ESS SYMPOSIUM

MAX IV – A WORLD-LEADING SYNCHROTRON FACILITY

TECHNOLOGIES AND SCIENTIFIC OPPORTUNITIES

Olof ’Charlie’ Karis, MAX IV interim director

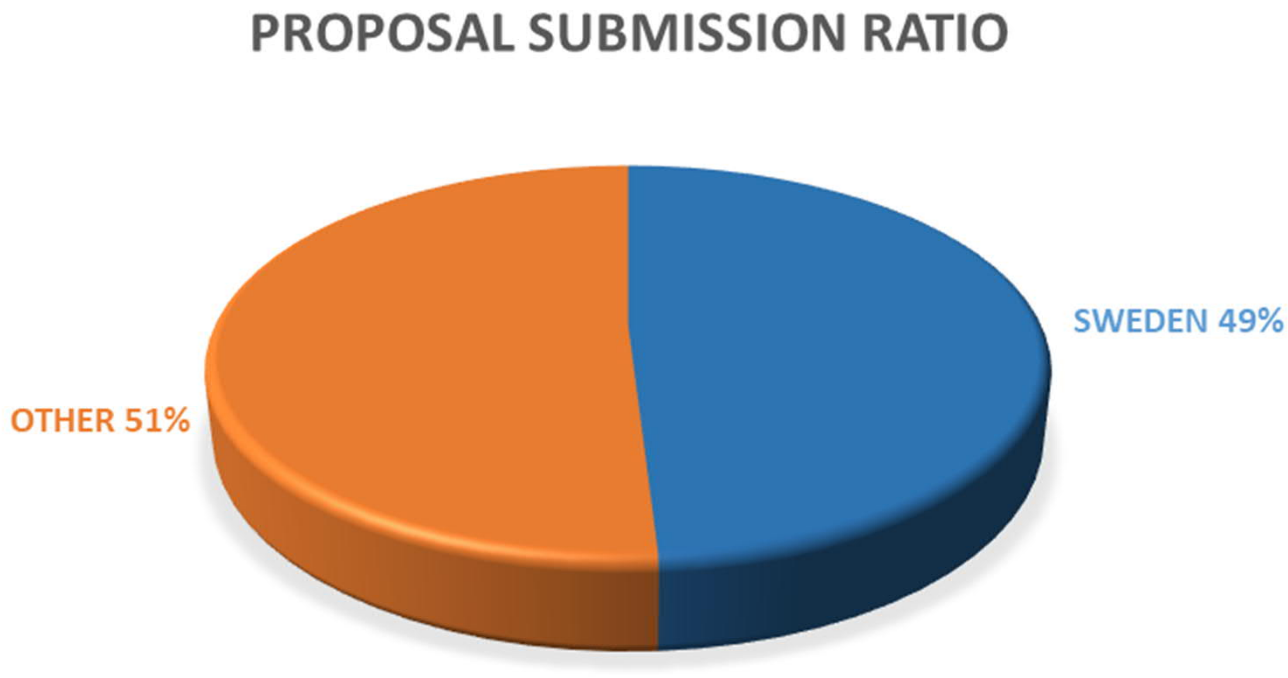
This is MAX IV

- A leading laboratory for X-ray research
- A fourth generation light source – up to 100 times brighter and highly coherent
- Available for academic and industrial users world-wide
- Largest user base is the Nordic and Baltic countries (~70% Nordic)

EH0 More accurate according to Pedro
Emelie Hilner, 2022-11-16T19:37:16.977

Of proposals submitted 2018-2021, 49% had been submitted by Swedish users*, while 51% belonged to users from foreign institutions.

