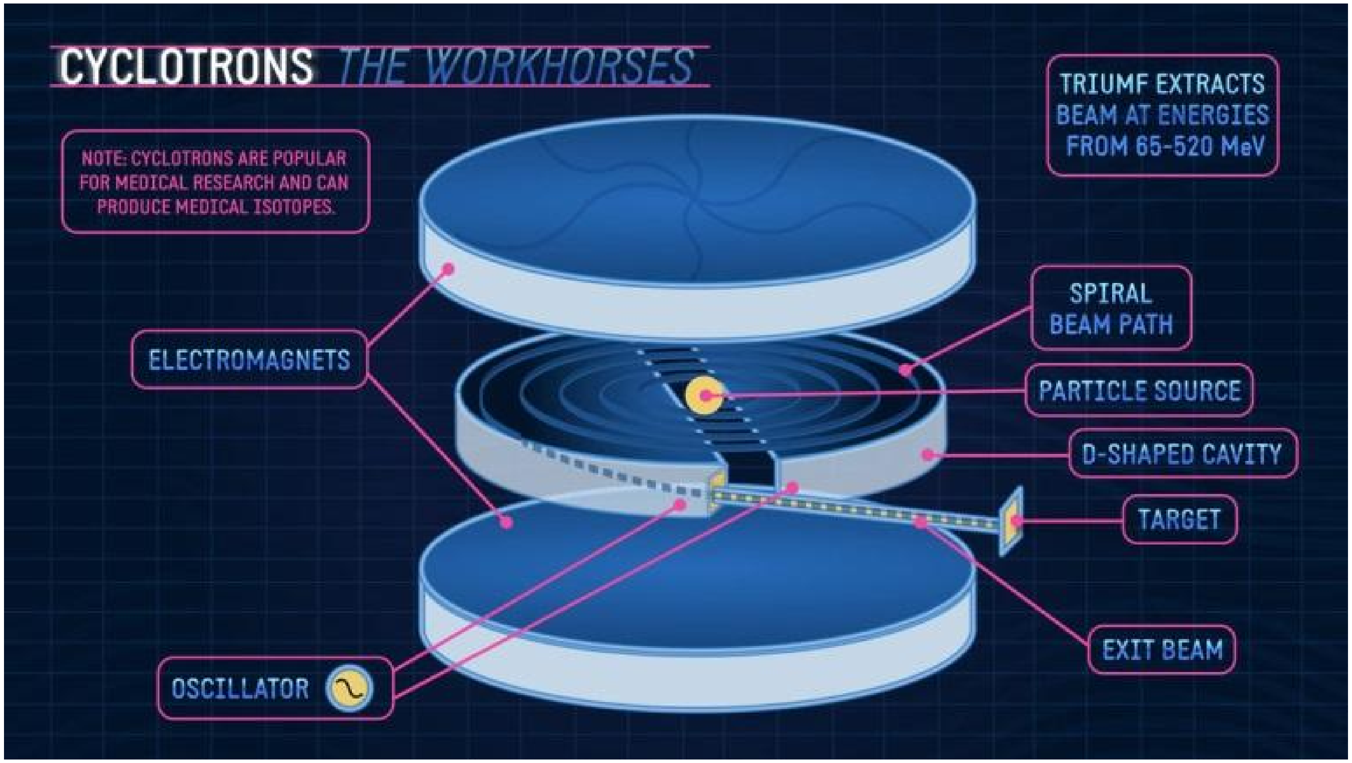
https://www.researchgate.net/figure/The-4-inch-cyclotron-vacuum-chamber-showing-the-single-dee-and-electrostatic_fig2_242117937



http://www2.lbl.gov/Science-Articles/Archive/rev-idea.html

EL CICLOTRÓN

CICLOTRONES

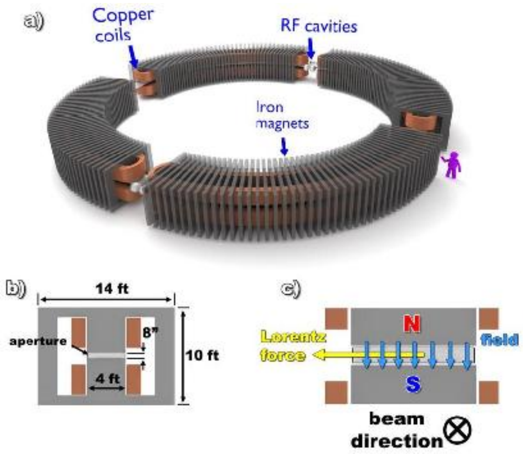


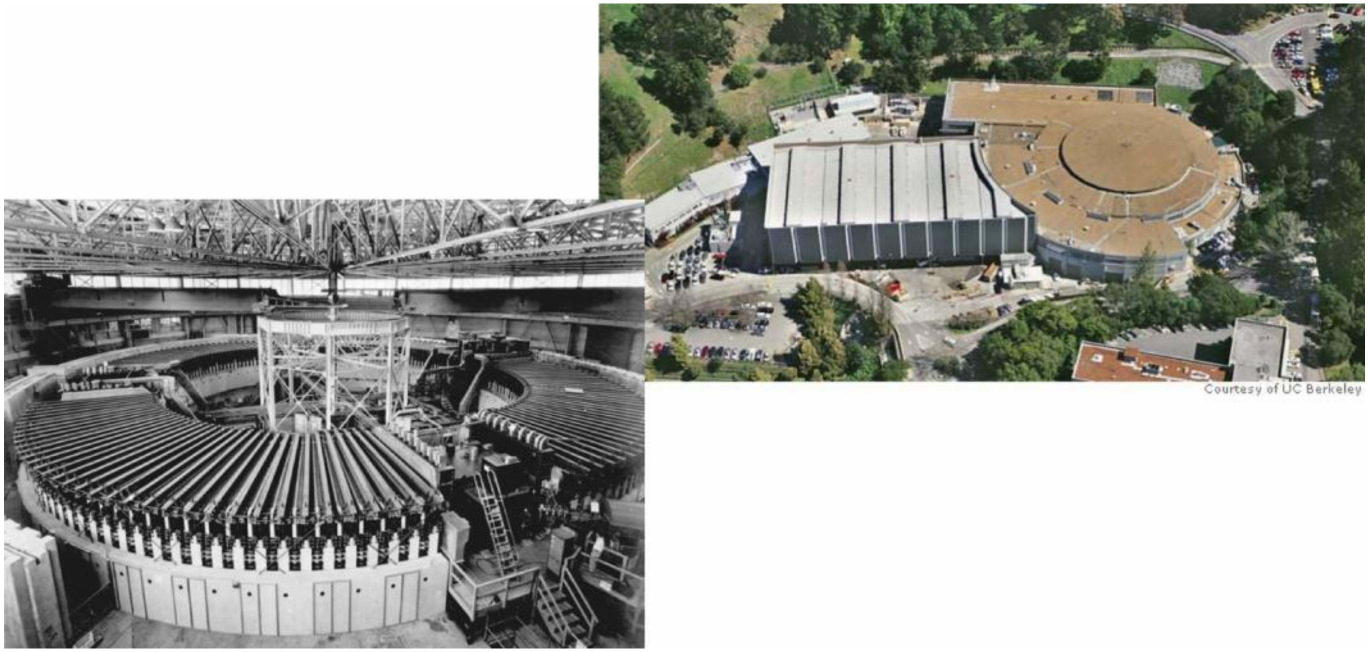
"Los **sincrotrones** son **descendientes** de otro tipo de colicionadores circulares llamados **ciclotrones**. Los ciclotrones aceleran particulas e un patron esperial, empezando desde su centro."

Los ciclotrones son frecuentemente utilizados para crear grandes cantidades de un tipo especifico de particulas, tales como muones o neutrons. También son populares en investigaciones medicas porque tiene el rango de energía e intensidad que producen isotopos medicos.

https://www.symmetrymagazine.org/article/a-primer-on-particle-accelerators

Bevatrón



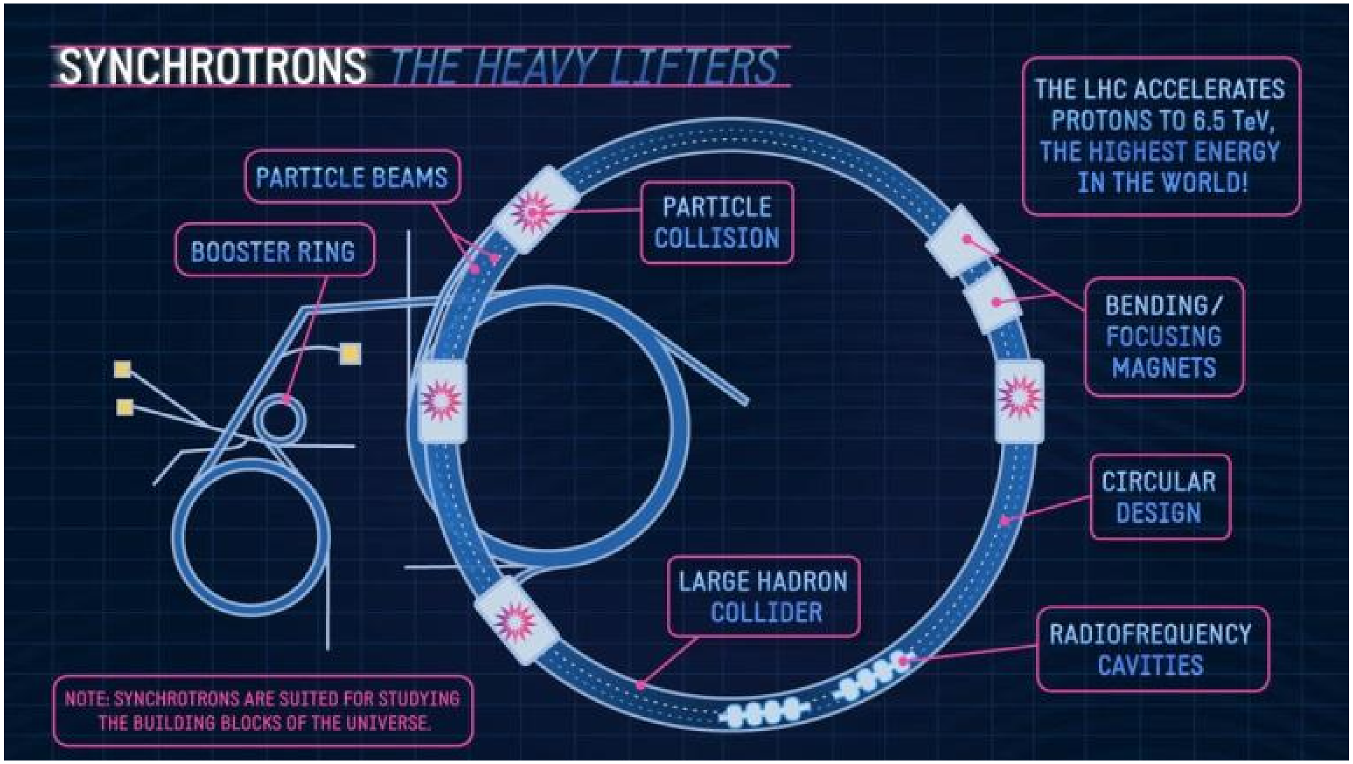

Courtesy of UC Berkeley

El **Bevatrón** o **Bevatron** (atom smasher) fue un acelerador de partículas -concretamente, un sincrotrón de focalización débil- del Lawrence Berkeley National Laboratory que comenzó a operar en 1954.

En los años siguientes al descubrimiento del antiprotón (1955), se efectuaron numerosos trabajos pioneros usando haces de protones extraídos del acelerador, haciéndolos colisionar contra blancos en los que se generaban haces secundarios de partículas elementales, no solamente de protones sino también de neutrones, piones, "partículas extrañas" y otras muchas

https://es.wikipedia.org/wiki/Bevatr%C3%B3n

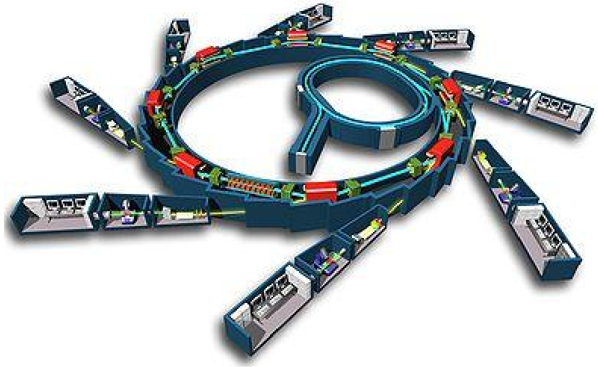
SINCROTRONES



"Los sincrotrones son aceleradores de particulas al mas alto nivel de energía, en el mundo. El gran colicionador de hadrones es el que se encuentra en lo mas alto de la lista, con su abilidad de acelerar particulas a una energia de 6.5 trillions de electronvolts antes que colicionen con particulas de igual energía, viajando en dirección opuesta. "

https://www.symmetrymagazine.org/article/a-primer-on-particle-accelerators

Sincrotrones

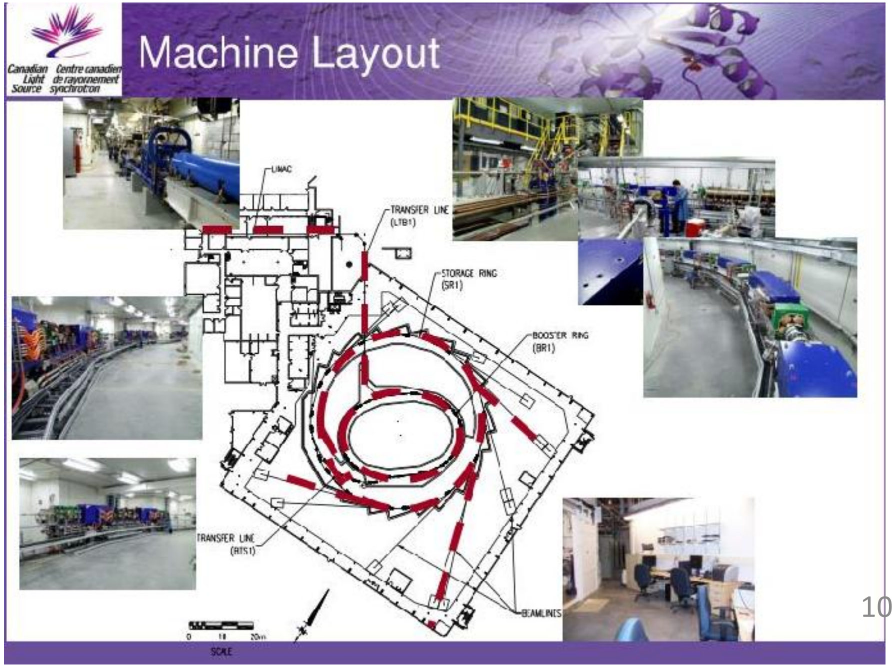


https://es.wikipedia.org/wiki/Sincrotr%C3%B3n

https://www.gleeble.com/products/specialty-systems/gleeble-synchrotron.html

http://www.everystockphoto.com/photo.php?imageId=21126715

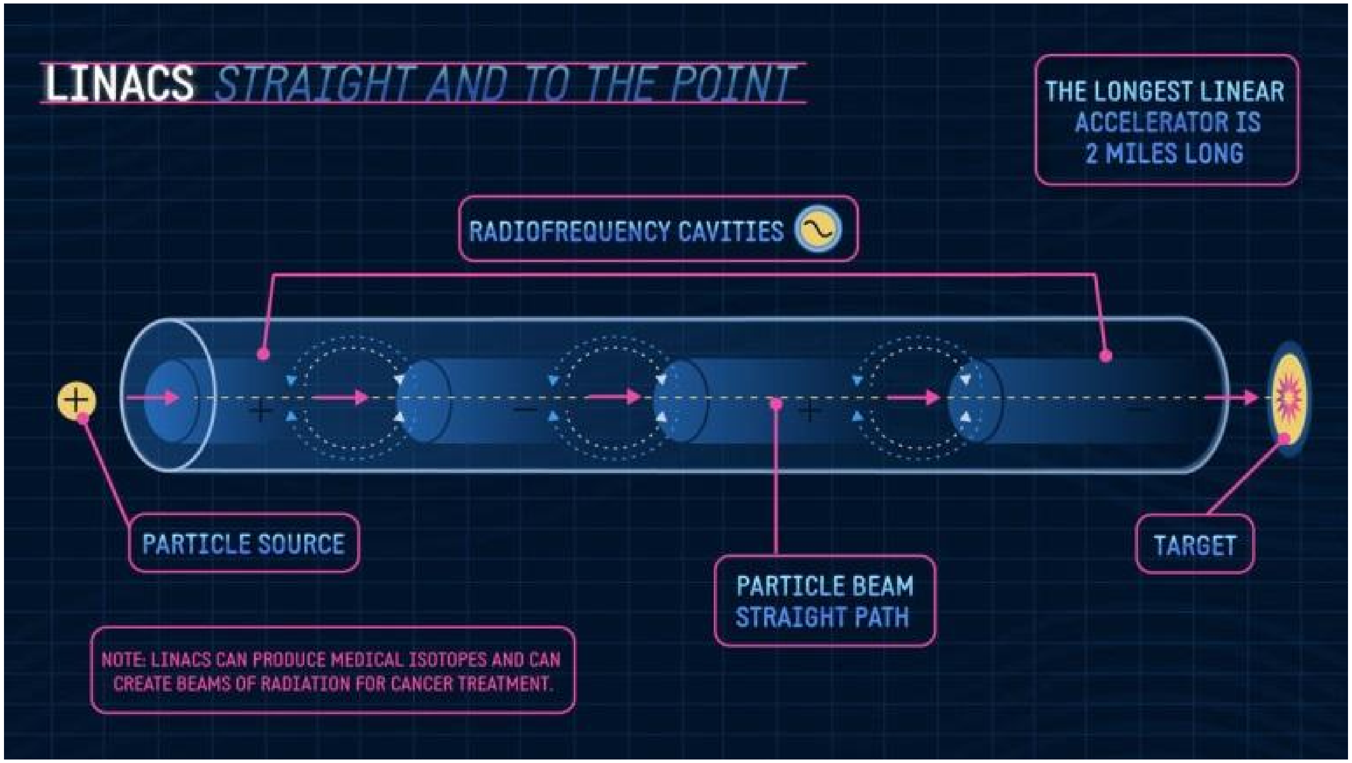
https://www.slideserve.com/rafael-curry/e-matias-canadian-light-source-university-of-saskatchewan



Canadian Light Source Centre canadien de rayonnement synchrotron

Machine Layout

Acelerador Lineal (LINACS)



“For physics experiments or applications that require a steady, intense beam of particles, linear accelerators are a favored design. SLAC National Accelerator Laboratory hosts the longest linac in the world, which measures 2 miles long and at one point could accelerate particles up to 50 billion electronvolts.”

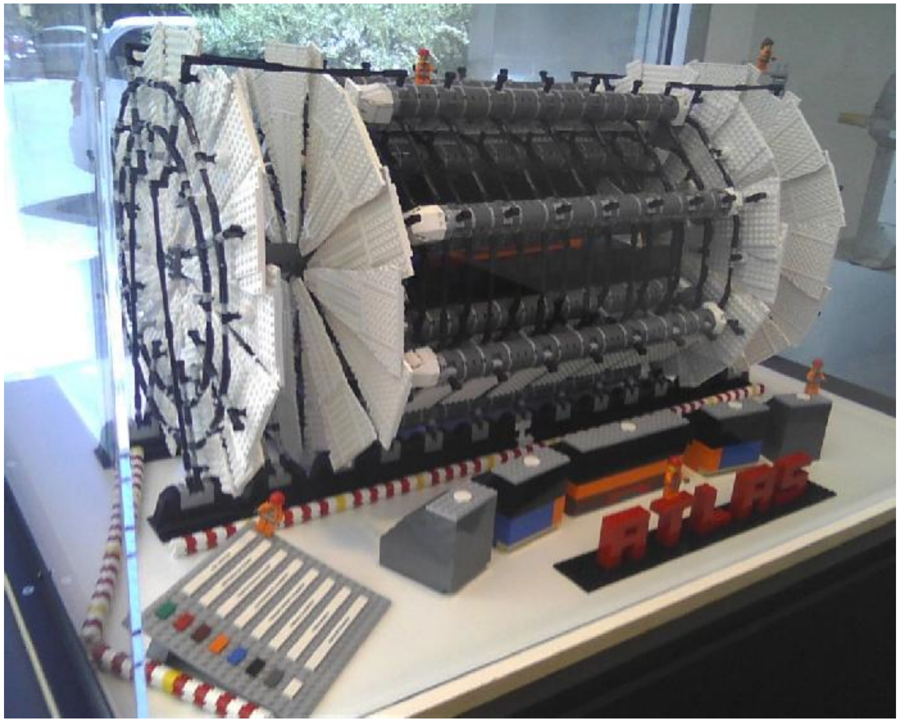
https://www.symmetrymagazine.org/article/a-primer-on-particle-accelerators

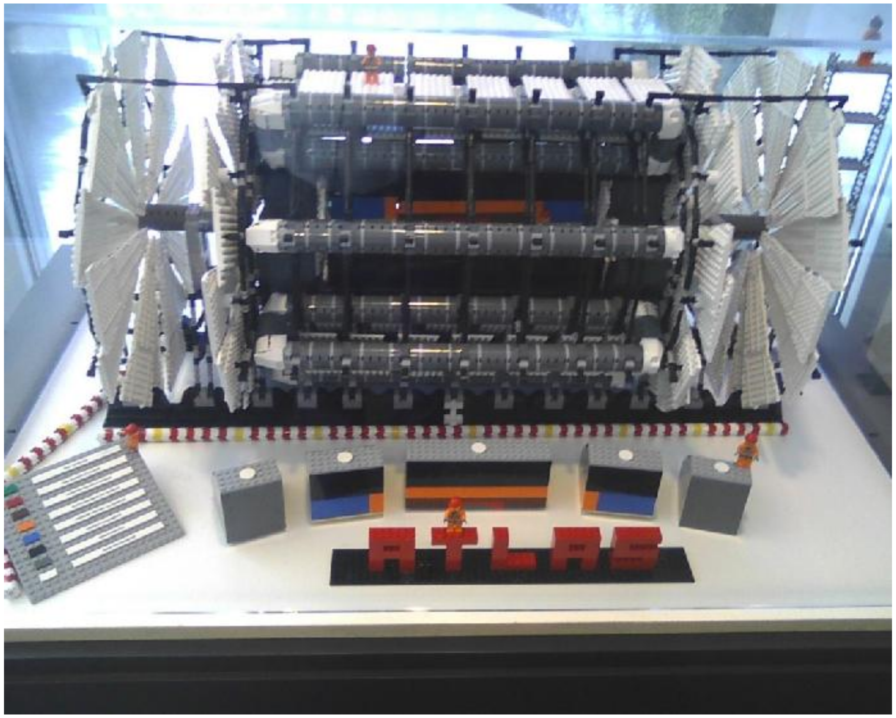
LINAC

https://portal.slac.stanford.edu/sites/lcls_public/headlines/Pages/Headlines-Vol3No2.aspx