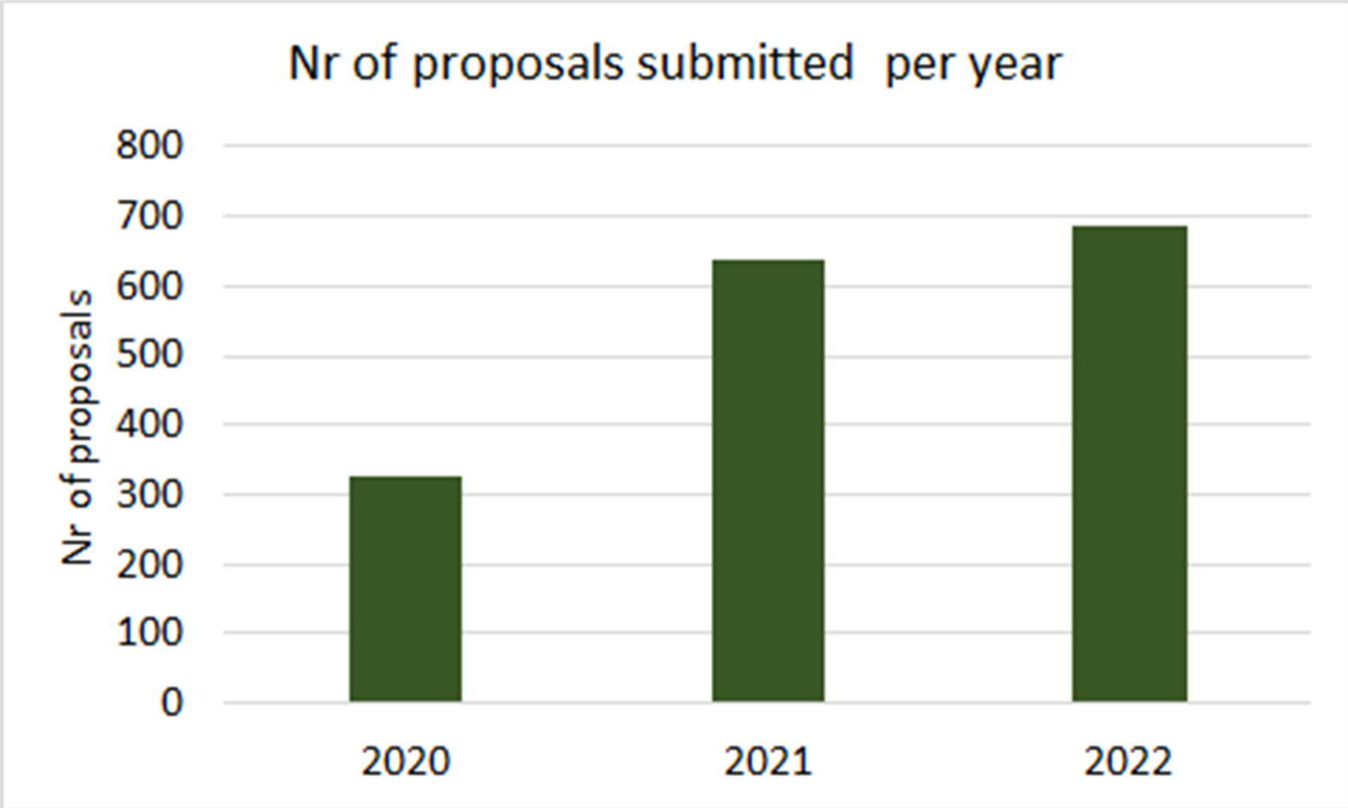
* Users affiliated to a Swedish Institution; the count refers to main submitters, without taking into account possible co-proposers affiliated to Swedish institutions