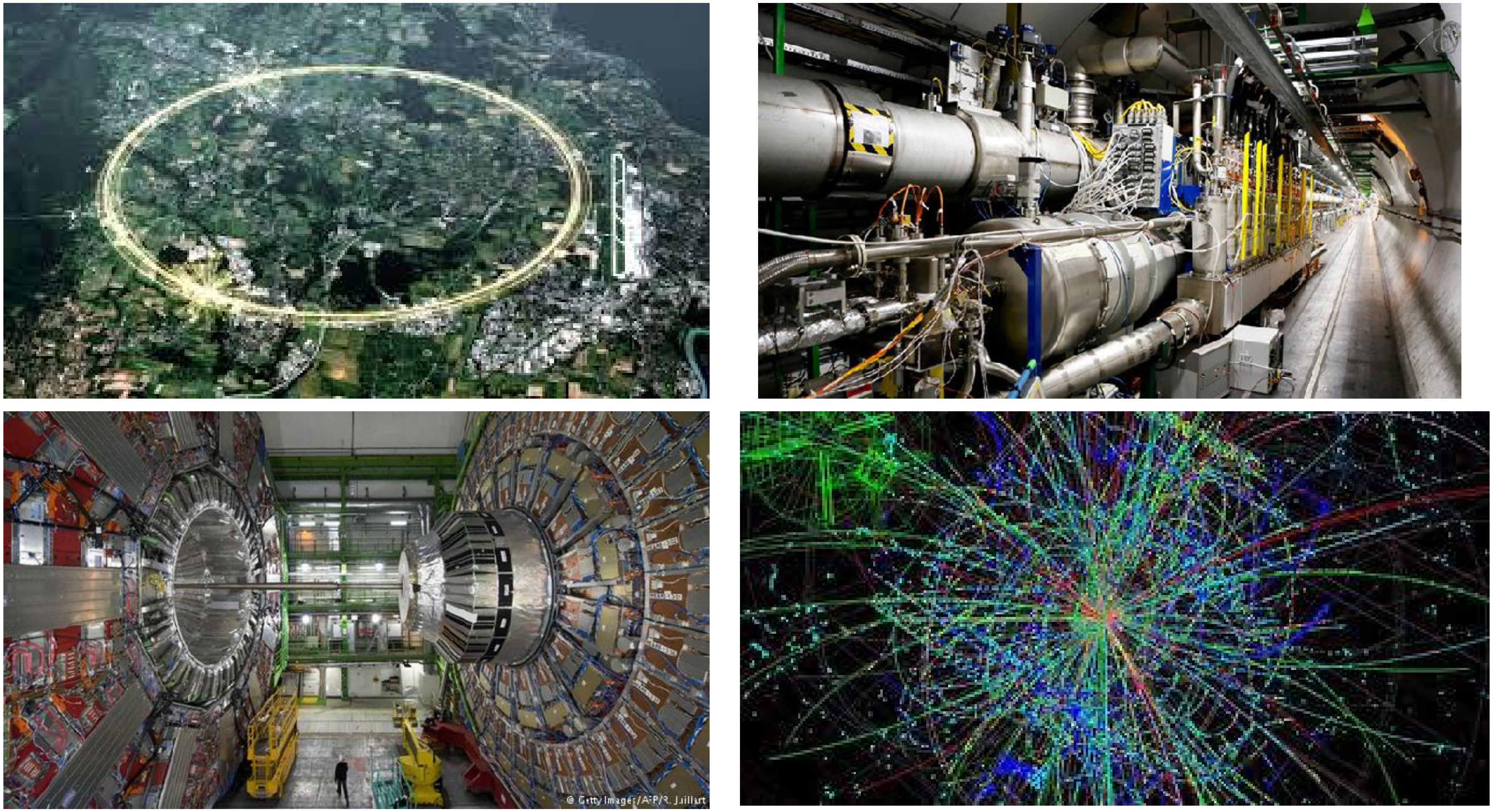
https://www.researchgate.net/figure/Part-of-the-beam-line-in-the-Stanford-Linear-Accelerator-Centre-SLAC-with-Linac_fig3_292748244

Diseñando ATLAS para el HLC





HLC



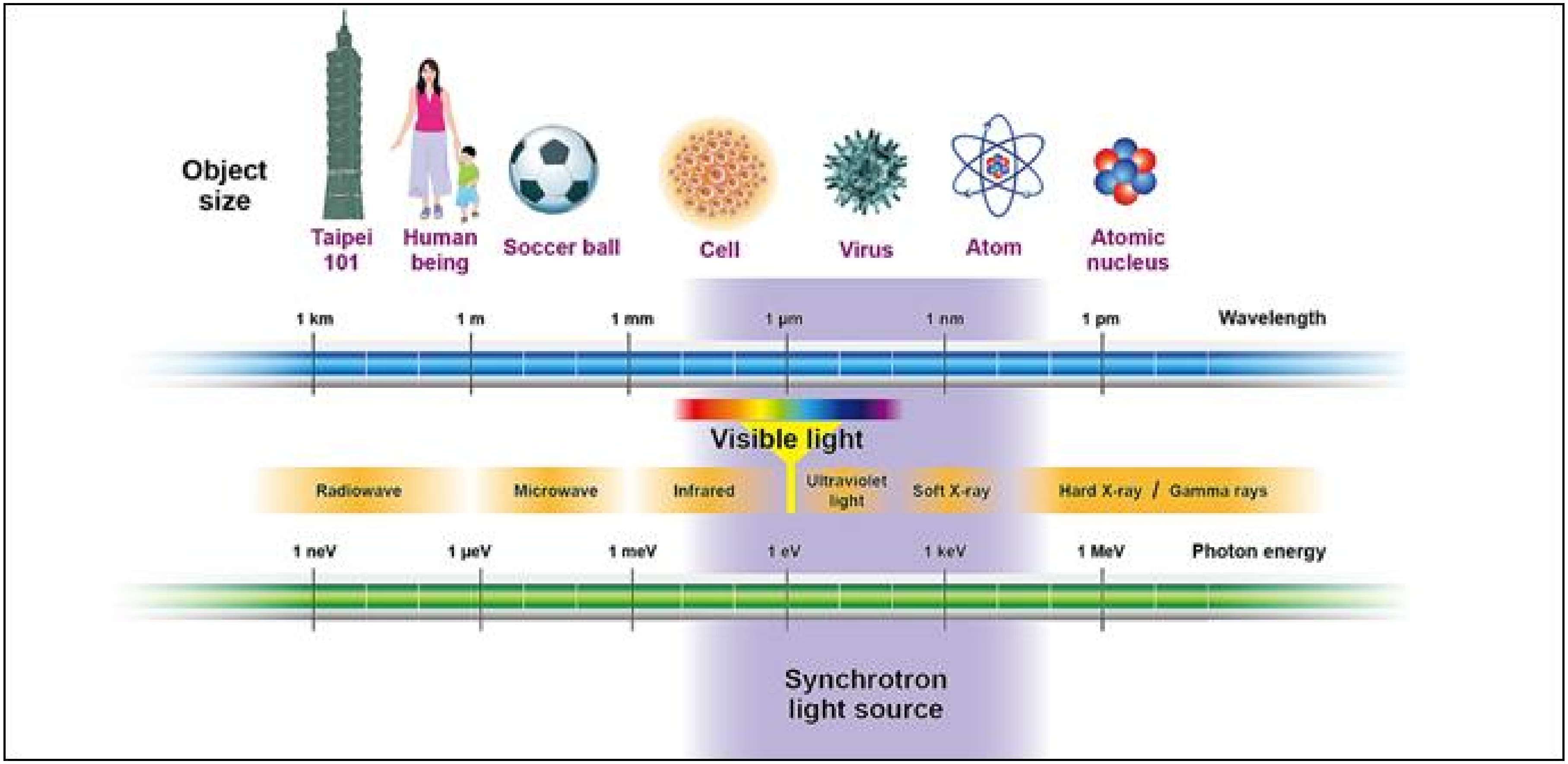
EL SINCROTRON

El sincrotrón

SINCROTRÓN_MEXICANO
Dur_5:52 min
Corte_Final

https://www.youtube.com/watch?v=URZYBwWRqA8

El sincrotrón
El espectro de energías y el estudio de la materia

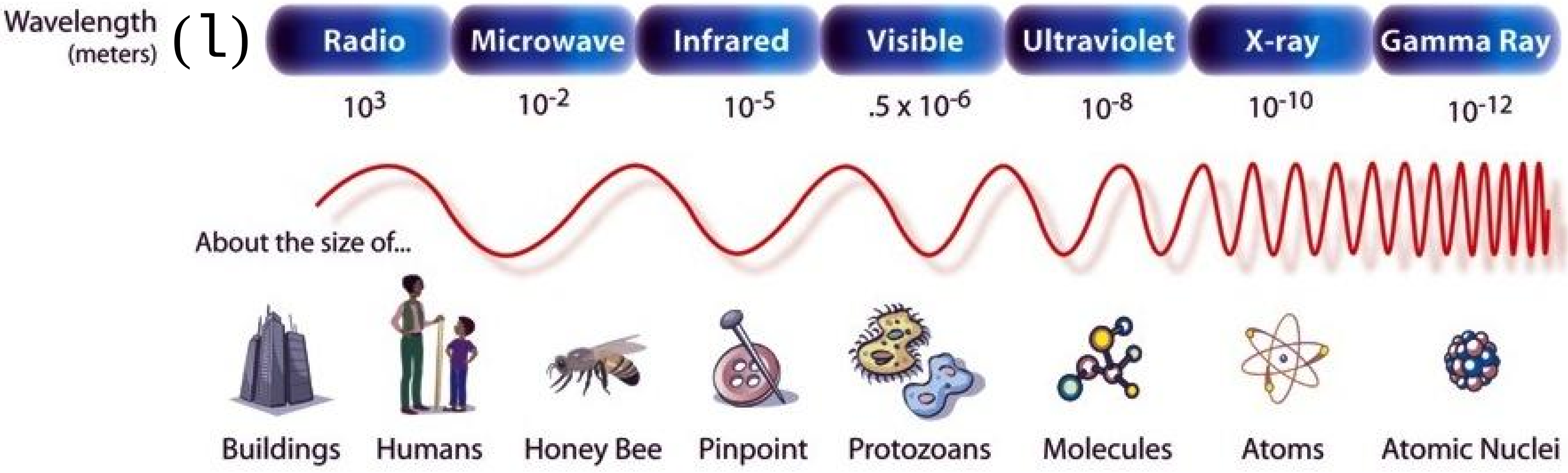


X-rays can probe smaller objects

Dr. Johanna Nelson Weker

In 1920s X-rays placed in the Electromagnetic spectrum

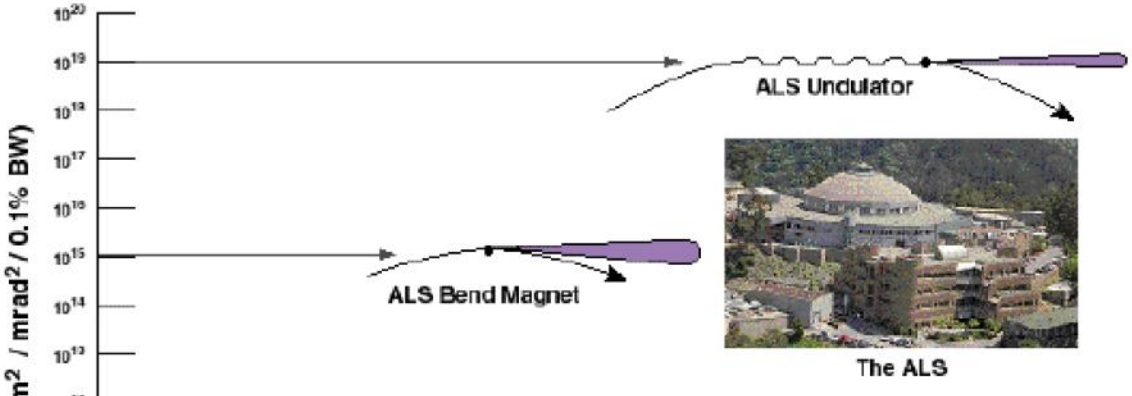
Higher energy (*E*) →

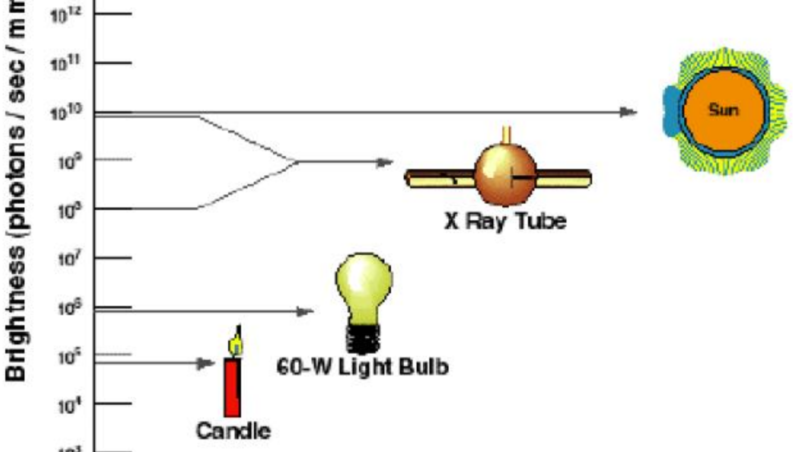


- Shorter wavelength than visible light
    - Probe smaller objects
- Higher energy than visible light

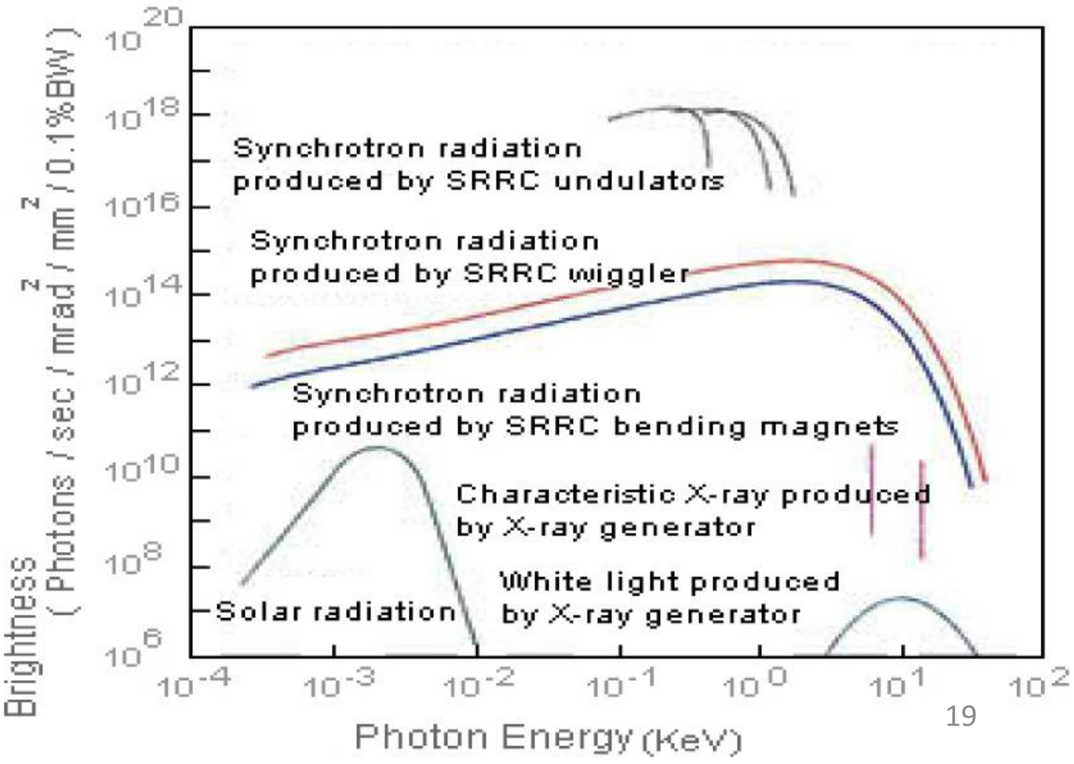
$$\boxed{E = \frac{hc}{l}}$$

¿Que tanta energía tenemos?



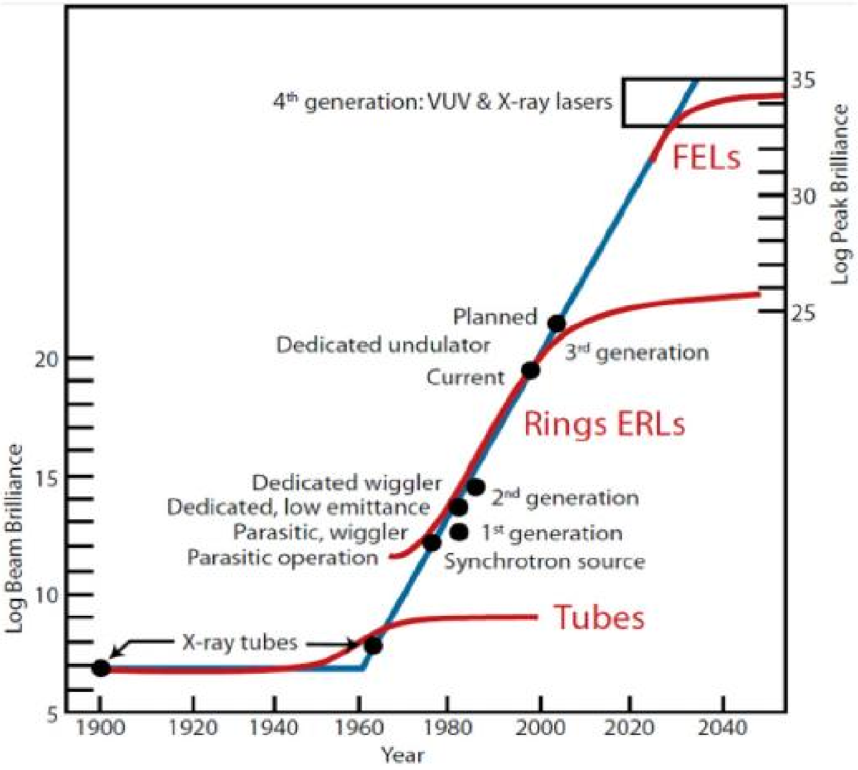


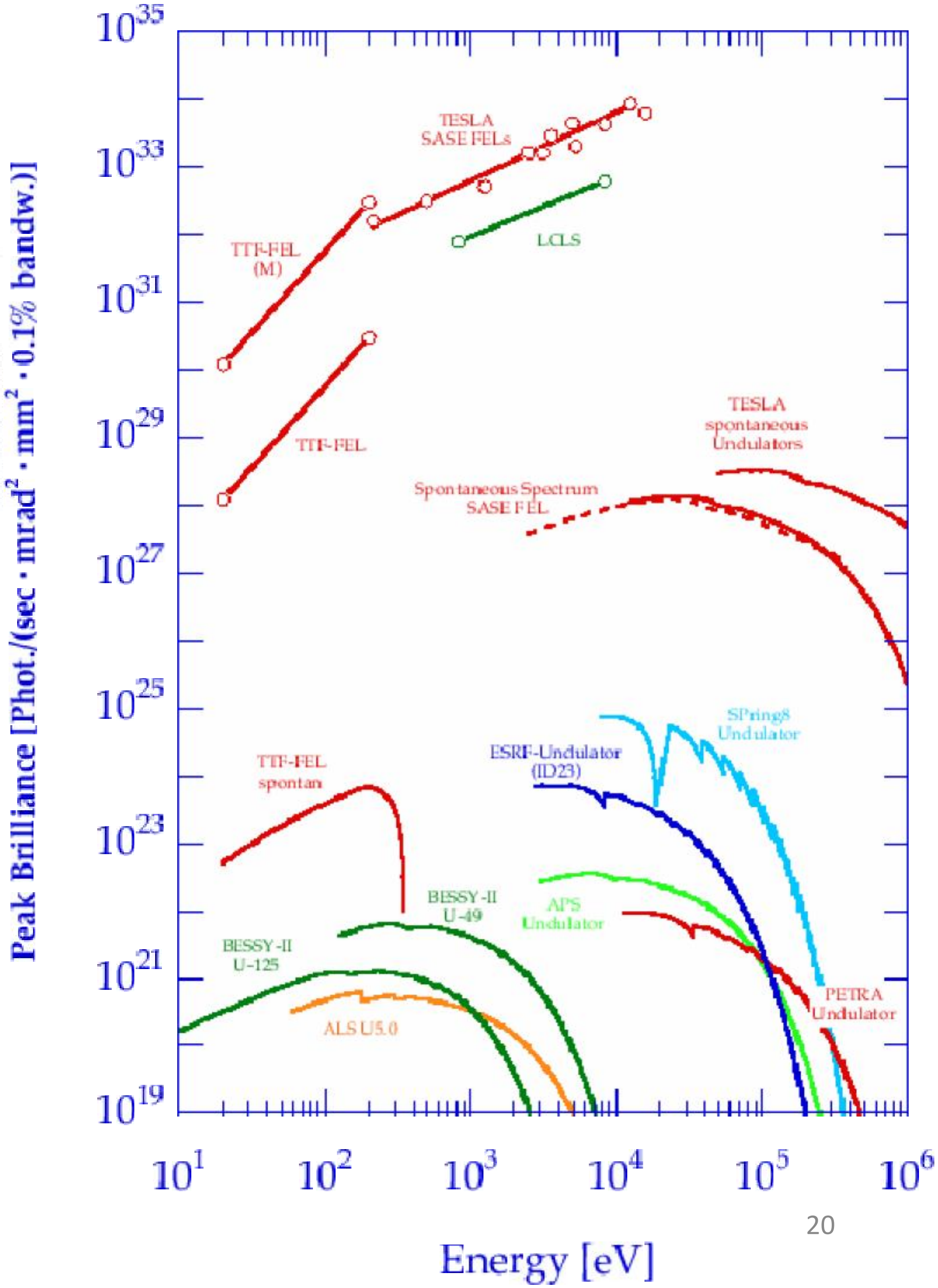
- **Alta brillantez**
- **Amplio espectro de energías**.
- **Sintonizable**
- **Altamente polarizada**
- **Emite en pulsos ultra cortos**



https://www.nsrrc.org.tw/english/lightsource.aspx
https://als.lbl.gov/about/about-the-als/

Evolución y perspectivas

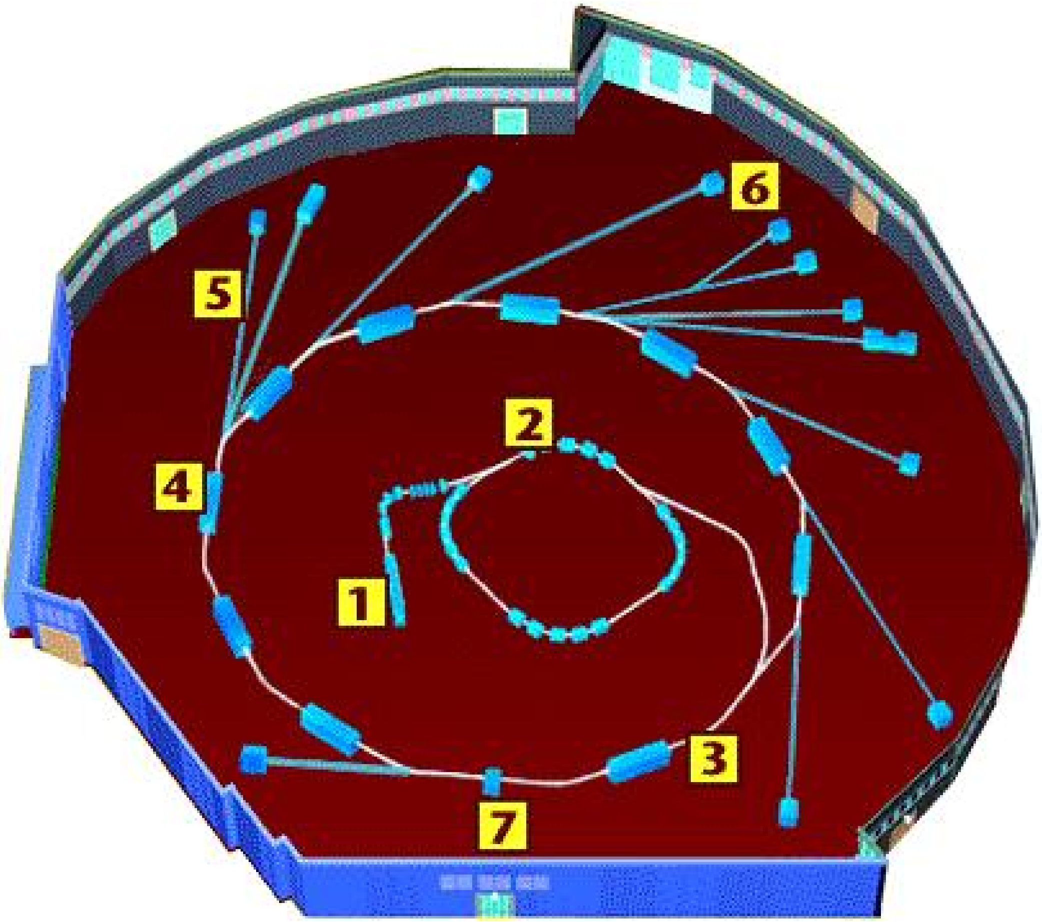




https://www.researchgate.net/figure/X-ray-brilliance-with-orders-of-magnitude-increase-with-time-Tubes-represent-X-tubes_fig2_279773280

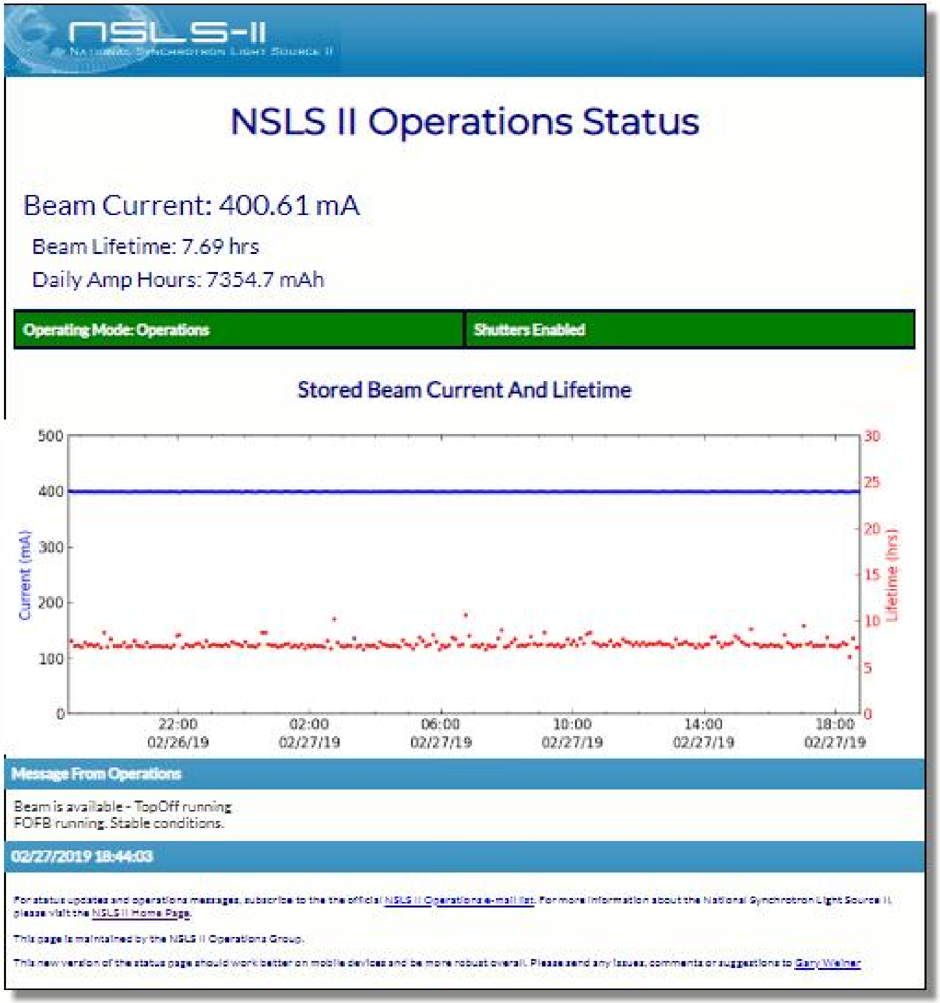
http://photon-science.desy.de/research/students__teaching/sr_and_fel_basics/fel_basics/tdr_spectral_characteristics/index_eng.html

La generación de la luz sincrotrónica



1. Linac (60% or 0.6c)
2. Booster Synchrotron (99.999994%)
3. Storage Ring,
4. Undulators and Wigglers
5. Beamline,
6. Experiment Station,
7. RF System

¿Tenemos haz?