EH0 In which call?
Emelie Hilner, 2022-11-16T19:39:24.312

OK0 0 2019-2021
Olof Karis, 2022-11-17T06:43:12.294

A steady increase in the number of submitted proposals



2021 Scientific Output

from 2021 Annual Laboratory Report

MAX IV 2020-2022

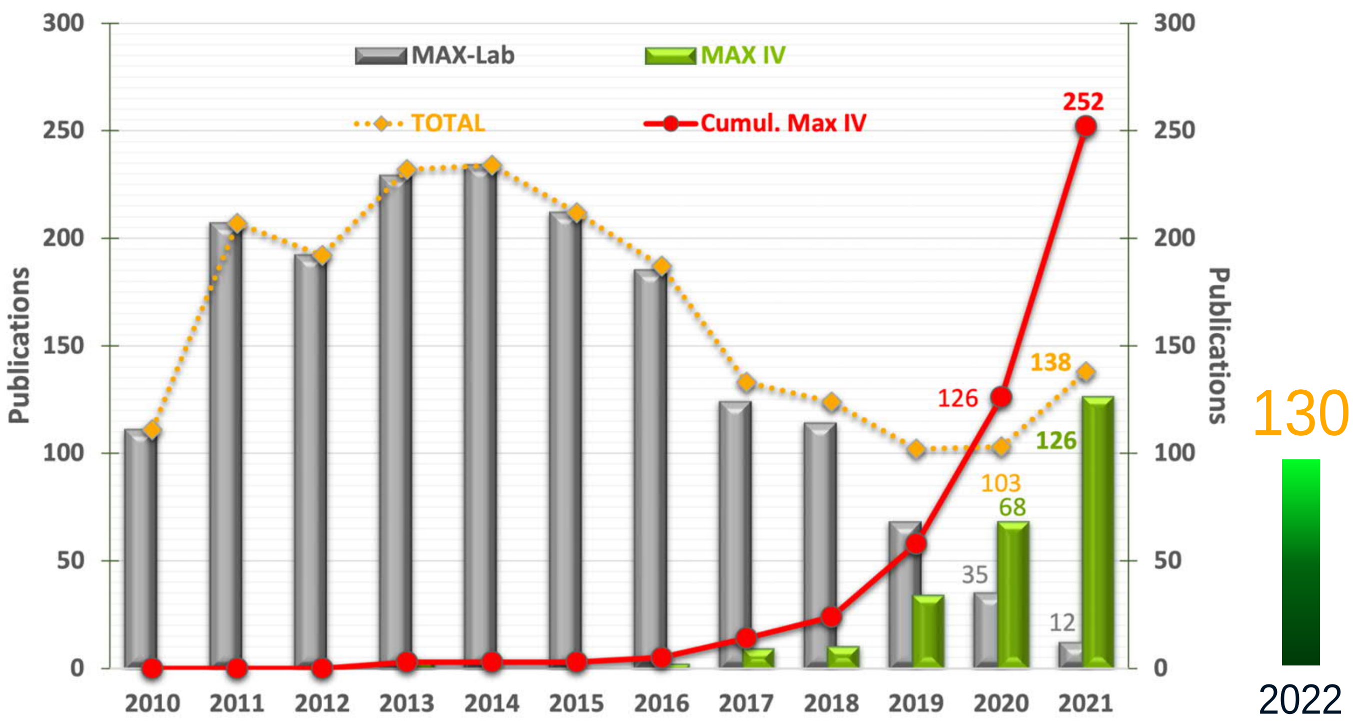
from scival

about 325 articles

about 6500 views

2147 individual co-authors
About 1660 citations

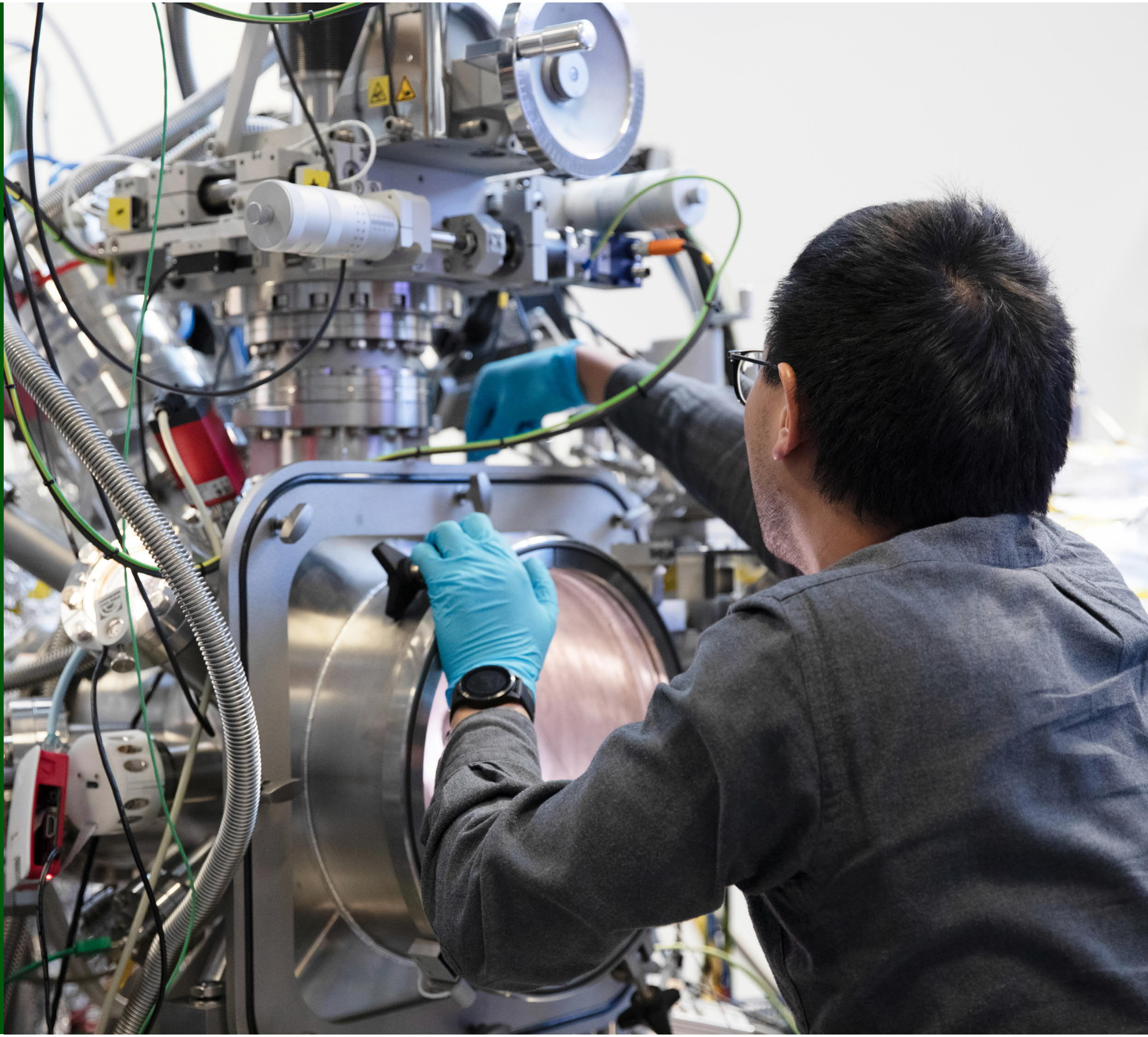
MAX IV



- Scientific Output of the facility continues to increase
- 34% increase from 2020
- 91% of publications with MAX IV beamlines data
- 10 PhD thesis based on MAX IV beamlines data

16 Beamlines

- Specialised techniques for studies of structure, chemistry, electronic properties etc.
- MAX IV light allows for more realistic experiments
- Time resolution and dynamics
- Operando and multimodal experiments



What is special about MAX IV ?

High brightness/coherence ➔ small emittance $\varepsilon_x = \sigma_x \sigma_{x'}$

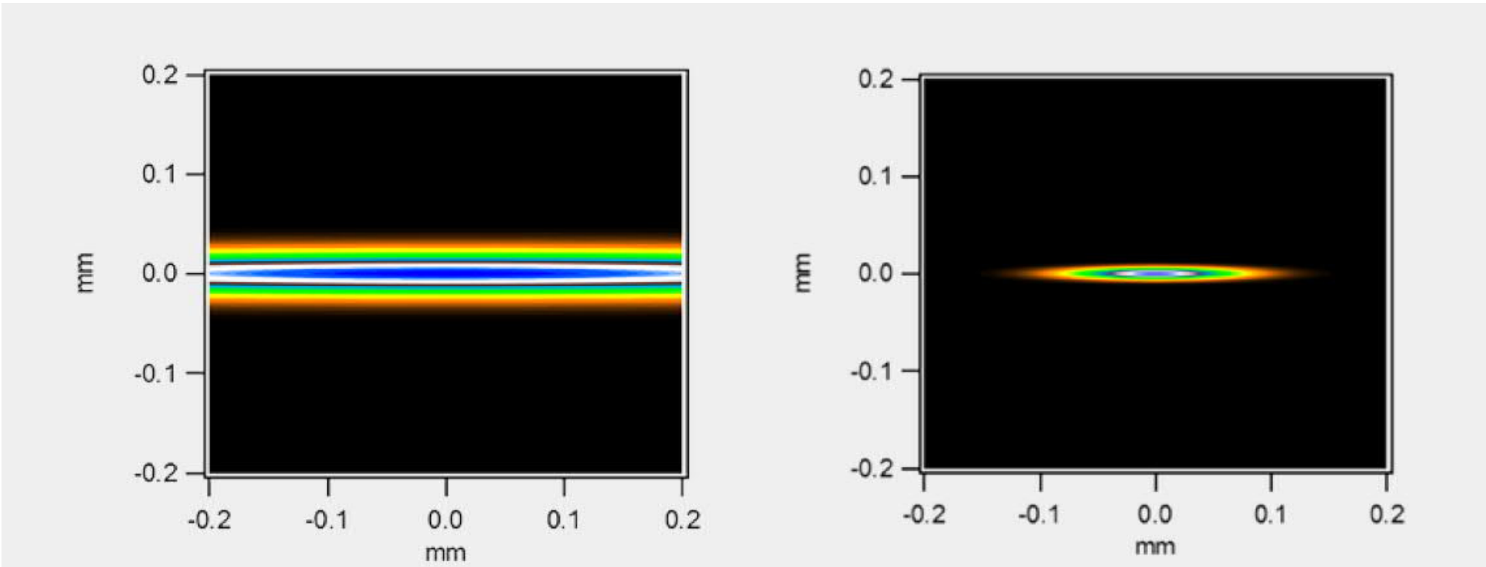
Electron beam divergence

Electron beam size

<u>**MAX IV is the first of new generation of ultralow emittance light sources**</u>

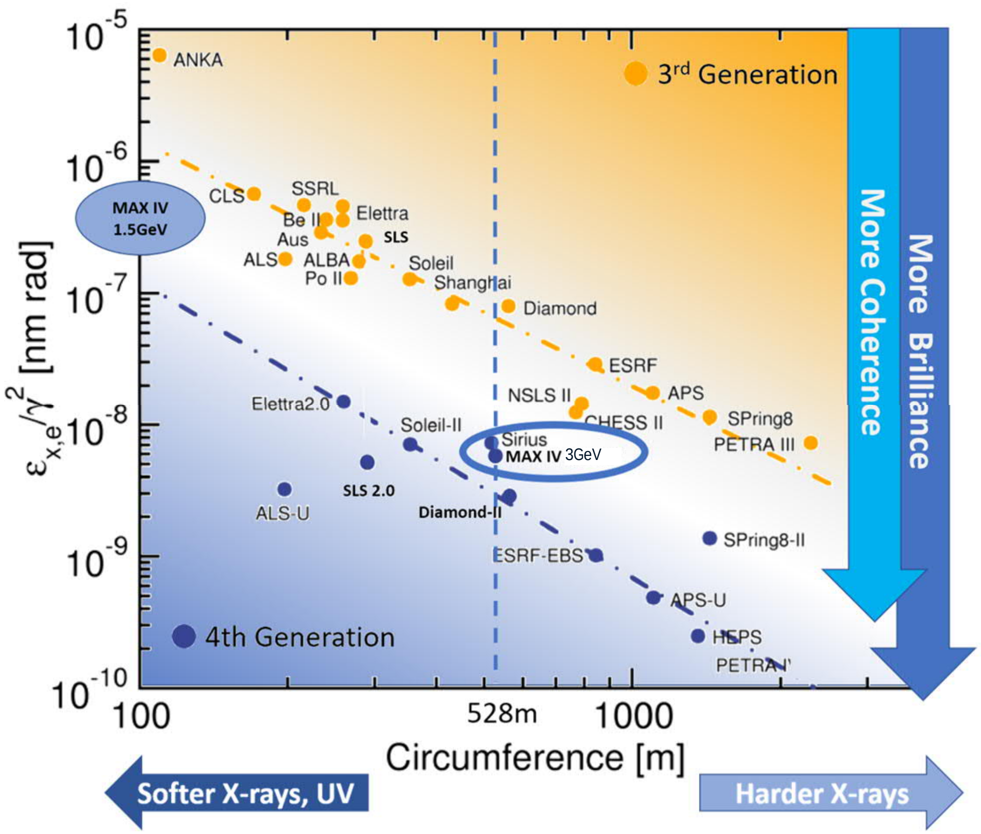
MAX II: Double Bend Achromat (DBA)
Third Generation