NSLS II Operations Status

Beam Current: 400.61 mA

Beam Lifetime: 7.69 hrs

Daily Amp Hours: 7354.7 mAh

Operating Mode: Operations	Shutters Enabled

Stored Beam Current And Lifetime

Message From Operations

Beam is available - TopOff running
FOFB running. Stable conditions.

02/27/2019 18:44:03

For status updates and operations messages, subscribe to the the official NSLS II Operations e-mail list. For more information about the National Synchrotron Light Source II, please visit the NSLS II Home Page.

This page is maintained by the NSLS II Operations Group.

This new version of the status page should work better on mobile devices and be more robust overall. Please send any issues, comments or suggestions to Gary Weiner

Los aceleradores y nuestro quehacer científico

AREAS DE LA MATERIAL											
Física del estado solido	**Ciencia de los materiales**	**Física Atómica**	**Física molecular**	**Química**	**Foto-química**	**Física nuclear**	**Estructura biomolecular**	**Biología celular**	**Geología**	**Fabricación industrial**	**TÉCNICAS UTILIZADAS**
X	X	X	X		X		X		X		Espectroscopia absorción/reflexión
X	X	X	X		X		X		X		Espectroscopia de emisión
X	X			X				X			Espectromicroscopia
X	X	X	X	X	X		X		X		Espectroscopia de foto-electrones
X	X	X	X	X	X				X		Espectroscopia de fotoiones
X	X	X	X	X	X		X	X	X		EXAFS, XANES
X	X		X								Holografía
X	X		X								Difracción de foto-electrones
X	X		X								Desorción fotoestimulada
X	X		X	X				X			Dicroísmo circular
X	X	X	X	X	X		X	X	X		Análisis por fluorescencia de RX
X		X	X	X							Fotones inelásticamente dispersados
X	X			X	X		X		X		Difracción/dispersión de RX
X	X			X							Ondas estacionarias de RX
	X			X	X		X		X		Dispersión Difusa de RX
	X			X	X		X		X		Dispersión de RX de ángulo rasante
							X	X	X		Microscopia de rayos X suaves
	X									X	Litografía de RX
									X		Tomografía
				X				X			Microtomografía
X	X	X	X				X				Interferometría de RX
								X	X		Imageología de RX
					X					X	Procesamiento asistido por fotones
										X	Microfabricación
						X					Dispersión inversa de Compton

Técnicas básicas

Espectroscopía

Es utilizada para estudiar las energías de las partículas que son emitidas o absorbidas por muestras que son expuestas al haz de luz y es comunmente utilizada para determiner las caracteristicas de los enlaces molegulares y el movimiento de electrones.

Microscópía/imageología

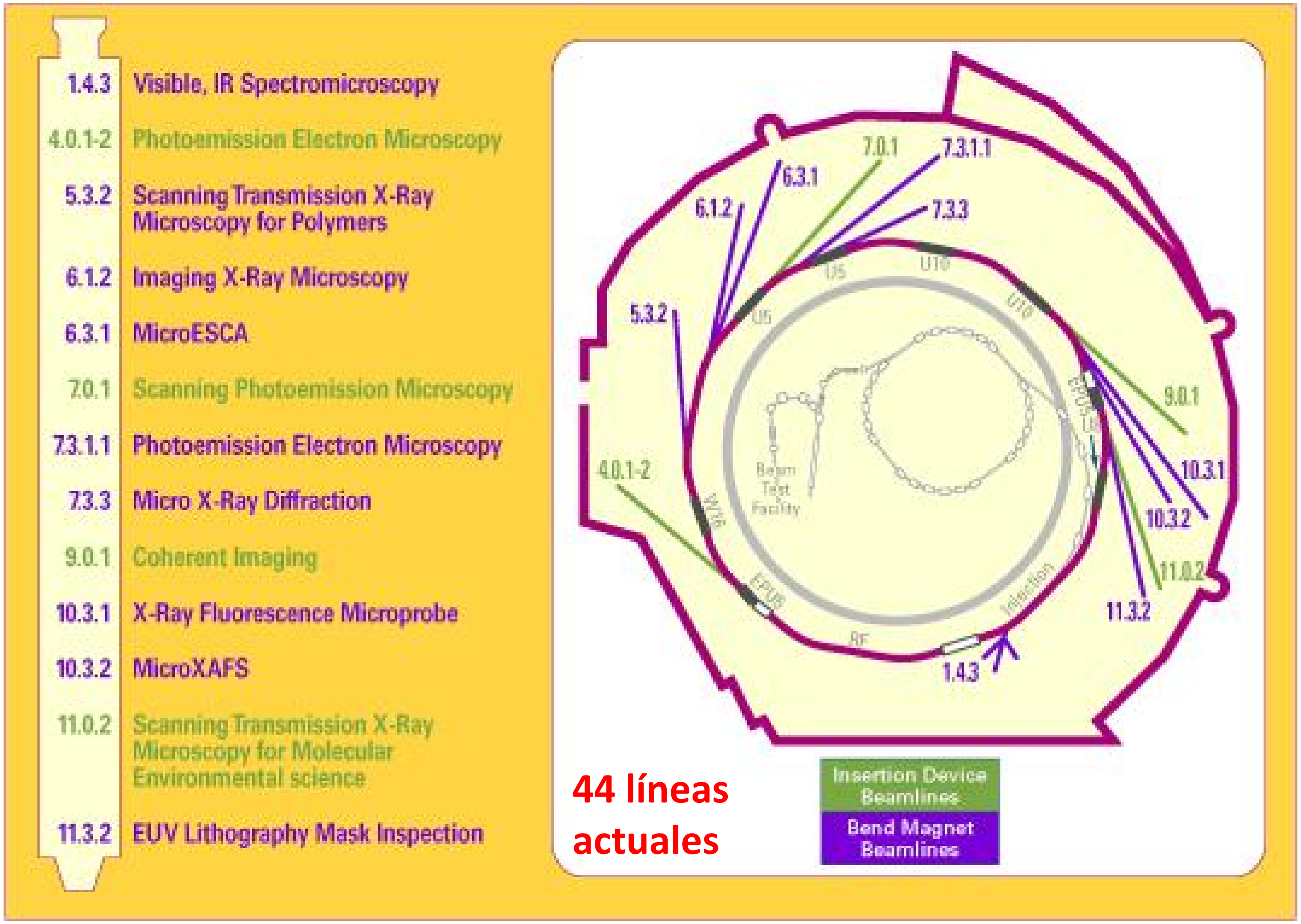
Estas técnicas utilizan el haz de luz para obtener imagines con resolución especial muy fina, de las muestras bajo estudio y son usadas en diversas areas de investigación, tales como la biologia cellular, litografía, microscopia infraroja, radiología y tomografía de rayos-X.

Dispersión/Difracción

Estas técnicas utilizan los patrones de luz producidos cuando los rayos-X son deflectados por la red de atomos estrechamente espaciada en los solidos y tambien para determiner la estructura de de cristales y moleculas grandes, tales como proteinas.

Que podemos hacer y como?

- **Explorar las propiedades de los materiales**
- **Analizar muestras por trazas de elementos**
- **Demostrar la estructura de atomos y moleculas**
- **Estudio de especimenes biologicos**
- **Investigar reacciones químicas**
- **Crear accesorios y maquinas.**

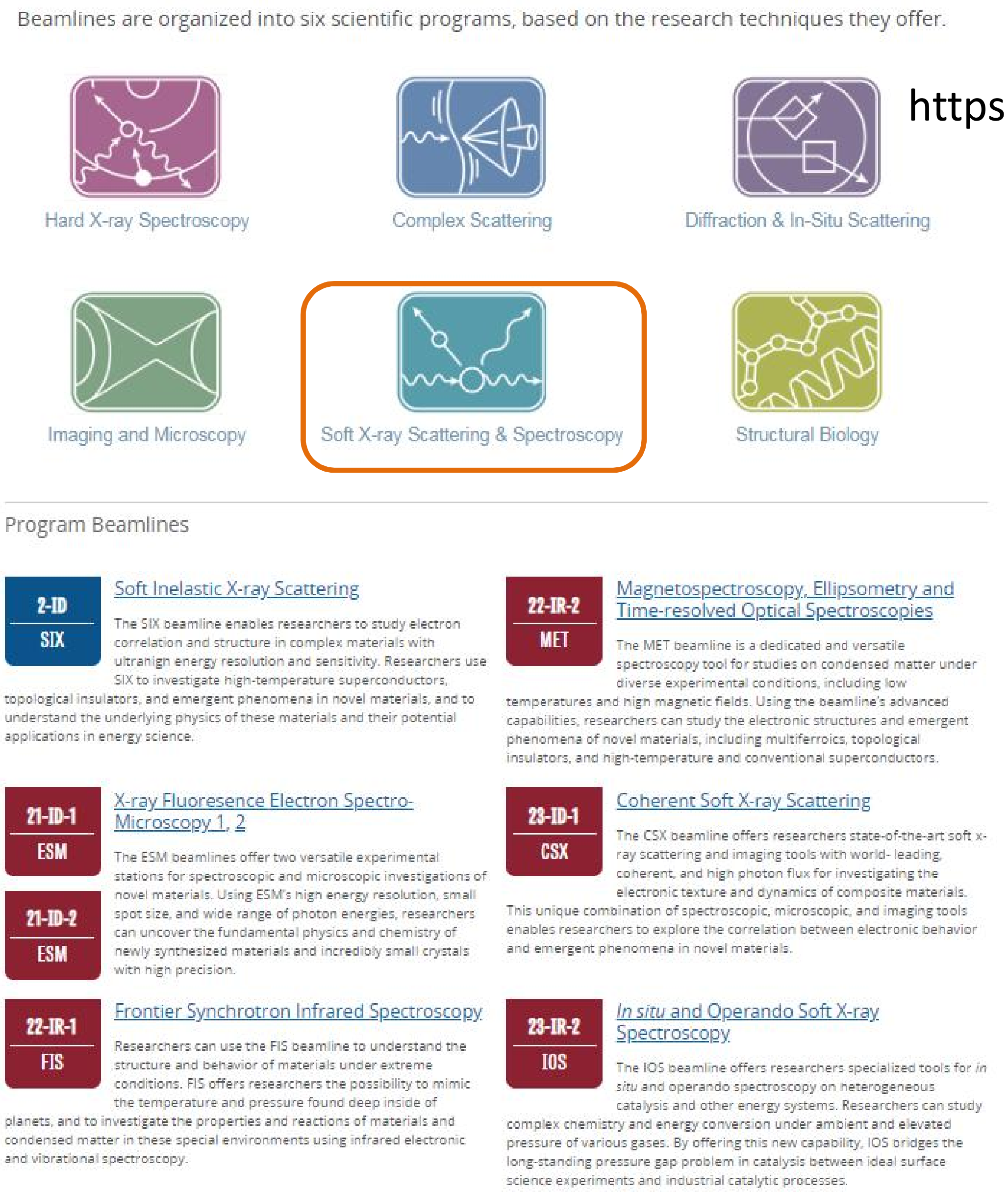


1.4.3	Visible, IR Spectromicroscopy
4.0.1-2	Photoemission Electron Microscopy
5.3.2	Scanning Transmission X-Ray Microscopy for Polymers
6.1.2	Imaging X-Ray Microscopy
6.3.1	MicroESCA
7.0.1	Scanning Photoemission Microscopy
7.3.1.1	Photoemission Electron Microscopy
7.3.3	Micro X-Ray Diffraction
9.0.1	Coherent Imaging
10.3.1	X-Ray Fluorescence Microprobe
10.3.2	MicroXAFS
11.0.2	Scanning Transmission X-Ray Microscopy for Molecular Environmental science
11.3.2	EUV Lithography Mask Inspection

44 líneas actuales

Categorías por programas científicos

https://www.bnl.gov/ps/



Beamlines are organized into six scientific programs, based on the research techniques they offer.

Program Beamlines

2-ID SIX — Soft Inelastic X-ray Scattering

The SIX beamline enables researchers to study electron correlation and structure in complex materials with ultrahigh energy resolution and sensitivity. Researchers use SIX to investigate high-temperature superconductors, topological insulators, and emergent phenomena in novel materials, and to understand the underlying physics of these materials and their potential applications in energy science.

21-ID-1 ESM, **21-ID-2 ESM** — X-ray Fluoresence Electron Spectro-Microscopy 1, 2

The ESM beamlines offer two versatile experimental stations for spectroscopic and microscopic investigations of novel materials. Using ESM's high energy resolution, small spot size, and wide range of photon energies, researchers can uncover the fundamental physics and chemistry of newly synthesized materials and incredibly small crystals with high precision.

22-IR-1 FIS — Frontier Synchrotron Infrared Spectroscopy

Researchers can use the FIS beamline to understand the structure and behavior of materials under extreme conditions. FIS offers researchers the possibility to mimic the temperature and pressure found deep inside of planets, and to investigate the properties and reactions of materials and condensed matter in these special environments using infrared electronic and vibrational spectroscopy.

22-IR-2 MET — Magnetospectroscopy, Ellipsometry and Time-resolved Optical Spectroscopies

The MET beamline is a dedicated and versatile spectroscopy tool for studies on condensed matter under diverse experimental conditions, including low temperatures and high magnetic fields. Using the beamline's advanced capabilities, researchers can study the electronic structures and emergent phenomena of novel materials, including multiferroics, topological insulators, and high-temperature and conventional superconductors.

23-ID-1 CSX — Coherent Soft X-ray Scattering

The CSX beamline offers researchers state-of-the-art soft x-ray scattering and imaging tools with world- leading, coherent, and high photon flux for investigating the electronic texture and dynamics of composite materials. This unique combination of spectroscopic, microscopic, and imaging tools enables researchers to explore the correlation between electronic behavior and emergent phenomena in novel materials.

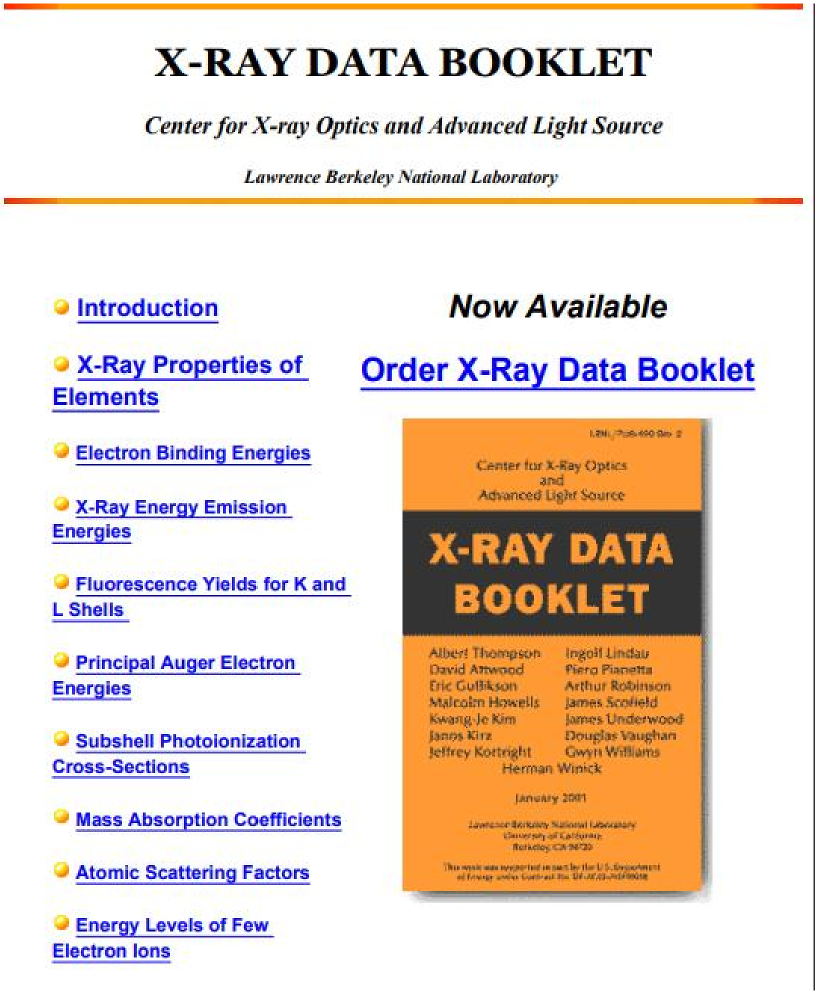
23-IR-2 IOS — *In situ* and Operando Soft X-ray Spectroscopy

The IOS beamline offers researchers specialized tools for *in situ* and operando spectroscopy on heterogeneous catalysis and other energy systems. Researchers can study complex chemistry and energy conversion under ambient and elevated pressure of various gases. By offering this new capability, IOS bridges the long-standing pressure gap problem in catalysis between ideal surface science experiments and industrial catalytic processes.

¿Como identifico las energías-materia?

Orange book

X-ray



X-RAY DATA BOOKLET

Center for X-ray Optics and Advanced Light Source

Lawrence Berkeley National Laboratory

- Introduction
- X-Ray Properties of Elements
- Electron Binding Energies
- X-Ray Energy Emission Energies
- Fluorescence Yields for K and L Shells
- Principal Auger Electron Energies
- Subshell Photoionization Cross-Sections
- Mass Absorption Coefficients
- Atomic Scattering Factors
- Energy Levels of Few Electron Ions

Now Available

Order X-Ray Data Booklet

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X-RAY DATA
BOOKLET

Albert Thompson
David Attwood
Eric Gullikson
Malcolm Howells
Kwang-Je Kim
Janos Kirz
Jeffrey Kortright
Ingolf Lindau
Piero Pianetta
Arthur Robinson
James Scofield
James Underwood
Douglas Vaughan
Gwyn Williams
Herman Winick

January 2001

http://xdb.lbl.gov/xdb.pdf

Range to cover: Beamline flux curve

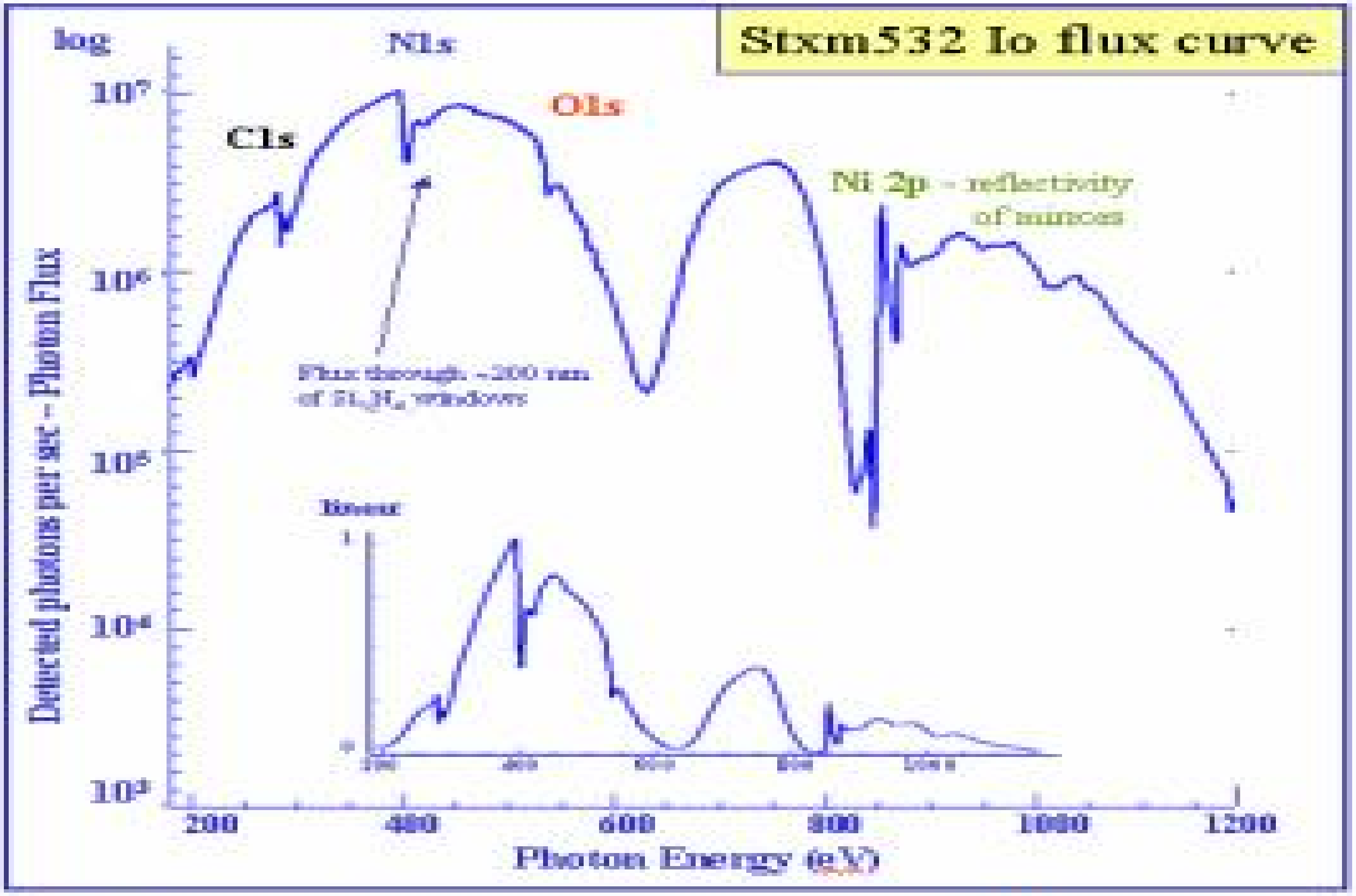


Fig. 1.2 Extended range flux curve of BL 532

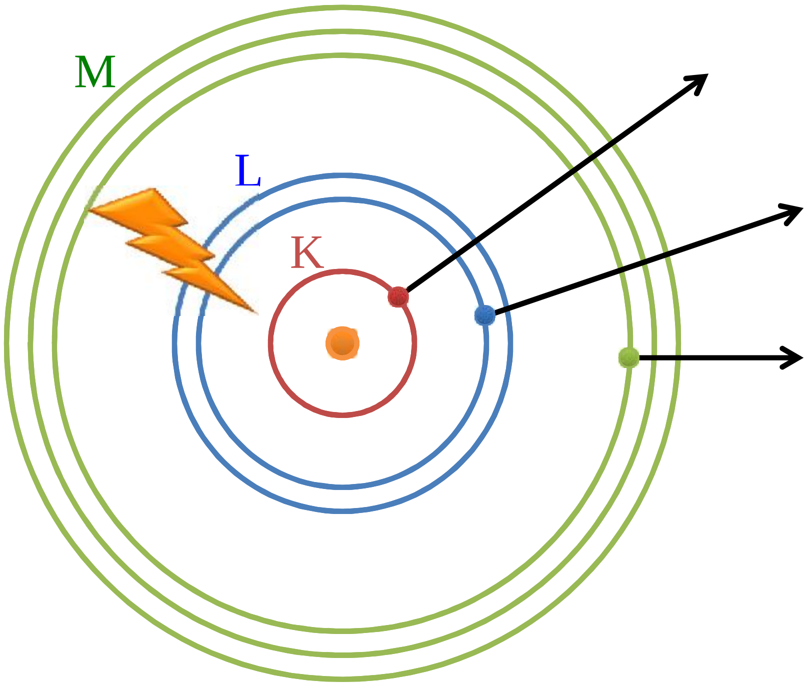
http://www2.lbl.gov/Science-Articles/Archive/sabl/2005/August/assets/docs/STXM_Beamline_5-3-2_Manual.pdf

Spectroscopic Imaging: absorption contrast

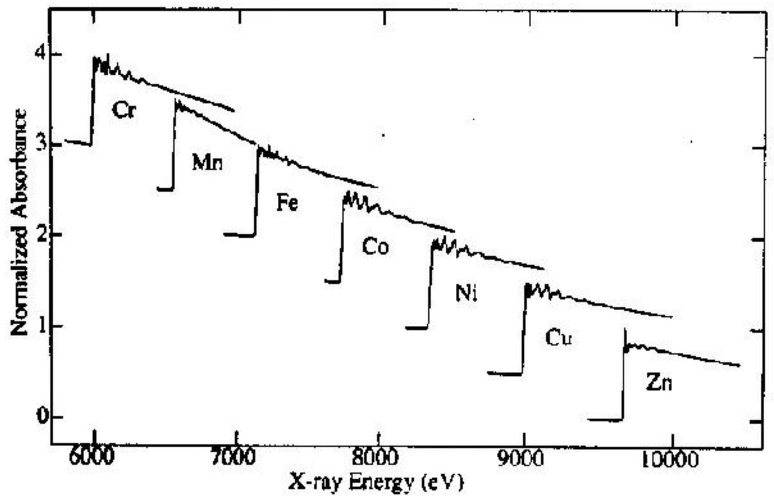
Electron Binding energies:

$E_K > E_L > E_M$

Binding energy = energy required to kick an electron completely out of the atom (characteristic to the element)

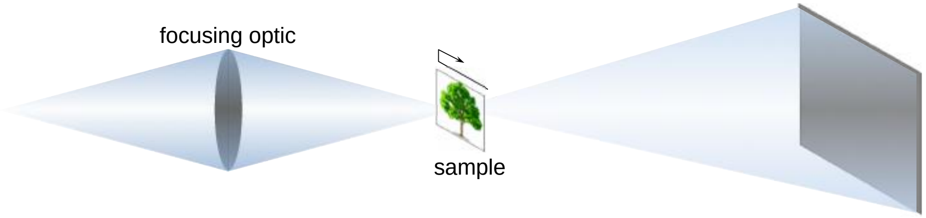


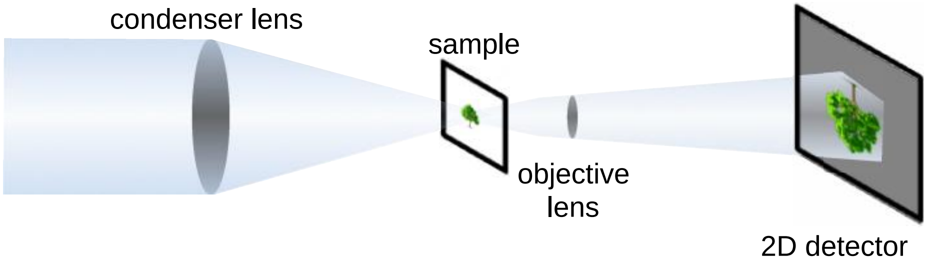
Photons with energy matching an electron binding energy are more likely to be absorbed



LAS TÉCNICAS

Full Field – Scanning microscopy
Benefits/downsides of each microscopy





Scanning

Pros

- Low dose
- Florescence or electron detection modes
- Variable field of view (“zoom in”)
- Compatible with mirror-based optics

Cons

- Slow

Full field

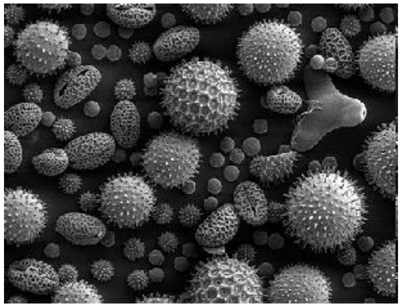
Pros

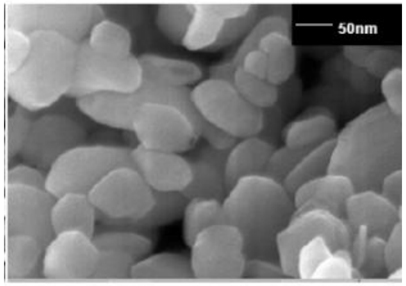
- Fast (3D, dynamics, …)

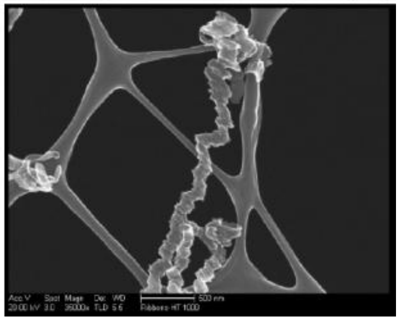
Cons

- High dose
- Field of view fixed by optic

Microscopy and spectroscopy → STXM







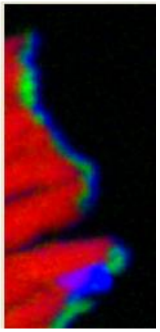
- OPTICAL
- AFM
- SPM
- SEM
- TEM
- CONFOCAL

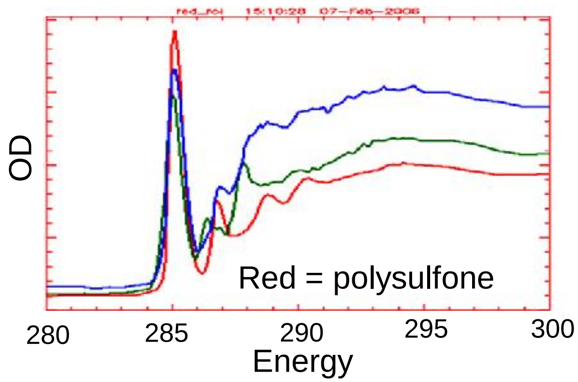
- FTIR
- RAMAN
- XANES
- NEXAFS
- EELS
- XPS

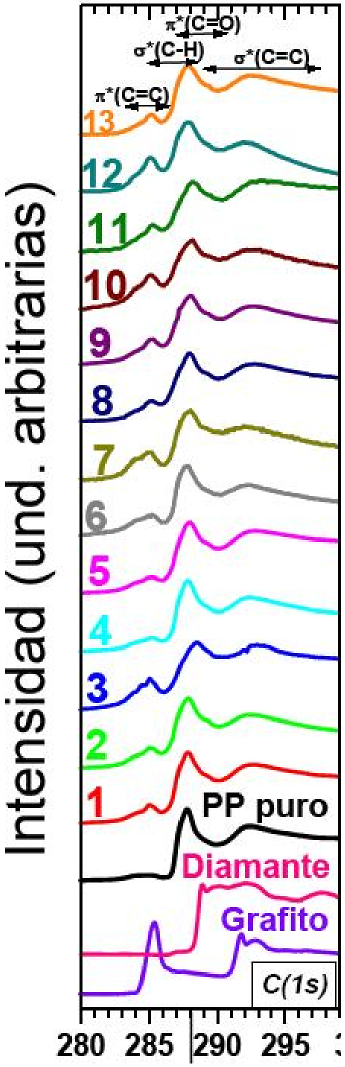
Resolution (spatial and spectral)

EDX
STXM
PEEM

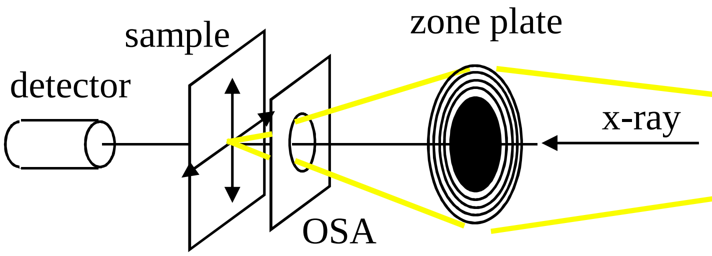
FTIR
XRF



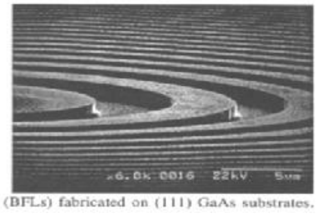




Scanning Transmission X-ray Microscopy (STXM)



Non-uniformly spaced X-ray opaque Au rings on X-ray transparent silicon nitride



SAMPLE:
filler particle impregnated polyurethane (courtesy: Dow)

Spatial resolution: ~ 50 nm → ~25 nm
analytics: NEXAFS
other possible detection modes:
luminescence, electron yield . . .

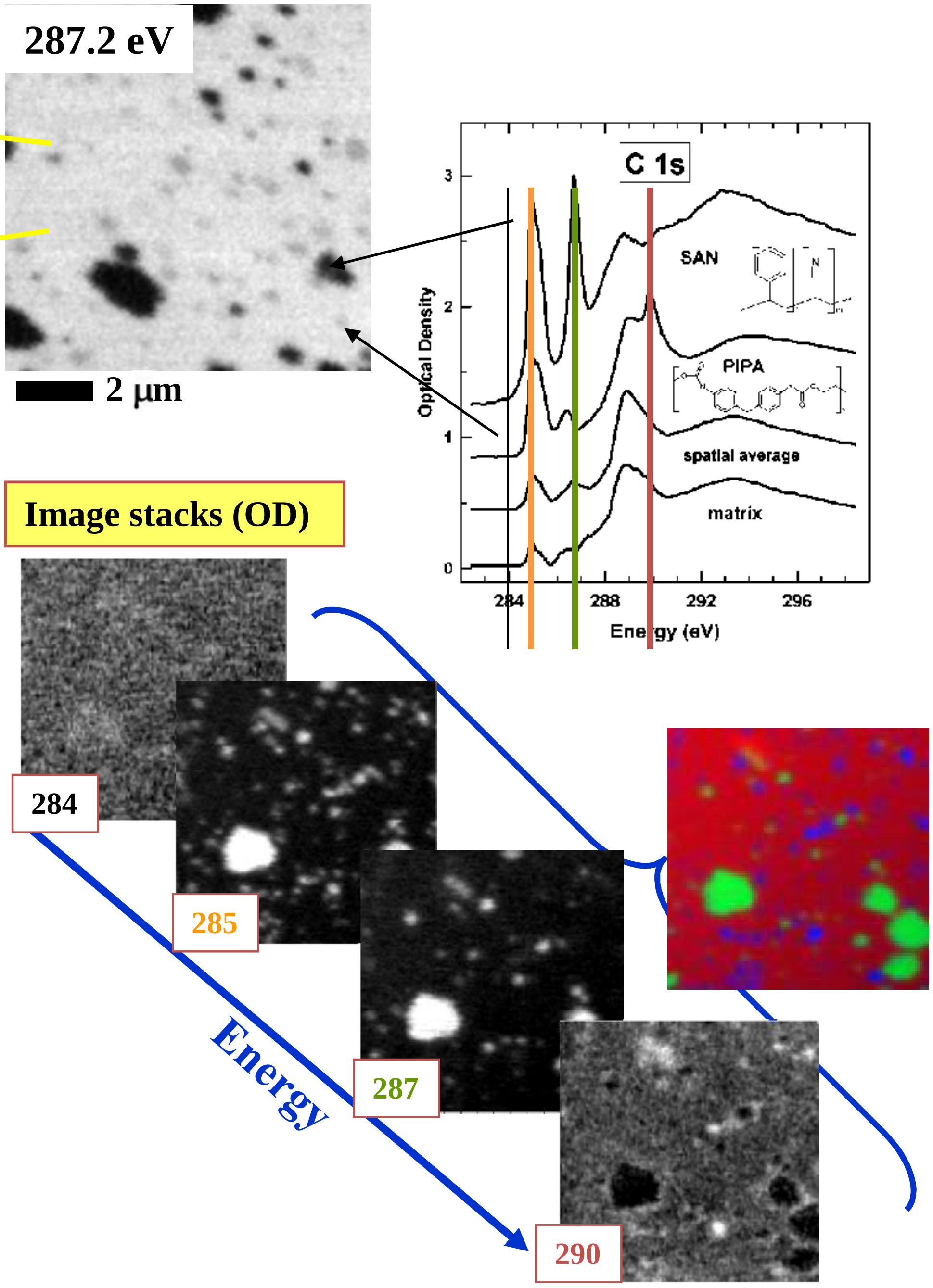
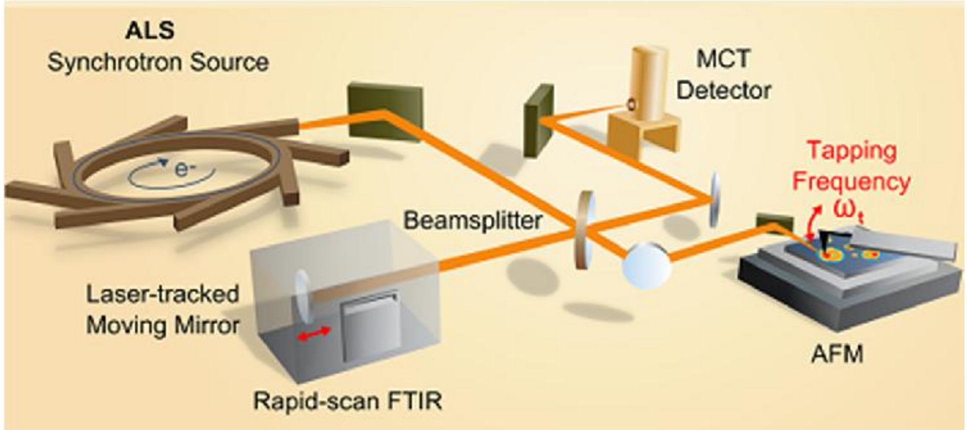


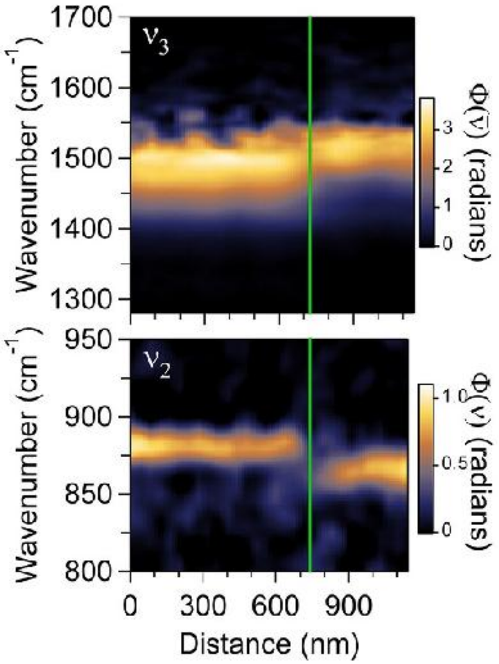
Image stacks (OD)

Técnicas hibridas (AFM-FTIR)

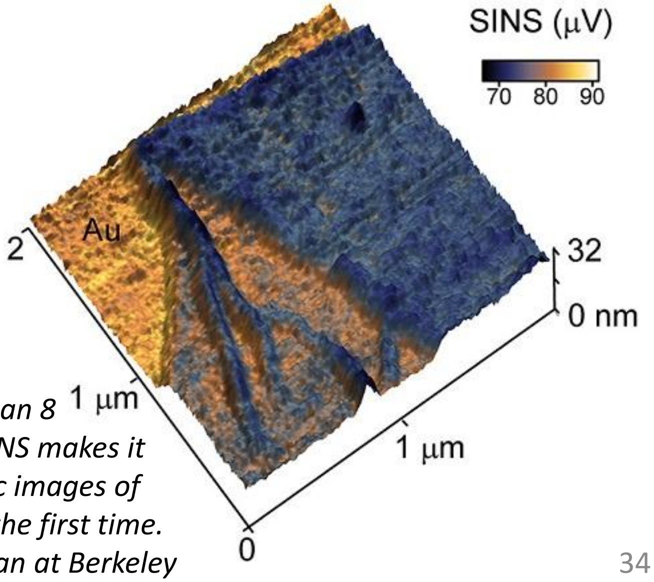
https://microscopy-analysis.com/editorials/editorial-listings/afm-synchrotron-light-probes-molecular-chemistry

AFM-synchrotron light probes molecular chemistry



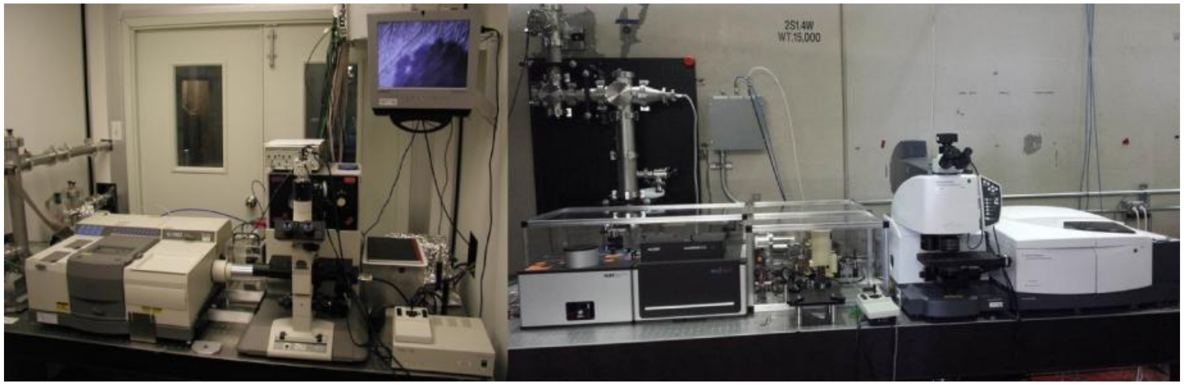


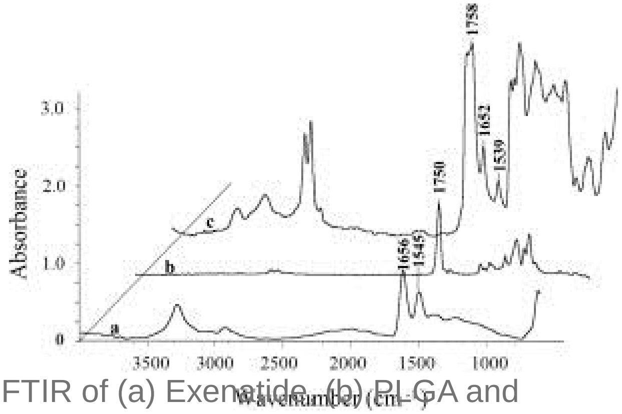
A spectral-linescan of a blue mussel shell, which transitions from calcite to aragonite, illustrates the spatial resolution and spectroscopic range capabilities of the SINS technique. [Berkeley Labs]



This peptoid nanosheet is less than 8 nanometres at certain points. SINS makes it possible to acquire spectroscopic images of these ultra-thin nanosheets for the first time. [Gloria Olivier and Ron Zuckerman at Berkeley Lab]

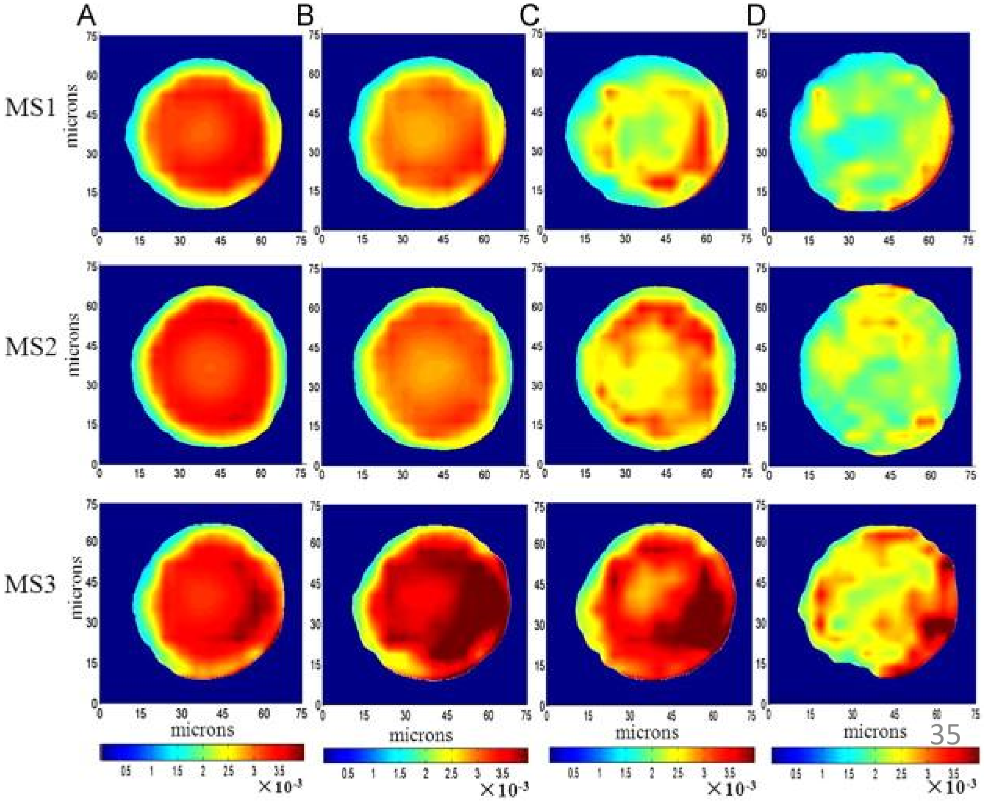
Microscopia y tomografía InfraRojo





SR-FTIR of (a) Exenatide, (b) PLGA and (c) single microsphere.

Optical path normalized image of different microspheres (MS1–MS3). (A) Carbonyl ester bond at 1750 cm^{-1} of PLGA; (B) CH_2 wagging at 1450 cm^{-1} of PLGA; (C) amide I bond at 1656 cm^{-1}; (D) amide II bond at 1545 cm^{-1}.