MAX IV: Multibend Achromat (MBA)
Fourth Generation



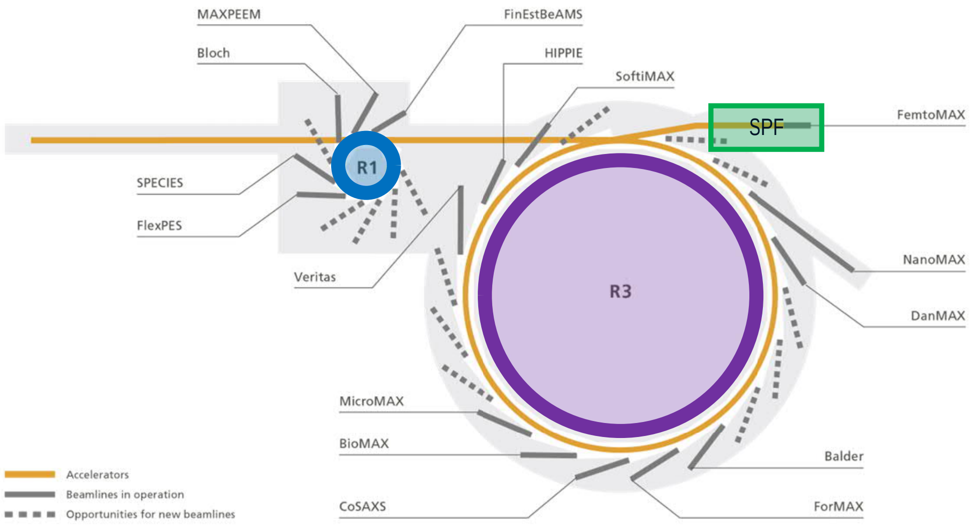
Accelerators

- Linac/SPF – Short Pulse Facility
  - Sub-picosecond pulse duration
- 1.5 GeV Storage Ring
  - C = 100m
  - Diffraction-limited X-rays at 16 eV
  - World-leading source of soft X-rays
- 3 GeV Storage Ring
  - C = 528m
  - Diffraction-limited X-rays at 300eV
  - First 4th generation storage ring



Most 4th generation light sources will be fully operational by the end of the decade

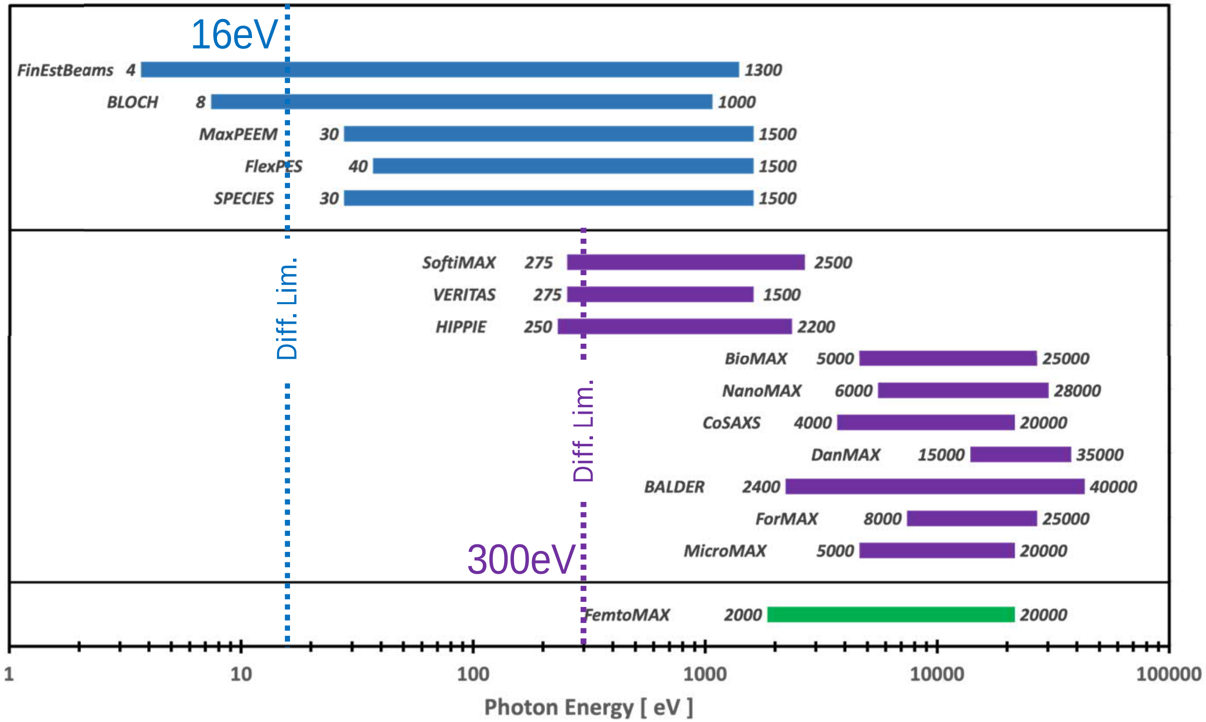
Beamline Portfolio



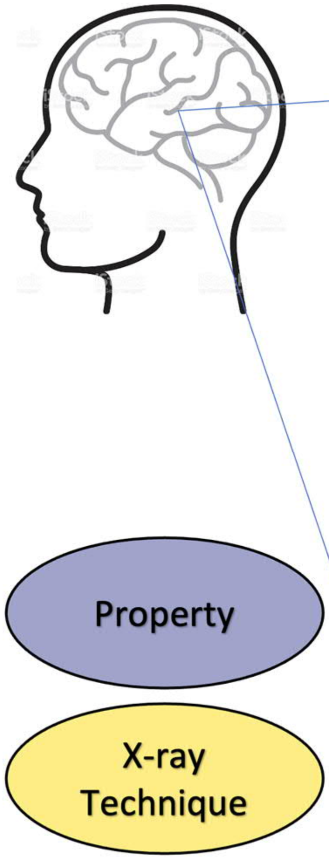
Soft X-rays
surface and sub-surface information

Hard X-rays
bulk information and buried interfaces

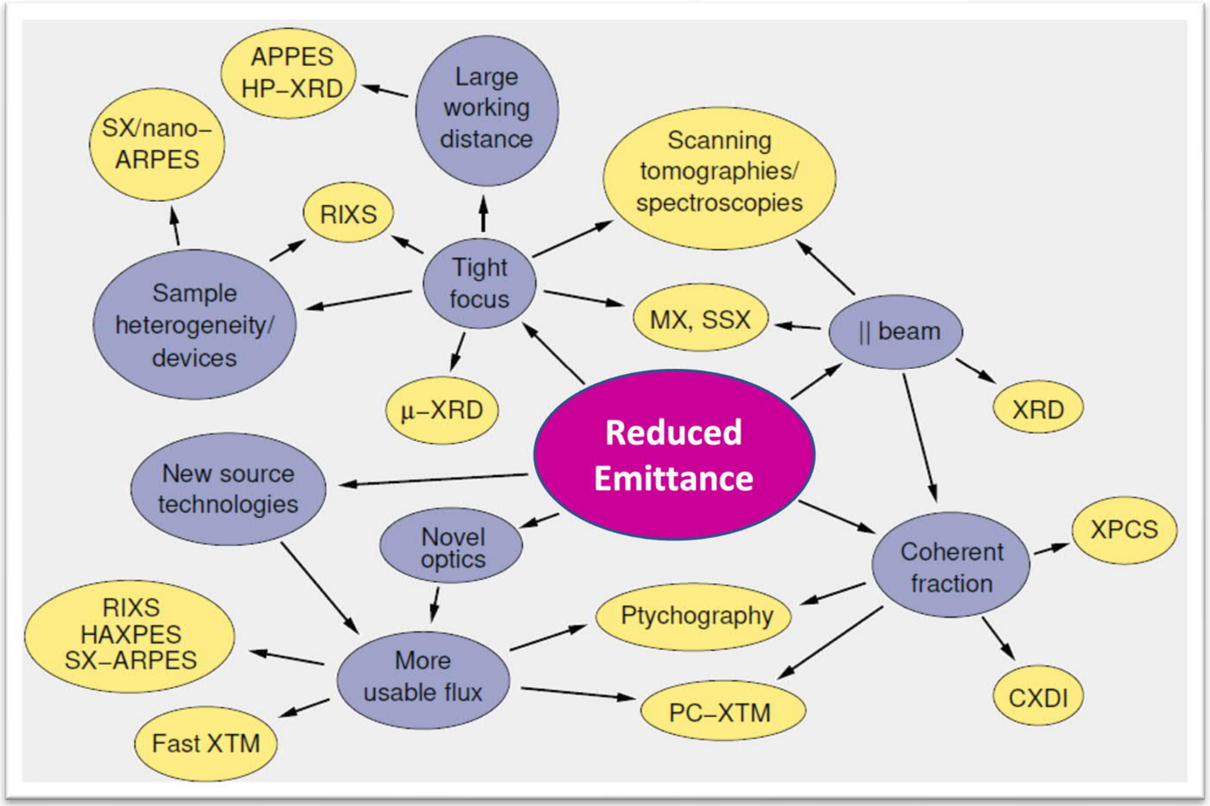
16 beamlines in operation covering a broad X-ray energy range from 4 eV to 40 keV