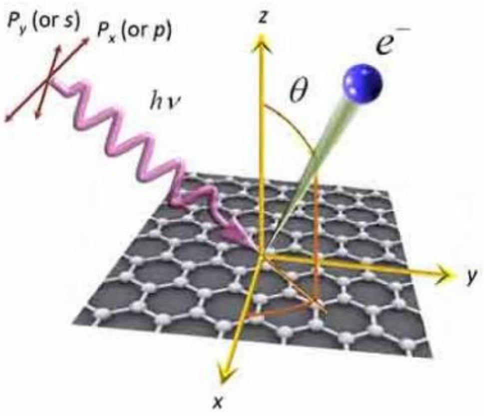
https://doi.org/10.1016/j.apsb.2015.03.008

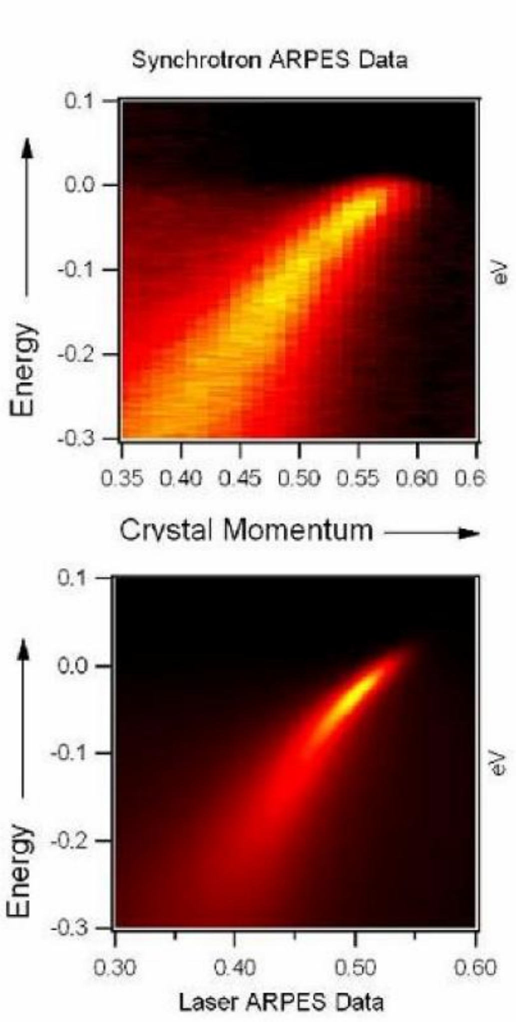
ARPES

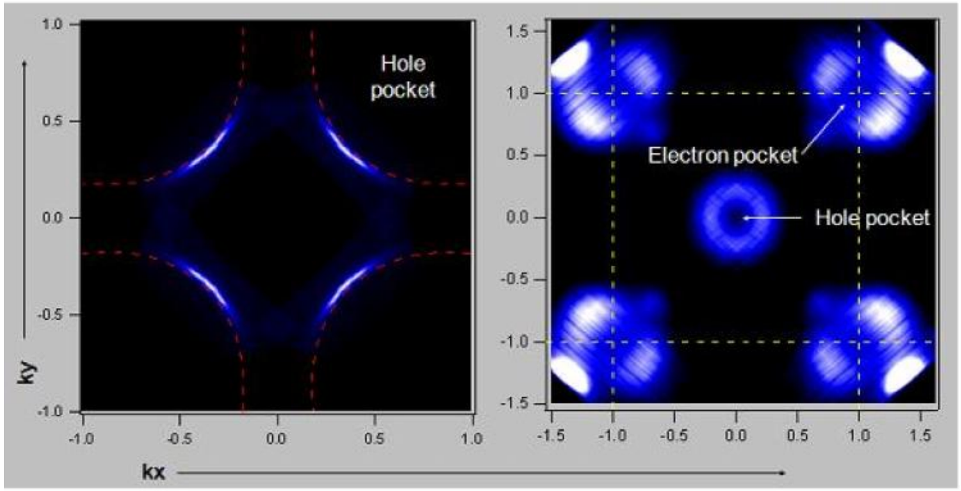
spatially-resolved **Angle-Resolved Photoemission Spectroscopy**

MAESTRO, the Microscopic and Electronic STRucture Observatory (ALS)

Cuando los fotones a una energía definida inciden sobre una muestra, permiten la medición de la energía cinetica y el ángulo de salida, brindando así información sobre el momento y el estado de la energía del electron en el material.

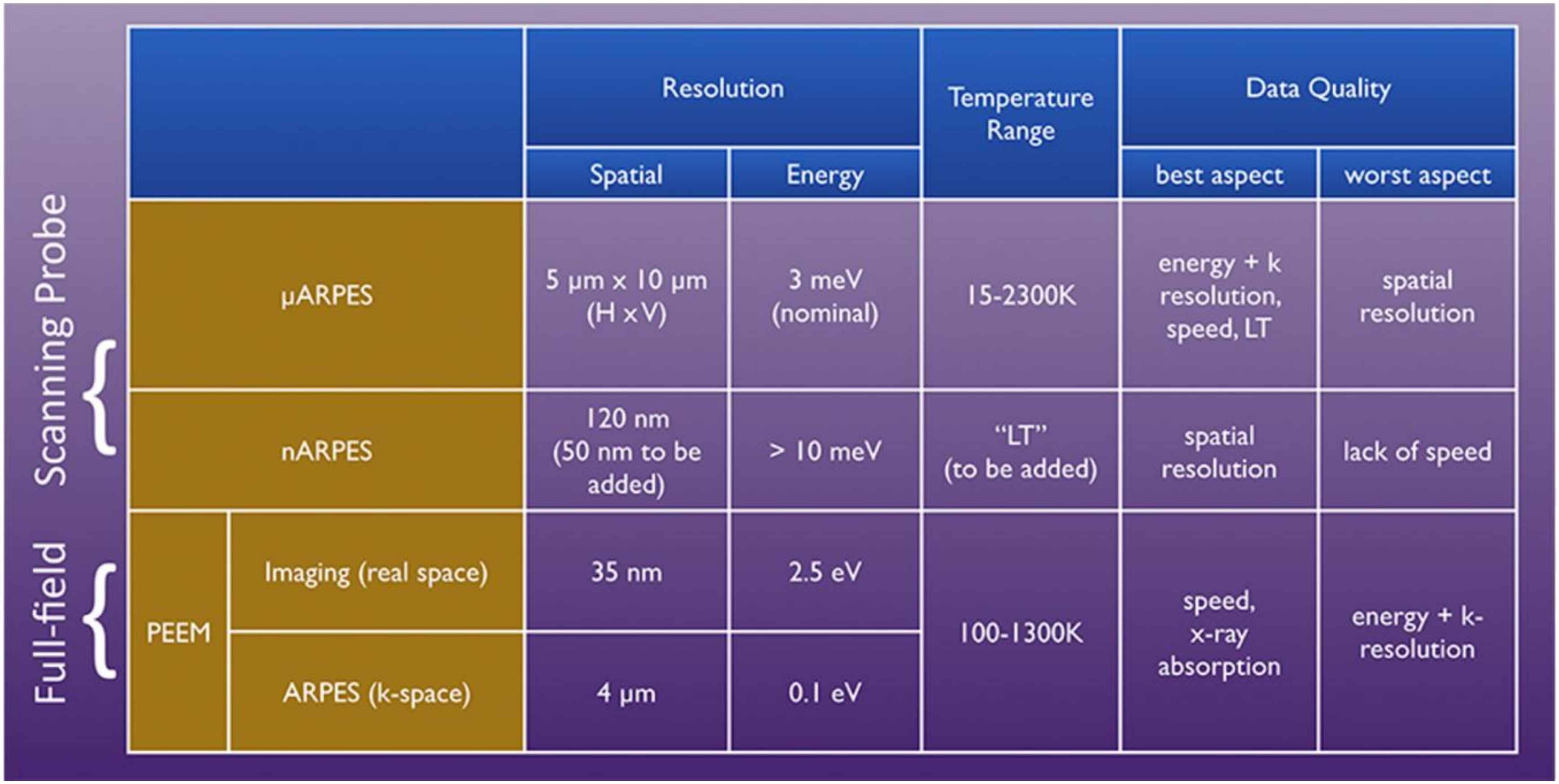






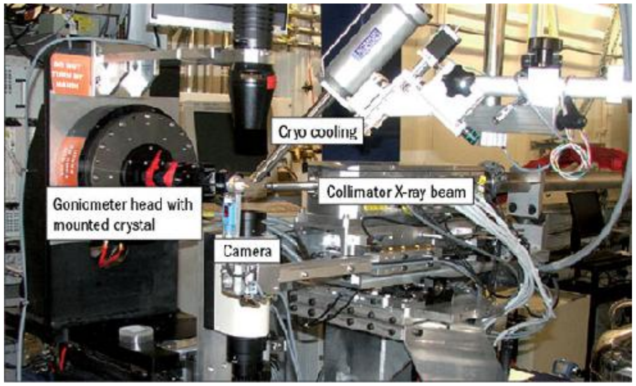
http://research.physics.berkeley.edu/lanzara/arpes.html

“tipos” de ARPES

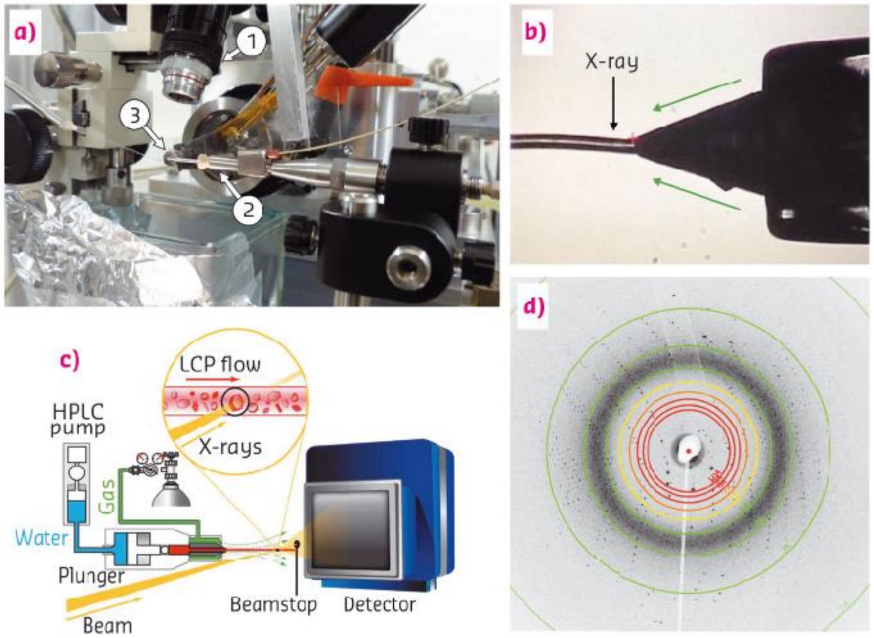


			Resolution		Temperature Range	Data Quality	
			Spatial	Energy		best aspect	worst aspect
Scanning Probe	μARPES		5 μm x 10 μm (H x V)	3 meV (nominal)	15-2300K	energy + k resolution, speed, LT	spatial resolution
	nARPES		120 nm (50 nm to be added)	> 10 meV	“LT” (to be added)	spatial resolution	lack of speed
Full-field	PEEM	Imaging (real space)	35 nm	2.5 eV	100-1300K	speed, x-ray absorption	energy + k-resolution
		ARPES (k-space)	4 μm	0.1 eV			

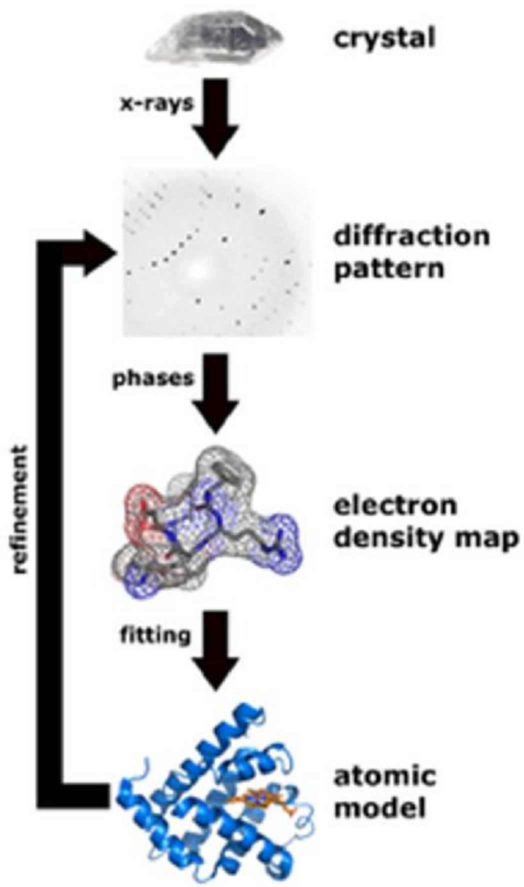
Cristalografía de proteínas



http://www.labtimes.org/labtimes/method/methods/2011_02.lasso

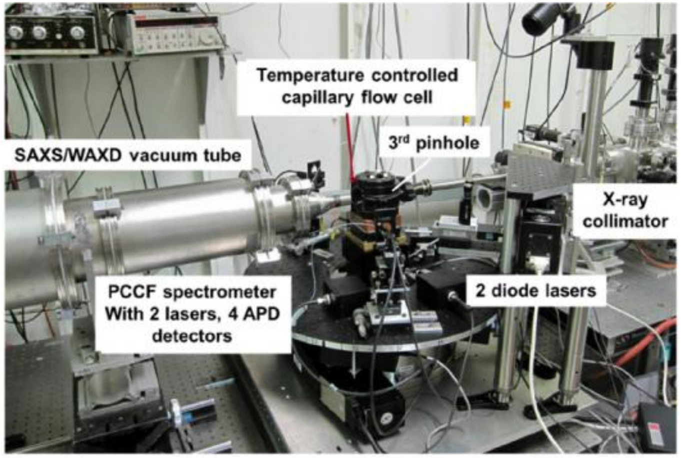


http://www.esrf.eu/home/UsersAndScience/Publications/Highlights/highlights-2015/structural-biology/sb10.html

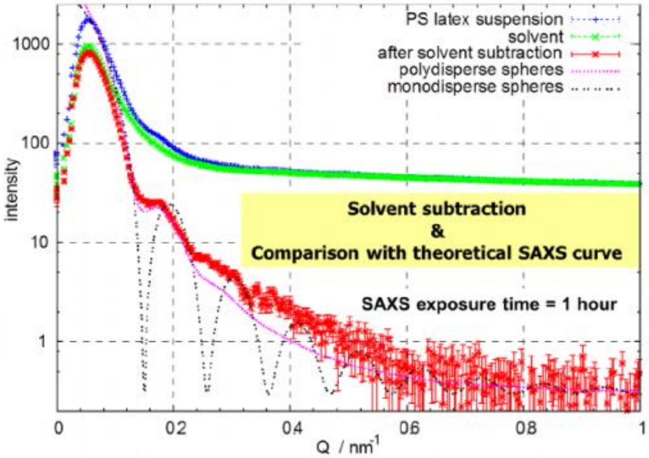


https://en.wikipedia.org/wiki/X-ray_crystallography

SAXS (dispersión - angular)



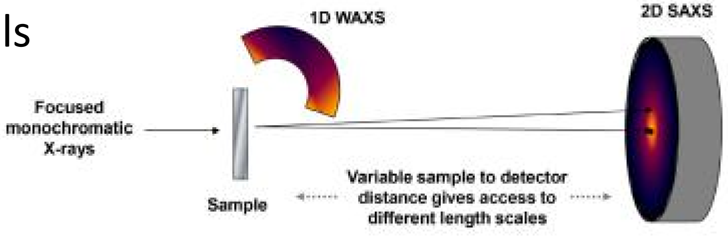
https://www.researchgate.net/figure/Combined-3D-PCCF-spectroscopy-and-synchrotron-SAXS-WAXD-set-up_fig3_276071127



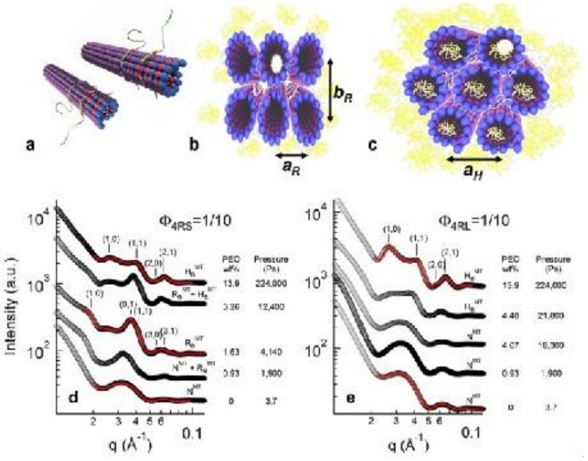
It can be applied to samples that are either difficult or impossible to crystallise, may be complex or composite systems or materials with large scale self-organisation.

https://www.diamond.ac.uk/industry/Techniques-Available/Small-Angle-X-ray-Scattering-SAXS.html

- Proteins & Biomaterials
- Polymers
- Environmental
- Colloids & Surfactants



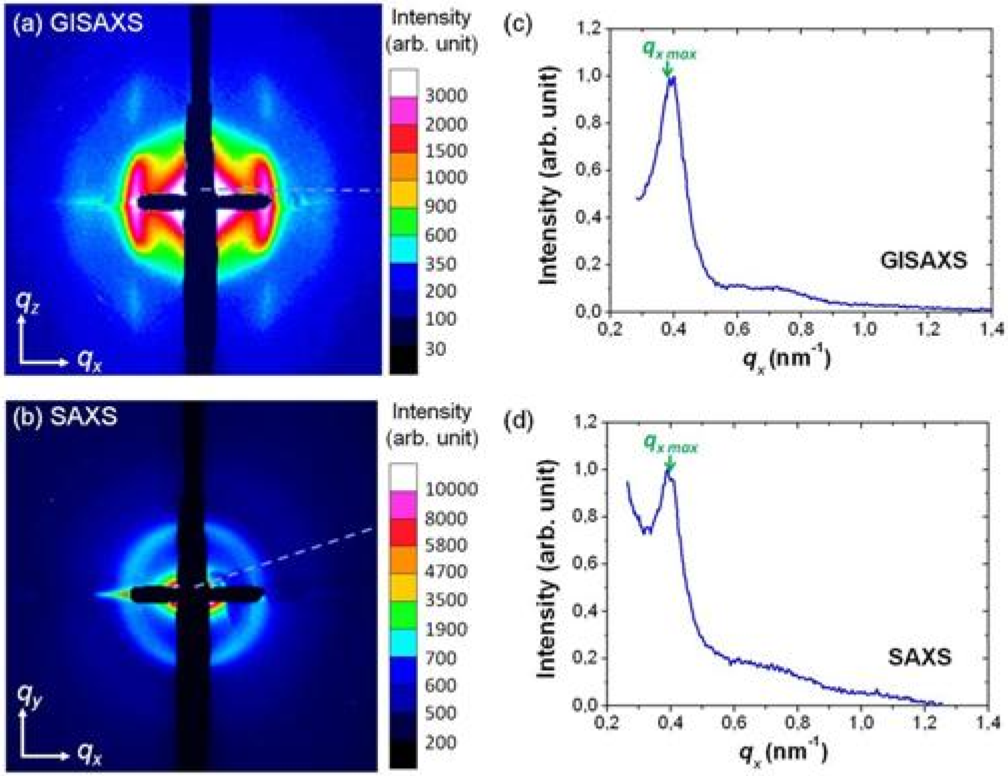
Synchrotron Small Angle X-ray Scattering Studies Reveal the Role of Neuronal Protein Tau in Microtubule Bundle Formation with Architectures Mimicking those Found in Neurons



SIXS (dispersión – superficie)

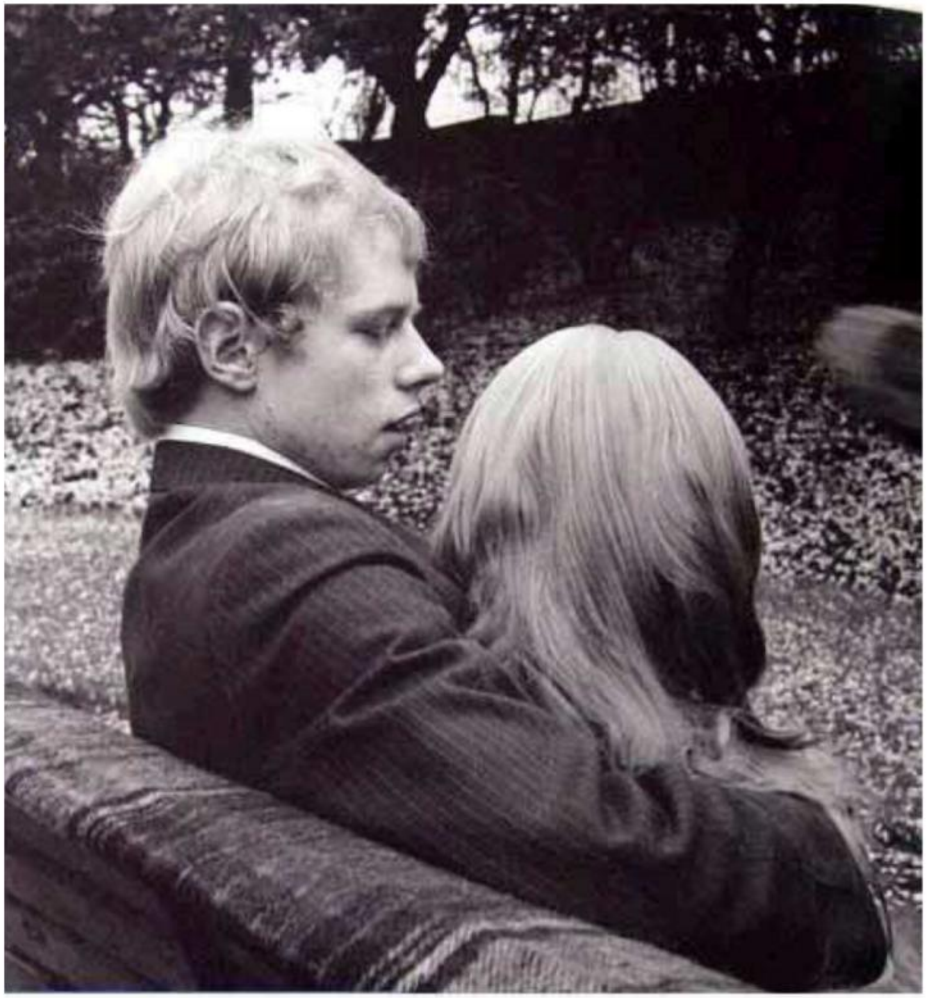
SixS (Surface Interface X-ray Scattering) is a beamline dedicated to the study of X-ray scattering from surfaces and interfaces of hard and soft matter in various environments in the 5-20 keV energy range. To be sensitive to the surface all the studies will be performed in grazing-incidence geometry.

dedicated to structural studies of interfaces (gas-solid, solid-solid or solid-liquid), as well as nano-objects.

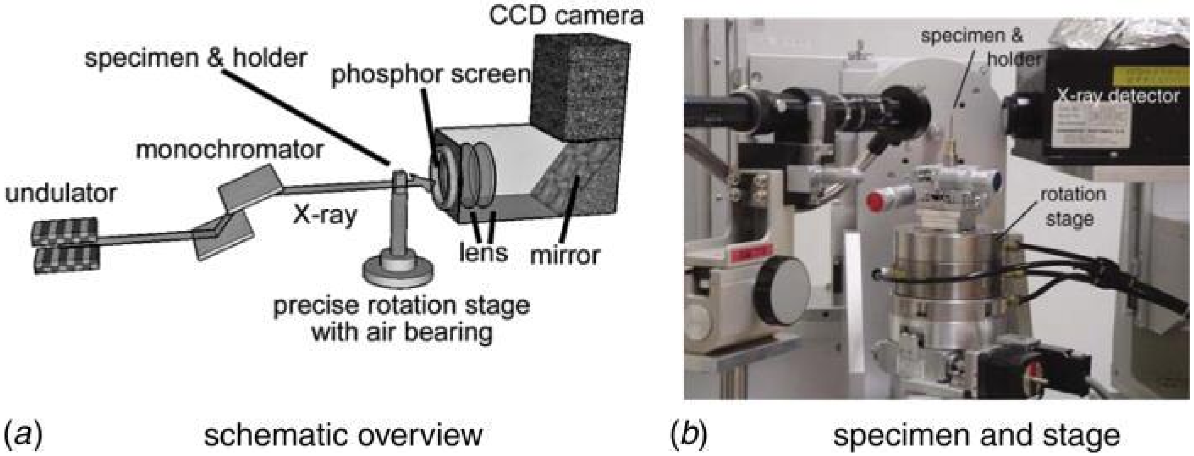


https://www.synchrotron-soleil.fr/fr/lignes-de-lumiere/sixs

2D imaging can be misleading!