Small Emittance



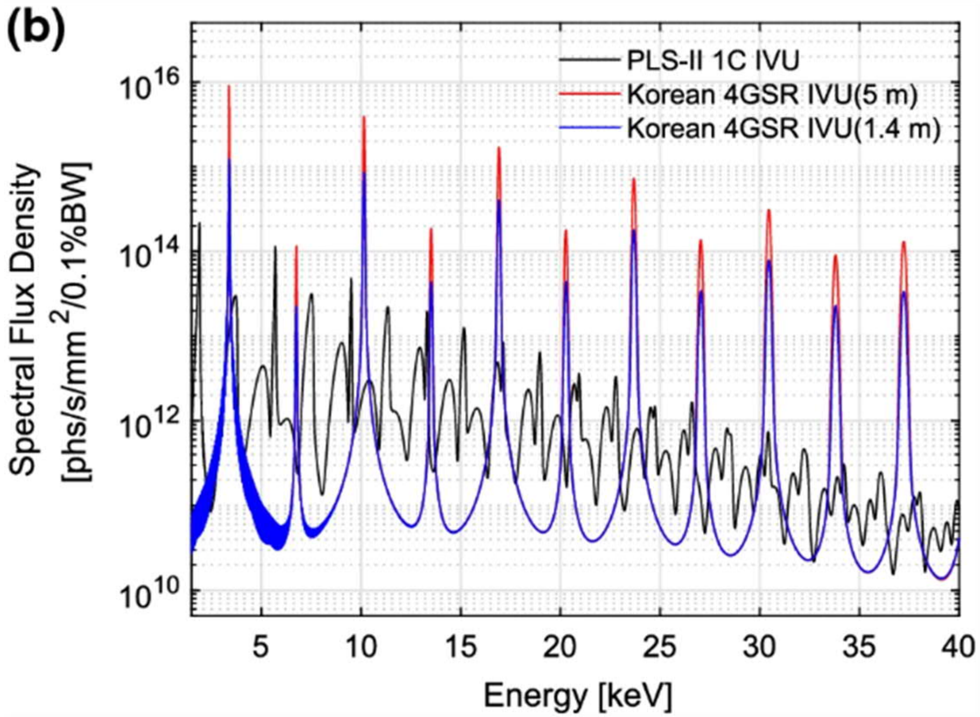
Adapted from SLS 2.0 – Beamline Conceptual Design Report - Jan 20, 2021



B. Cho *et al.*, J. Kor. Phys. Soc. 78:467 (2020)

Small Emittance – Photon /eV

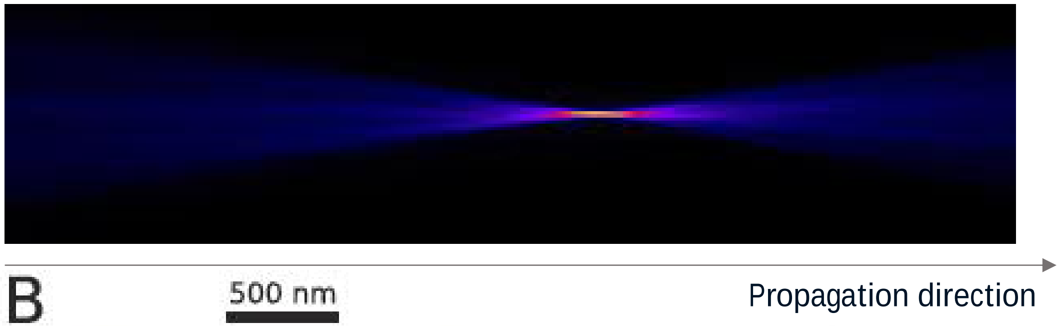
A larger number of photons per energy bandwidth