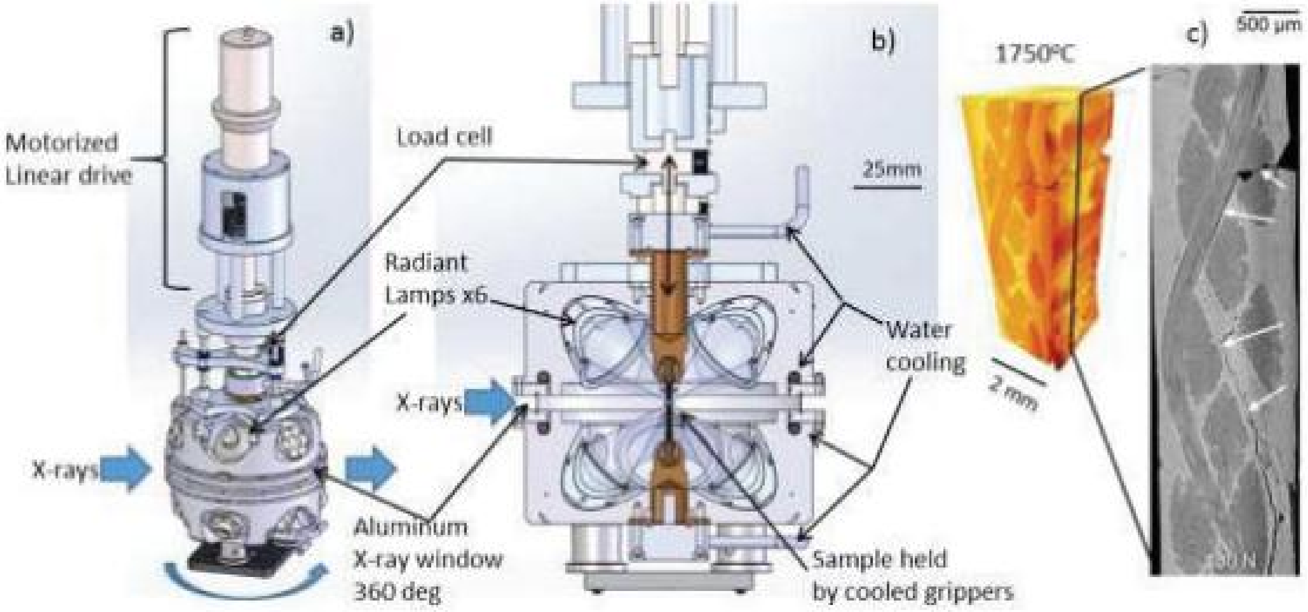


Microtomografia (µCT)



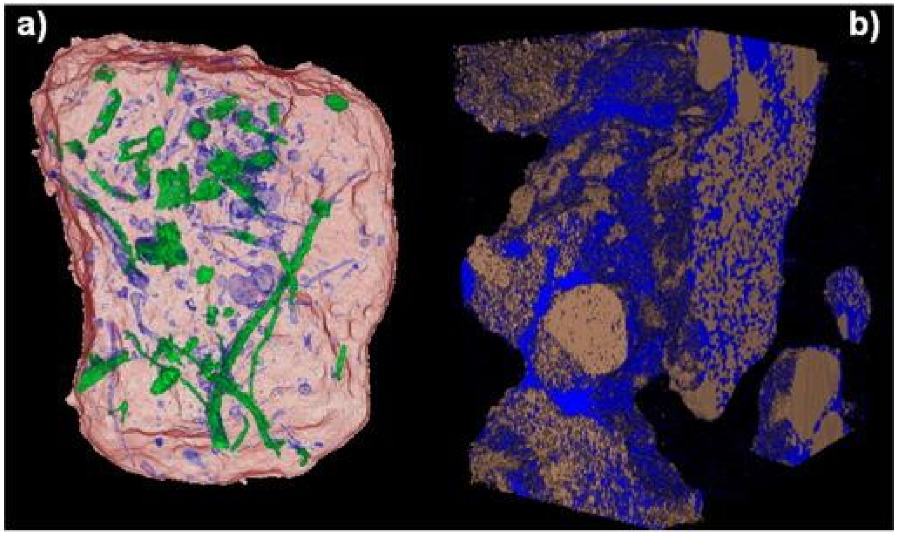
(*a*) schematic overview (*b*) specimen and stage

http://electronicpackaging.asmedigitalcollection.asme.org/article.aspx?articleid=1409860



https://aip.scitation.org/doi/pdf/10.1063/1.4952925

Microtomografia (µCT)

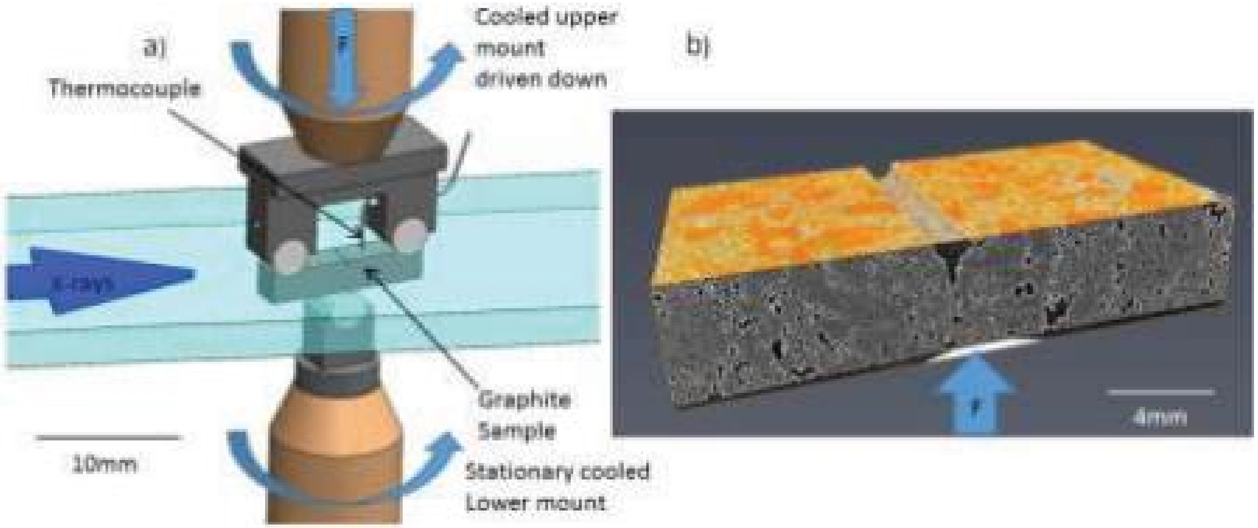


Geoderma, Volume 287, 1 February 2017, Pages 31-39
Soil pores and their contributions to soil carbon processes

Examples of X-ray µ-CT images of (a) pieces of particulate organic matter (green) and pores (blue) identified within a soil macro-aggregate(6 µm resolution); and b) water (blue) filled pores within solid matrix (brown) of soil sample (2 µm resolution).

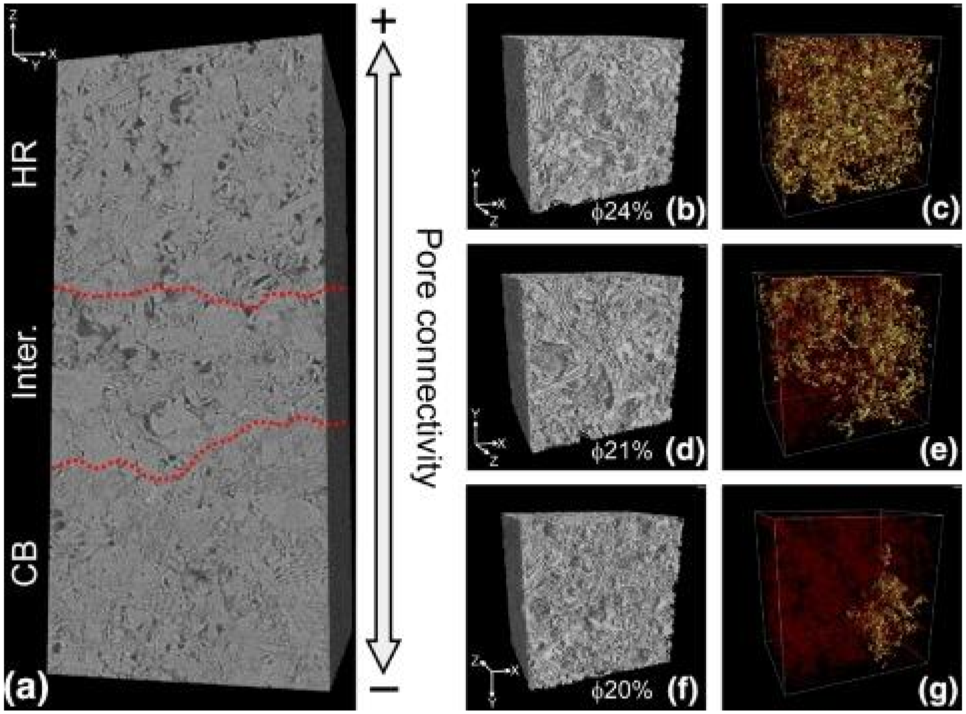
https://aip.scitation.org/doi/pdf/10.1063/1.4952925

a) Schematic layout of the three-point bender inside the hot cell. b) 3D view of a notched Gilsocarbon nuclear graphite specimen fractured under load at 1000oC



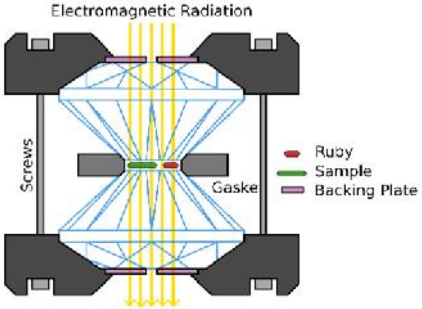
Microtomografia (µCT)

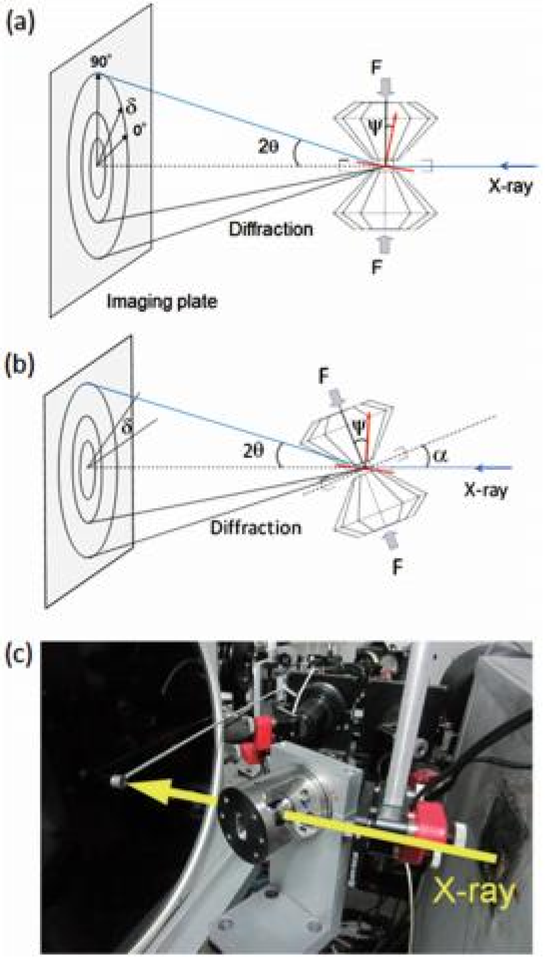
Using synchrotron X-ray microtomography to characterize the pore network of reservoir rocks: A case study on carbonates , Advances in Water Resources, Volume 95, September 2016, Pages 254-263.



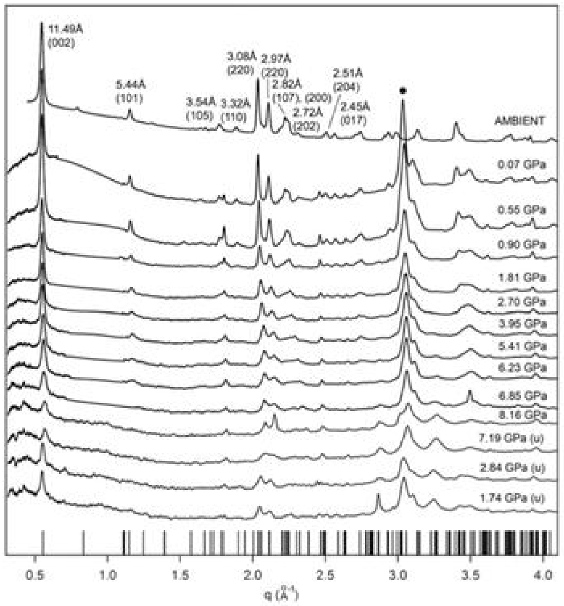
Volume renderings of the laboratory sample Bolo5. In (a) the total volume of the sample is shown. We divided the entire volume in 3 portions: Host Rock (HR), Intermediate portion (Inter.) and the Compaction Band (CB) produced in laboratory. The porosity (ϕ) decreases from HR to CB as shown in (b), (d) and (f). The connectivity also decreases from HR to CB as the size of the main backbone decreases from HR to Inter. to CB.

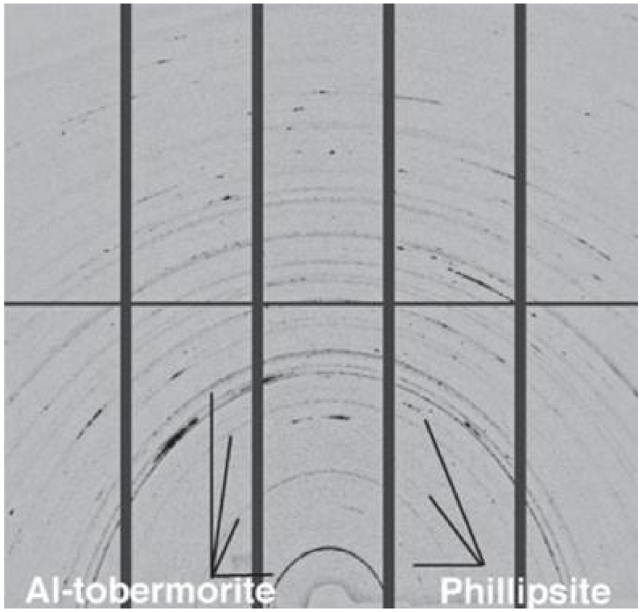
Difracción de rayos-X de alta presión





Chin. Phys. B Vol. 25, No. 7 (2016) 076106



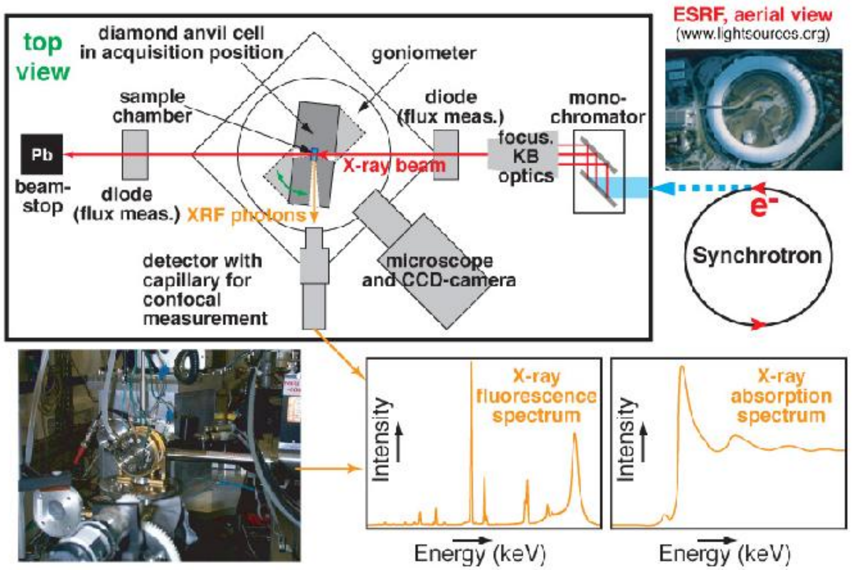


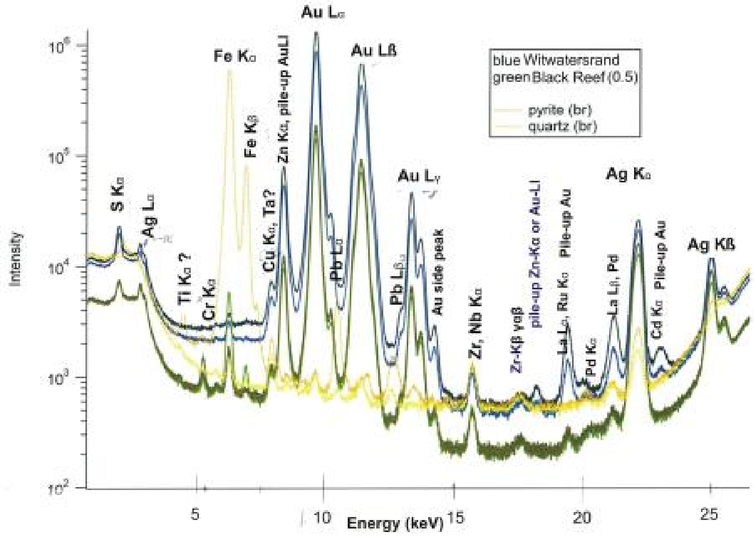
https://als.lbl.gov/learning-from-roman-concrete/

Learning from Roman Seawater Concrete

SEPTEMBER 25, 2013

XRF (Fluorescencia)



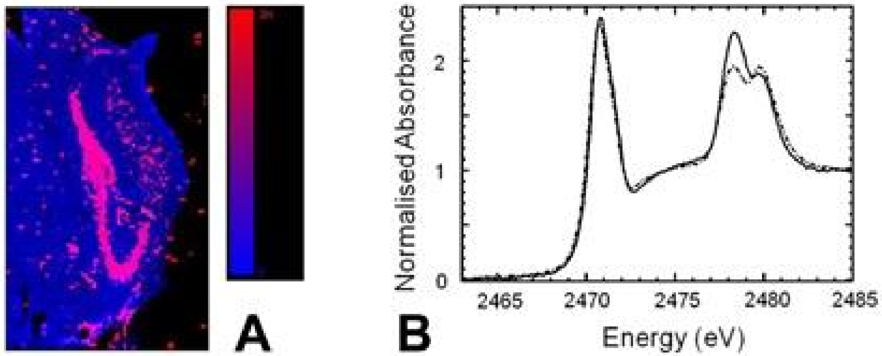


Synchrotron micro-XRF spectrum of BR and Wits Gold, and pyrite and quartz at 30 keV energy.

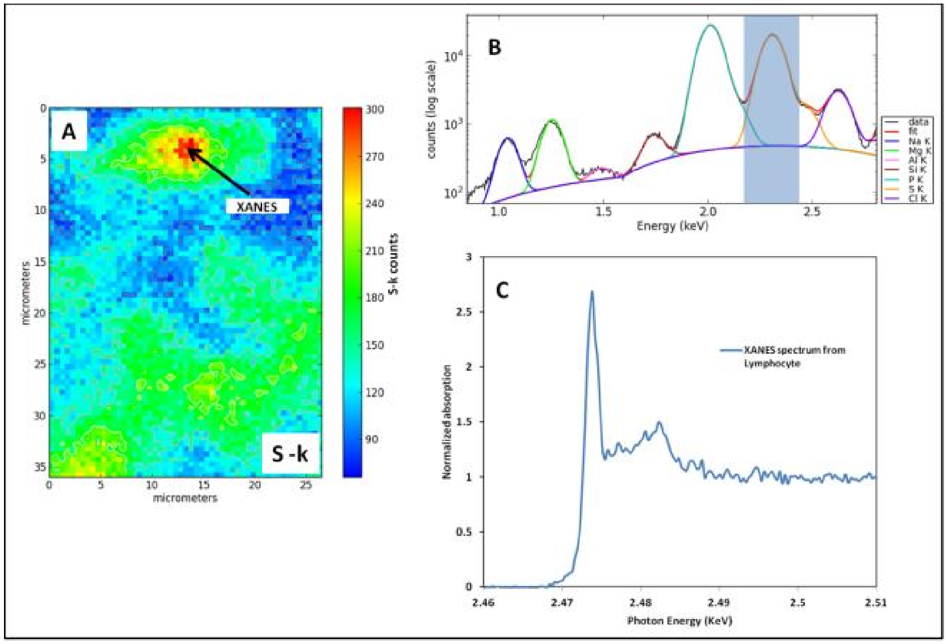
In situ XRF/XAS experiments at synchrotron radiation facilities (example: microfocus beamline ID22, European Synchrotron Radiation Facility, Grenoble).

XRF - XAS - XANES

The Elements of Stroke



XRF mapping at Beam Line 10-2 (Figure 2B) revealed the distribution of Zn and K in healthy brain tissue, and brain tissue following ischemic stroke (Silasi et al. 2012). Sulfur K-edge XAS was performed at Beam Line 4-3 (Figure 2B), and revealed increased levels of taurine within grey matter (black line), relative to white matter (dashed line). This trend was only observed in non-fixed flash frozen brain tissue (Hackett et al. 2012).
SLAC - STANFORD

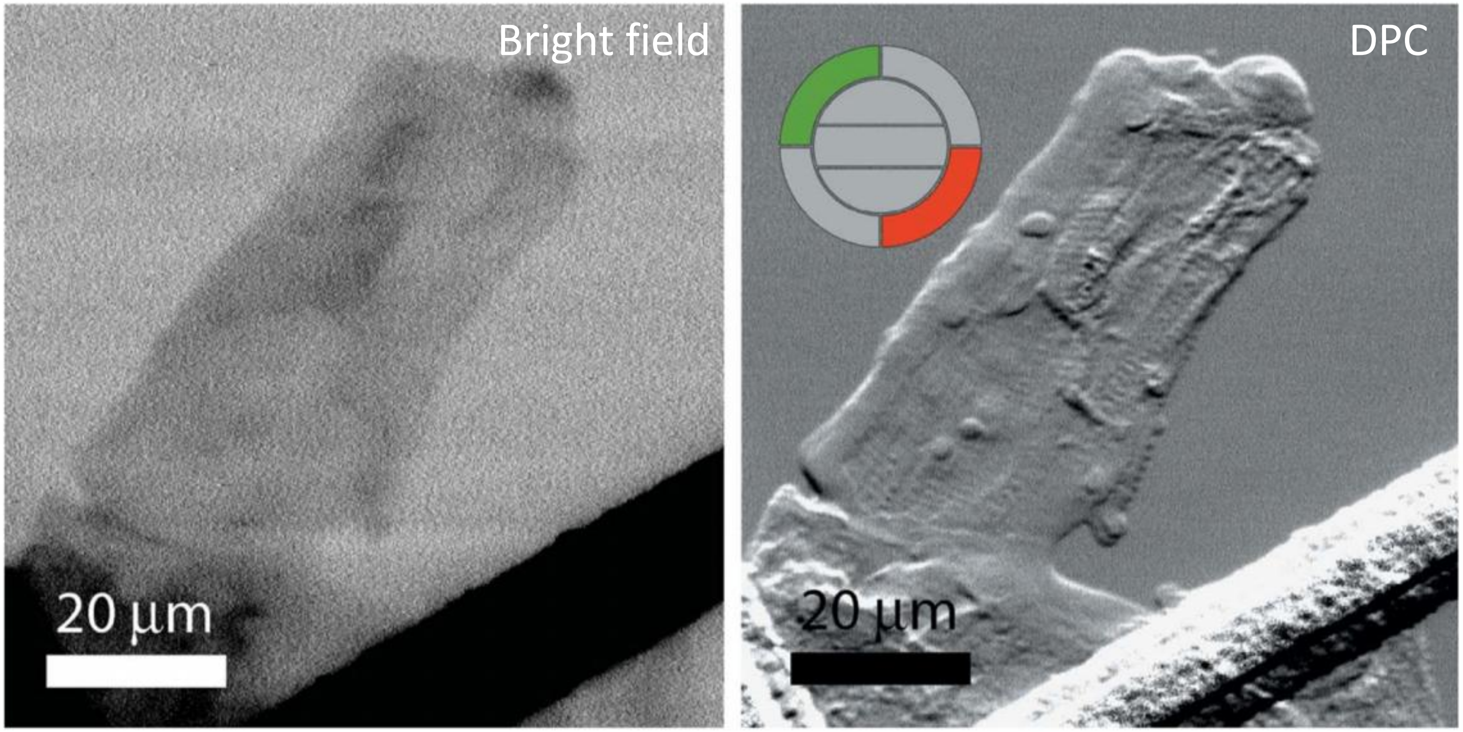


Typical combined XRF/XANES analysis of a lymphocyte cell. A) XRF distribution map of S obtained with 3KeV incident beam (1m2 pixel size). B) XRF spectrum of the full map showing the fit for different elements performed using PyMCA [30]. The blue shadowed-box corresponds to the region of interest used to obtain the XRF intensity for S XANES. C) XANES spectrum obtained from the spot marked on A.

https://www-ssrl.slac.stanford.edu/content/science/highlight/2012-09-24/elements-stroke
https://www.eurekaselect.com/138399/article

Differential phase contrast with segmented detector

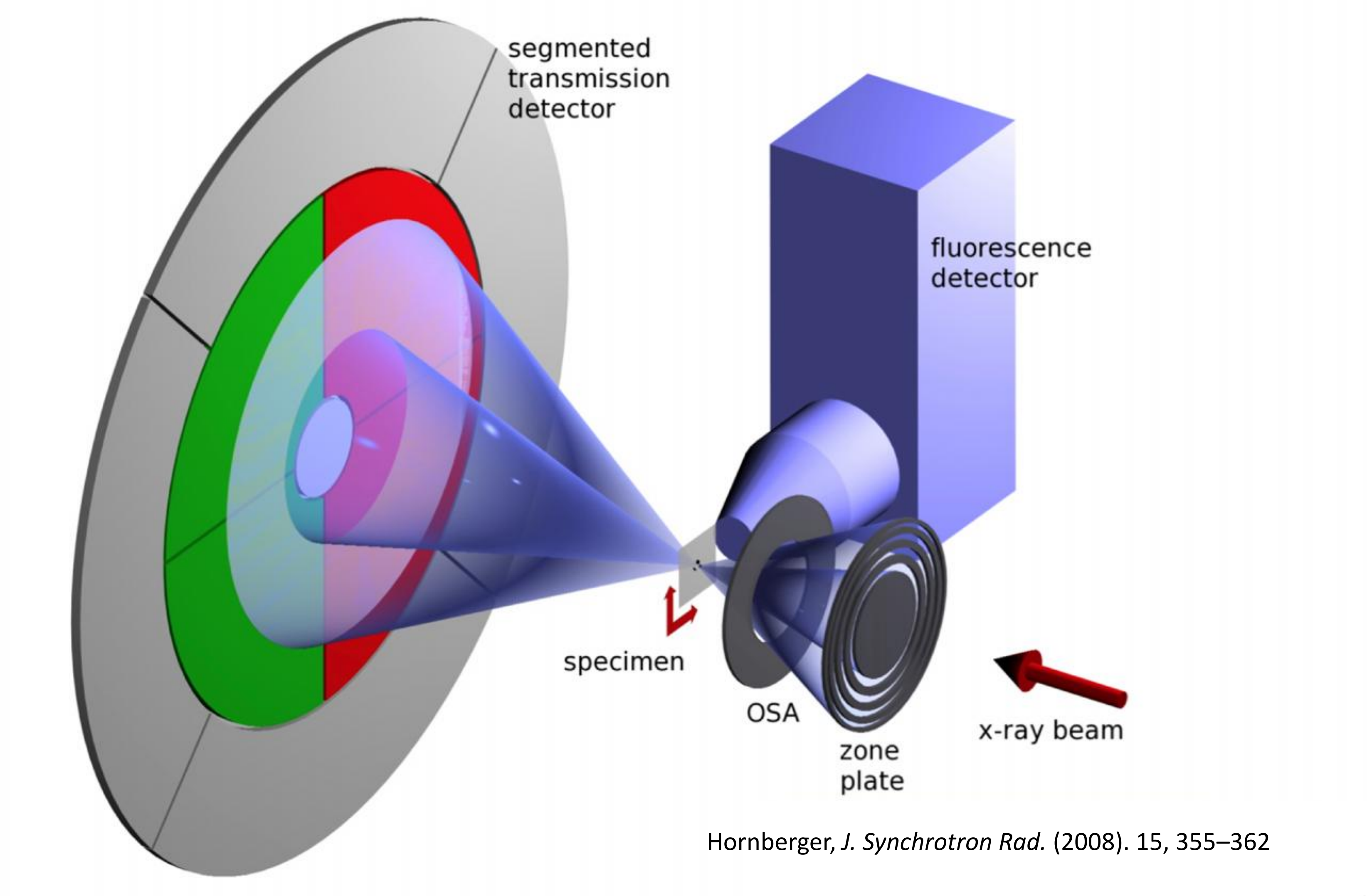
freeze-dried cardiac myocyte



Now the shadow is diagonal from the top left to bottom right

Hornberger, *J. Synchrotron Rad.* (2008). 15, 355–362

How a phase object changes the scattered beam

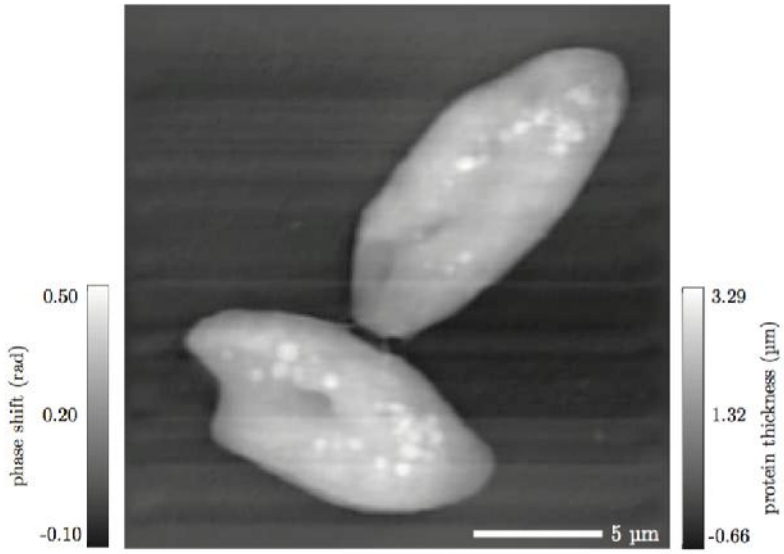


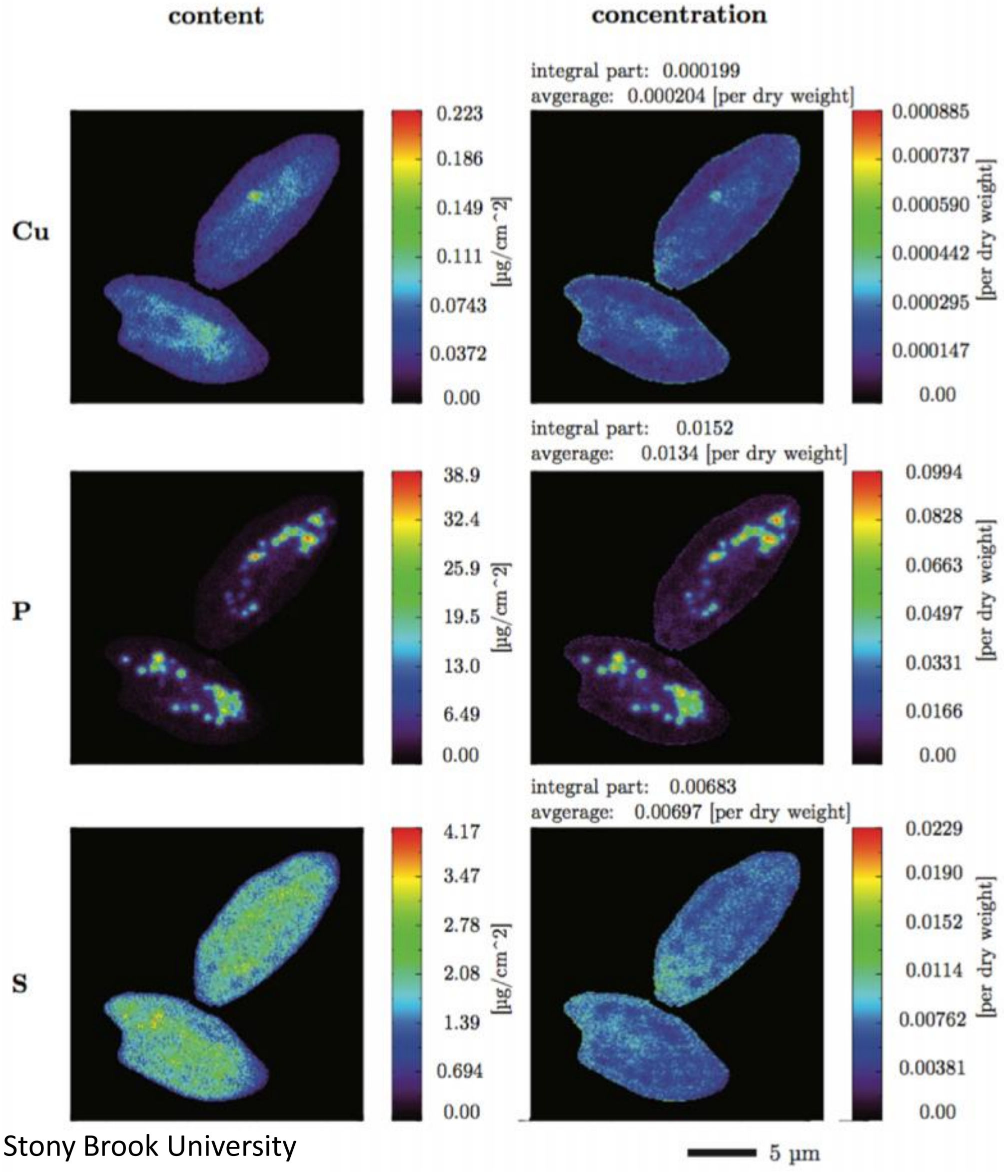
Hornberger, *J. Synchrotron Rad.* (2008). 15, 355–362

Slide courtesy of Christian Holzner

Quantitative phase gives thickness estimate

- Quantitative phase give thickness estimate
    - composition assumed: 48.6% H, 32.9% C, 8.9% N, 8.9% O, 0.6% S
- Convert fluorescence signal to elemental concentrations



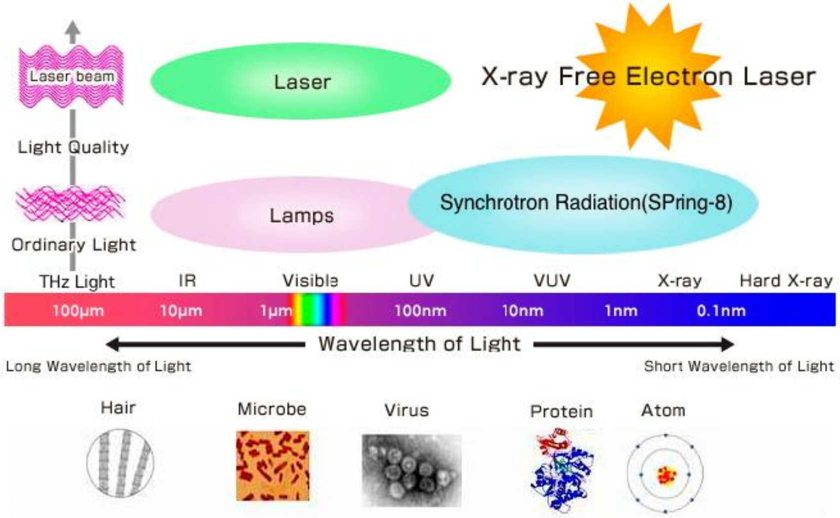


Holzner, 2010 *Doctoral dissertation* Dept. of Physics and Astronomy, Stony Brook University

X-FEL

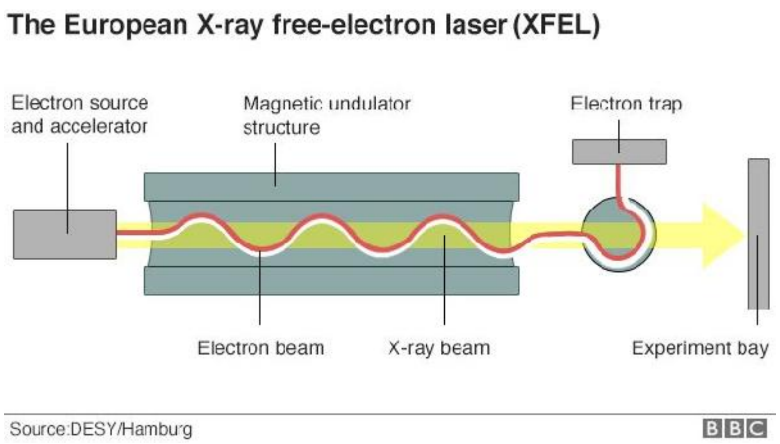
X-ray Free Electron Laser (XFEL) is an X-ray combining the features of lasers at the free electron state. It may be the most promising light source for the next generation of scientific exploration and discovery.

The X-rays produced at SPring-8 are ten billion times brighter than the sun. However, the peaks and troughs of the light waves are not aligned. Laser light is light with its waves aligned. The light produced by the XFEL will be a billion times brighter than SPring-8. A brighter light will be a major step forward and enable us to observe faster movement in a smaller region.



http://xfel.riken.jp/eng/xfel/index.html

XFEL



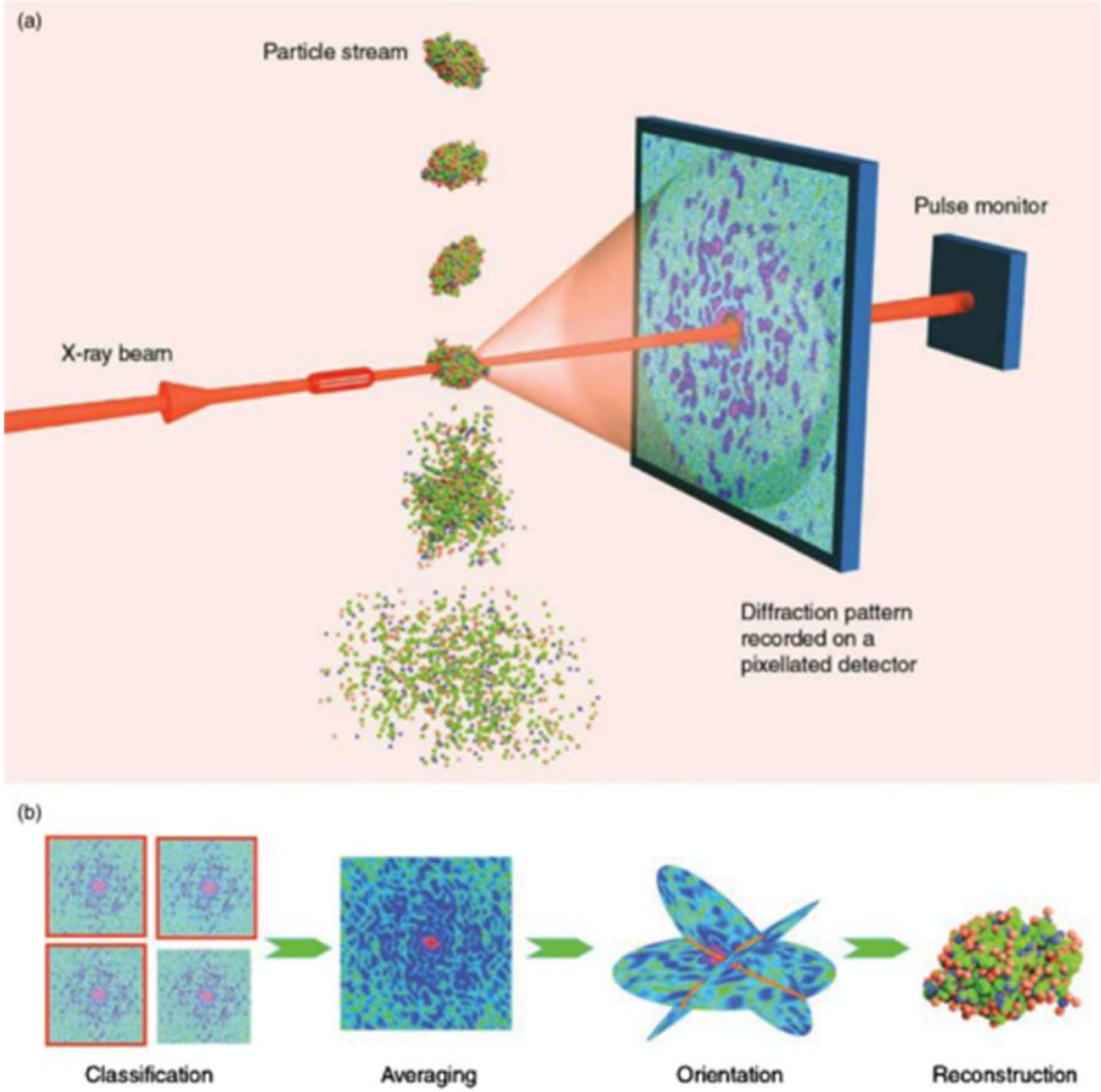
https://www.bbc.com/news/science-environment-41117442

- At the head of the XFEL, bunches of electrons are first sped up to near-light-speed in a super-cold, evacuated accelerator
- The particles are directed down long undulators - magnetic systems that produce a slalom course for the electrons
- As they wiggle back and forth in the undulators, the fast-moving electrons emit very bright X-ray flashes
- The particles interact with this great sea of X-rays and begin to organise themselves into even tighter groupings
- This intensifies the brilliance of their emission and gives it coherence - the X-rays are "in sync" and laser-like
- Having done their job, the electrons are siphoned off, leaving the X-ray flashes to hit their experimental targets

The machine will deliver trillions (1,000,000,000,000) of X-ray photons in a pulse lasting just 50 femtoseconds (0.000,000,000,000,05 sec), and it can repeat this 27,000 times a second.
It allows for time-resolved investigations that are beyond what is possible in standard synchrotrons.
For example, scientists will use a jet to stream their samples in front of the beam, priming them with another laser so that chemical reactions are triggered at just the right moment to be caught by the pulses.

"The huge hope for XFEL is that we will be able to do single particle imaging. So, you just put a stream of your protein complex or virus into the beam and you'd have enough photons that an individual biological entity would scatter those photons for you to get the shape of it,"

CDI ideal for X-ray Free Electron Lasers (XFELS)

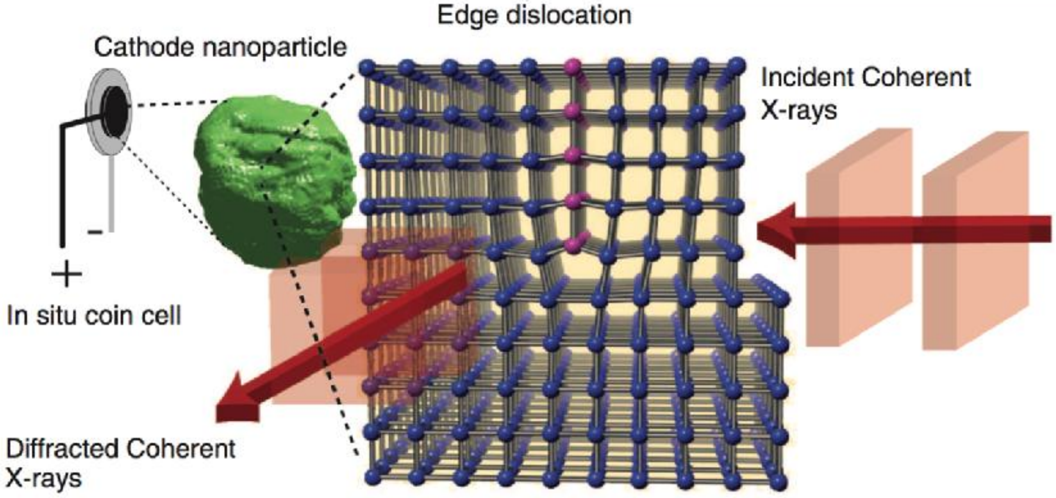


Diffract before destroy!

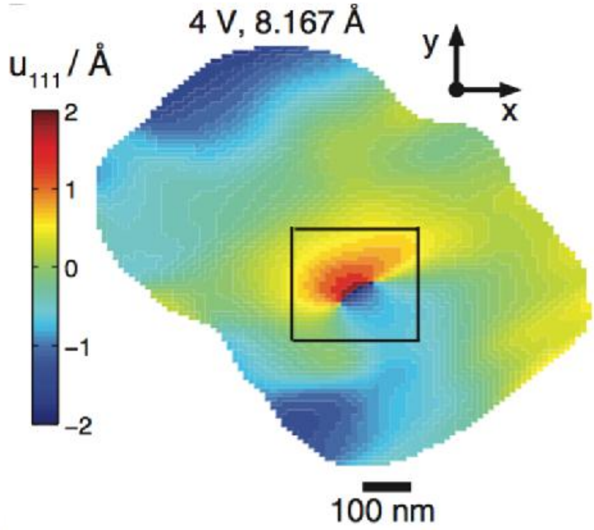
- For 3D data, many particles must be imaged
- Assumes all particles are identical
- Averages out difference
- Won't work for cells

Gaffney and Chapman, 2007, *Science* **316** 1444

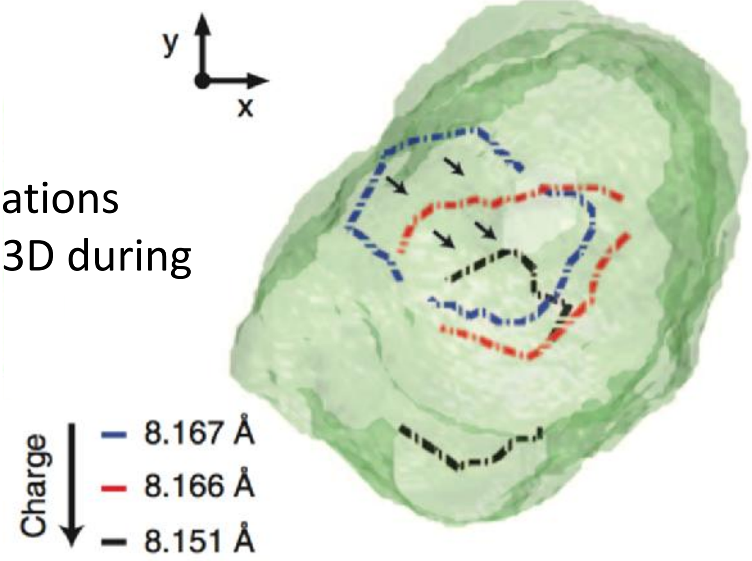
Mapping strain in battery particle during cycling



Phase jump indicates edge dislocation in 2D

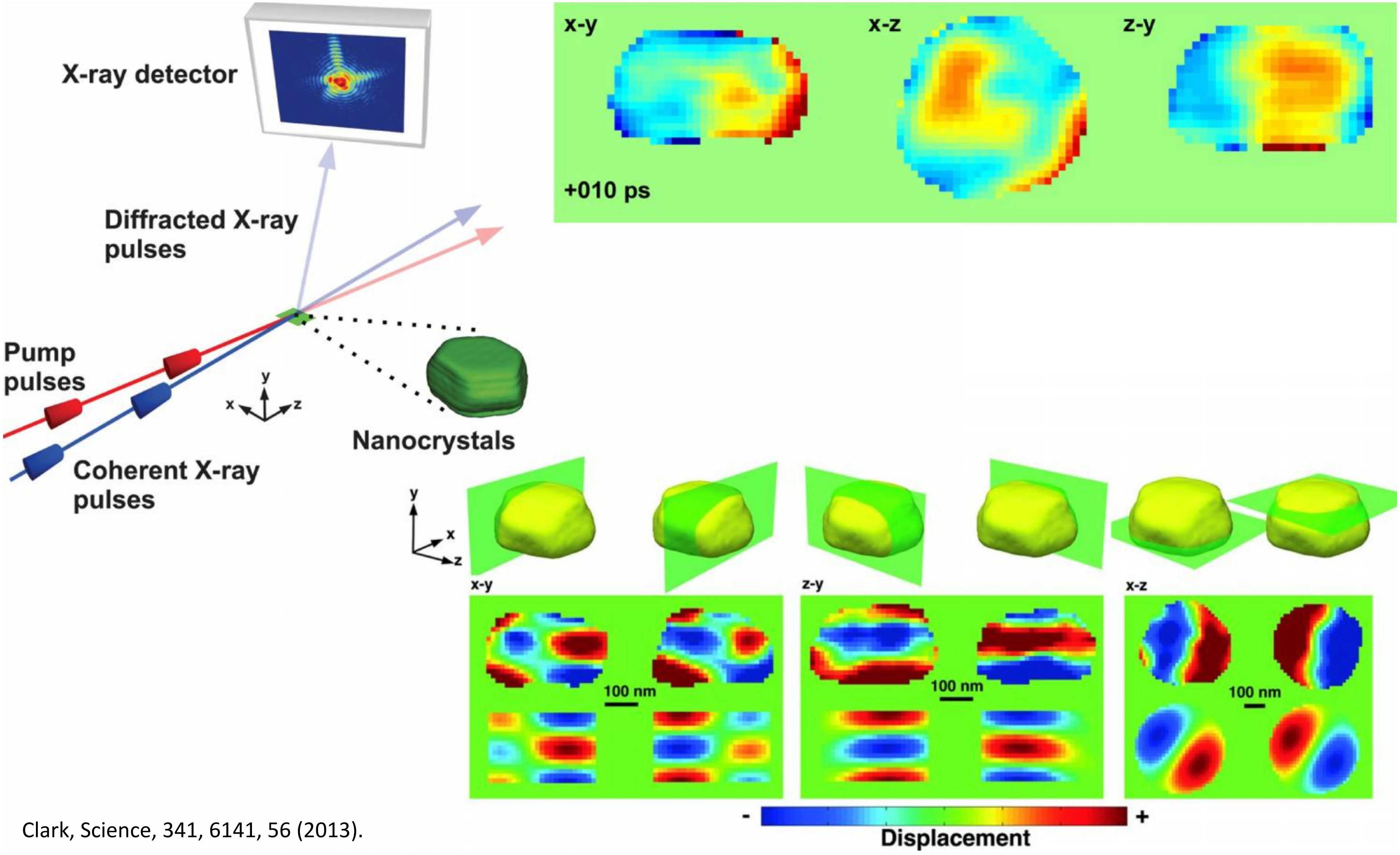


Track edge dislocations (dashed lines) in 3D during charging



Ulvestad, et al., *Science*, 348, 6241 (2015).

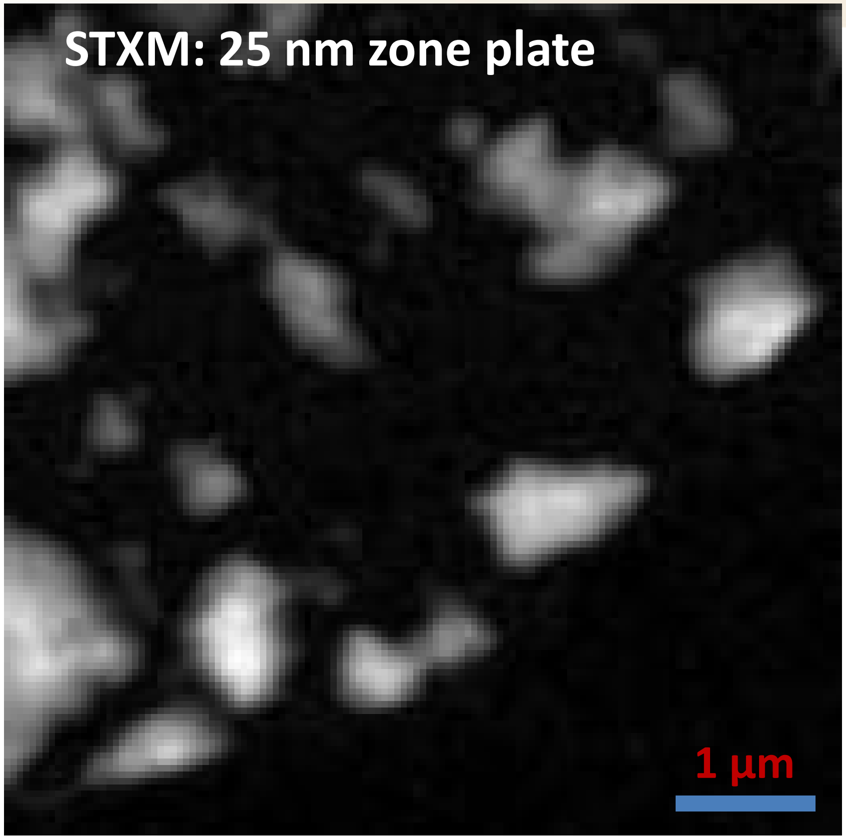
Bragg CDI at an XFEL: imaging acoustic phonons

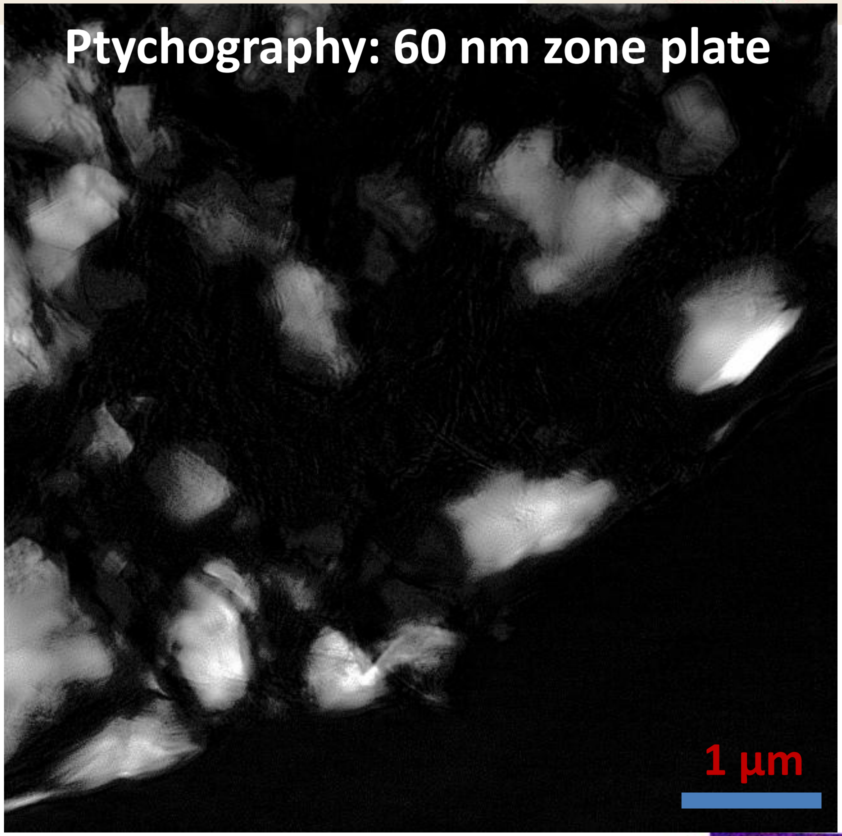


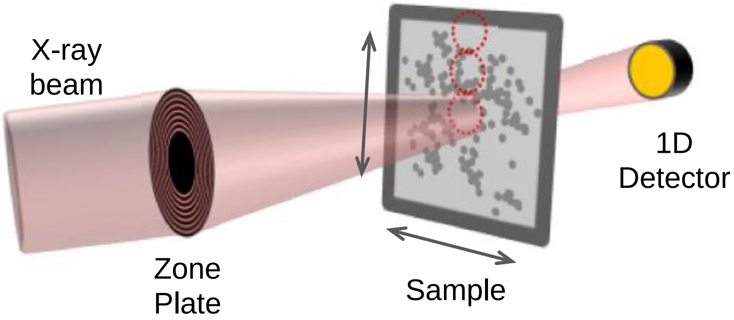
Clark, Science, 341, 6141, 56 (2013).

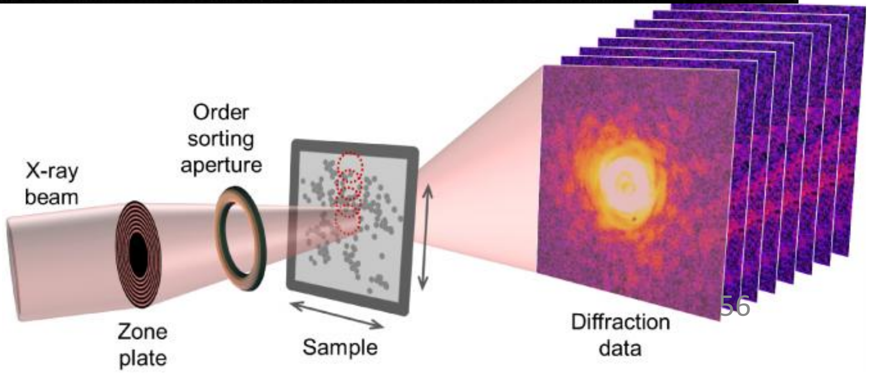
La maps (M_5 edge @ 836 eV)
(ALS BL 5.3.2.1)

STXM vs. ptychography

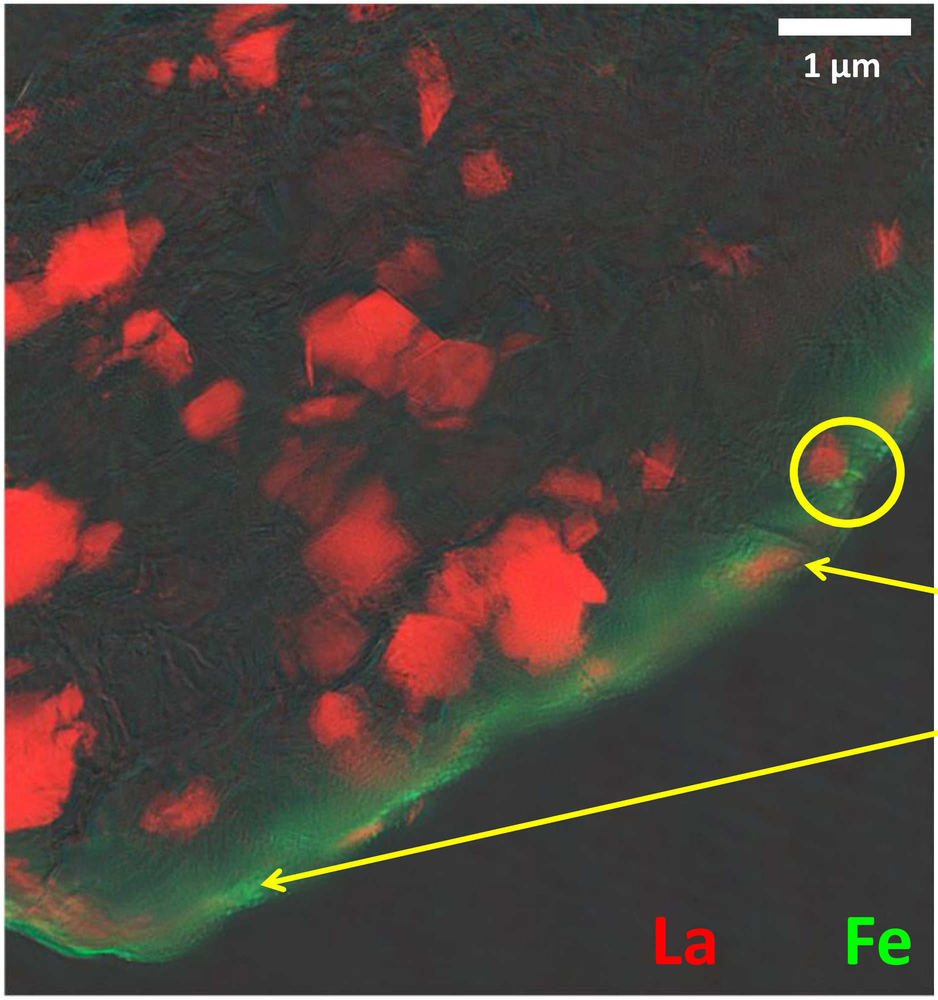

STXM: 25 nm zone plate


Ptychography: 60 nm zone plate



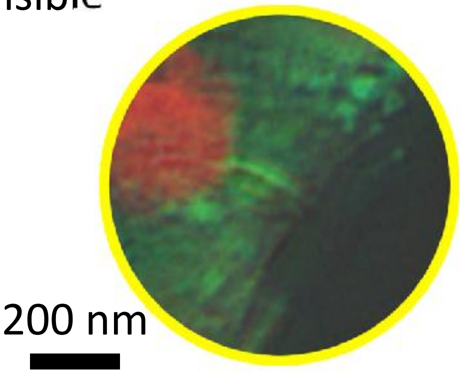


Elemental mapping illuminates Fe contamination



- La: marker for La-exchanged ultrastable yttrium (USY) zeolite crystallites
- Distributed throughout
- Particle size 0.1 to 3 µm^2

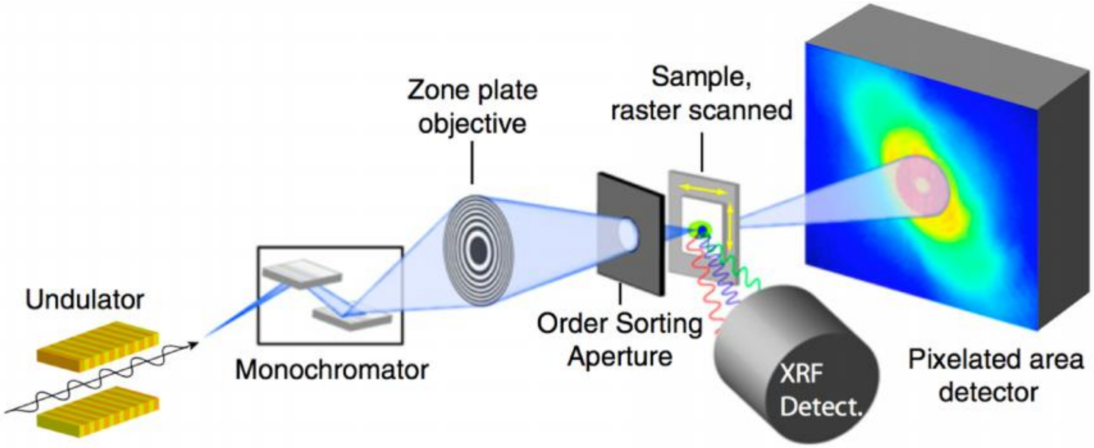
- Fe: deposited at particle edge
    - Penetrates ~1 µm into particle
    - And outside of particle
    - Small nodules visible



Resolution estimated ≤ 12 nm

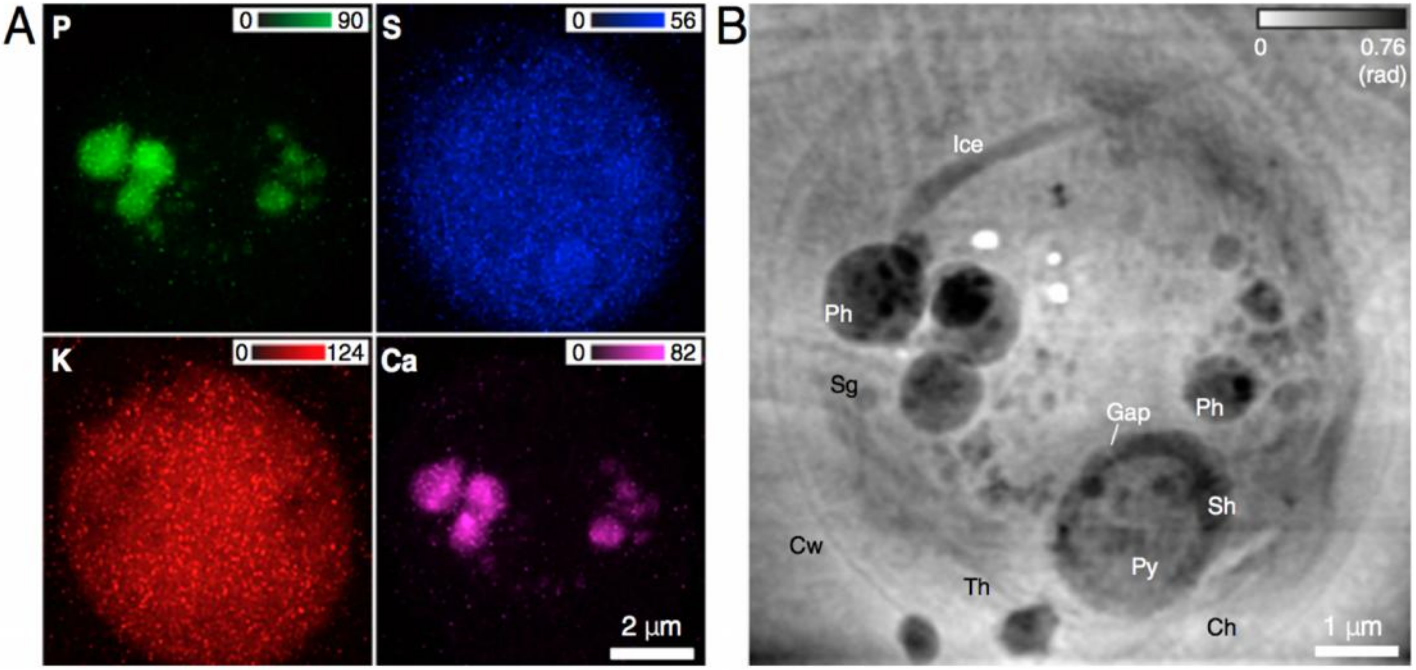
A.M. Wise *et al*. ACS Catal. (2016), 6, 2178–2181

Ptychography with simultaneous fluorescence microscopy



Biological samples are pure phase objects (no absorption contrast) with hard X-rays

Frozen hydrated alga (5.2 keV)

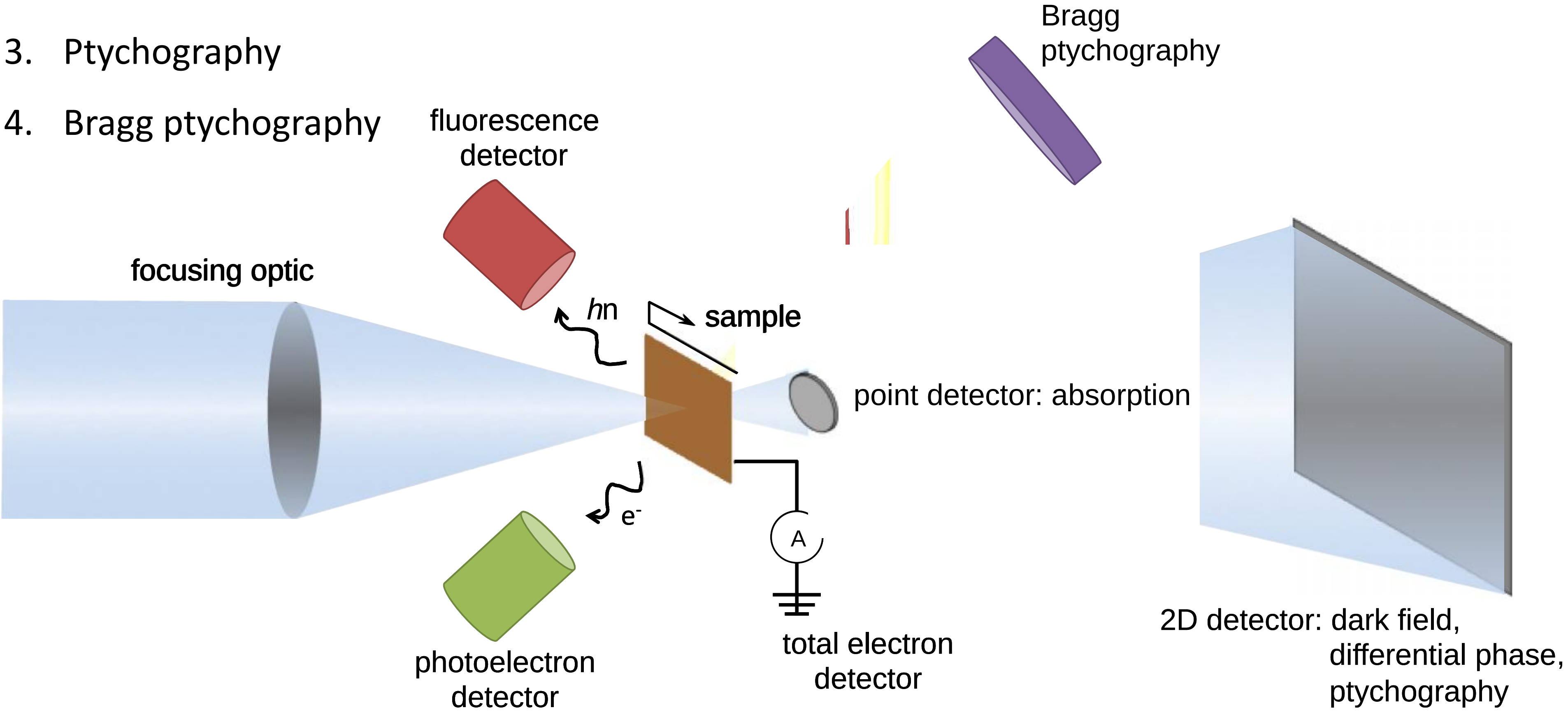


Deng, *et al. PNAS*, 112, 8, 2314 (2015).

Summary of X-ray microscopy

Scanning microscopy

1. Scanning transmission X-ray microscopy (STXM)
    - Fluorescence and electron detection
2. Differential phase contrast imaging/dark field
3. Ptychography
4. Bragg ptychography



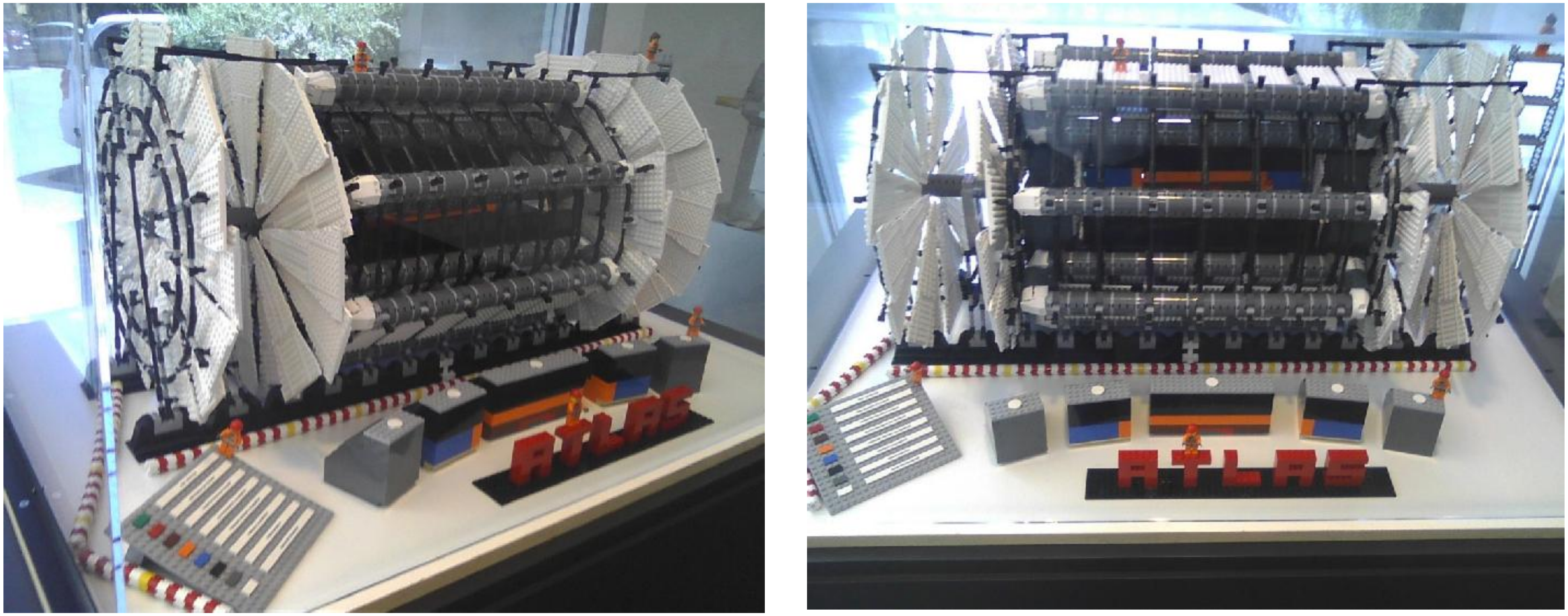
¿Y EN MÉXICO?

PROYECTO:

- ✓ MORELOS (2011)
- ✓ HIDALGO (2018)

- ❖ REDFAE
- ❖ REDTULS
- ❖ UNIVERSIDADES Y CENTROS DE INVESTIGACIÓN

Diseñando ATLAS para el HLC



¡¡GRACIAS!!

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UNACH
28 de febrero de 2019