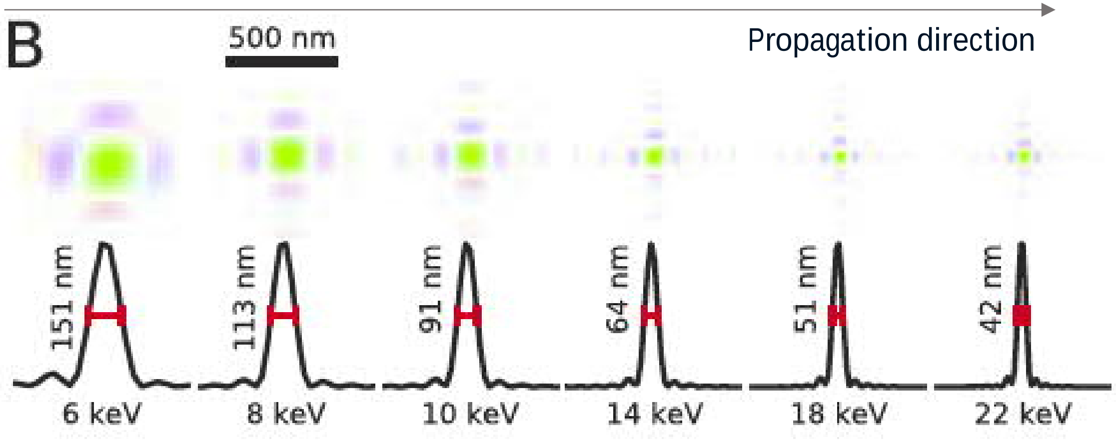
FlexPES	FinEstBeAMS	Bloch	Veritas	NanoMAX	Balder	CoSAXS	MicroMAX
SPECIES	MaxPEEM	HIPPIE	SoftiMAX	DanMAX	ForMAX	BioMAX	FemtoMAX

Small Emittance – Focusing to μm & sub-μm sizes

A larger number of photons in smaller beam size



Ptychographic reconstruction of a focused beam



Measurement of the energy dependence of the focused beam size at NanoMAX

Björling *et al.*, Optics Express 28 (4) 5069 (2020)

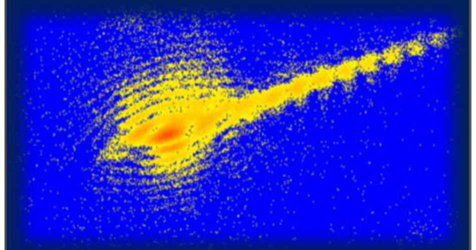
FlexPES	FinEstBeAMS	Bloch ✓	Veritas ✓	NanoMAX ✓	Balder ✓	CoSAXS ✓	MicroMAX ✓
SPECIES	MaxPEEM	HIPPIE ✓	SoftiMAX ✓	DanMAX ✓	ForMAX ✓	BioMAX ✓	FemtoMAX

Small Emittance Coherence

A larger number of coherent photons – Explore opportunities with coherence

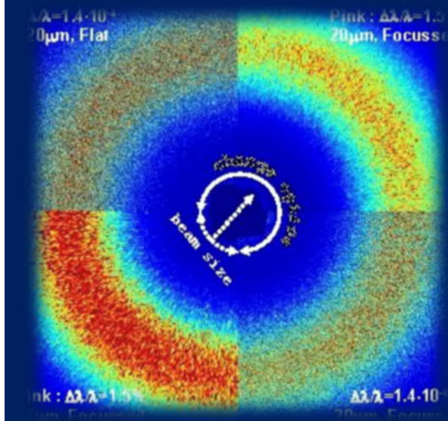
Looking forward

Coherent Diffraction Imaging

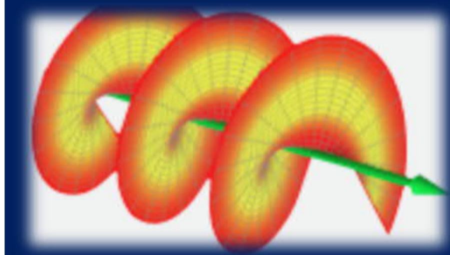


Phase Contrast

Speckle Spectroscopy



Orbital Angular Momentum



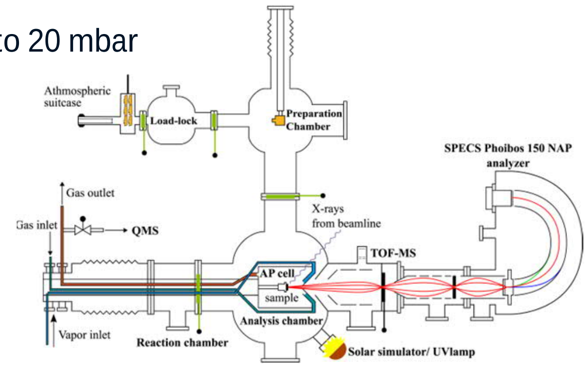
FlexPES	FinEstBeAMS	Bloch	Veritas	NanoMAX ✓	Balder	CoSAXS ✓	MicroMAX
SPECIES	MaxPEEM	HIPPIE	SoftiMAX ✓	DanMAX ✓	ForMAX ✓	BioMAX	FemtoMAX

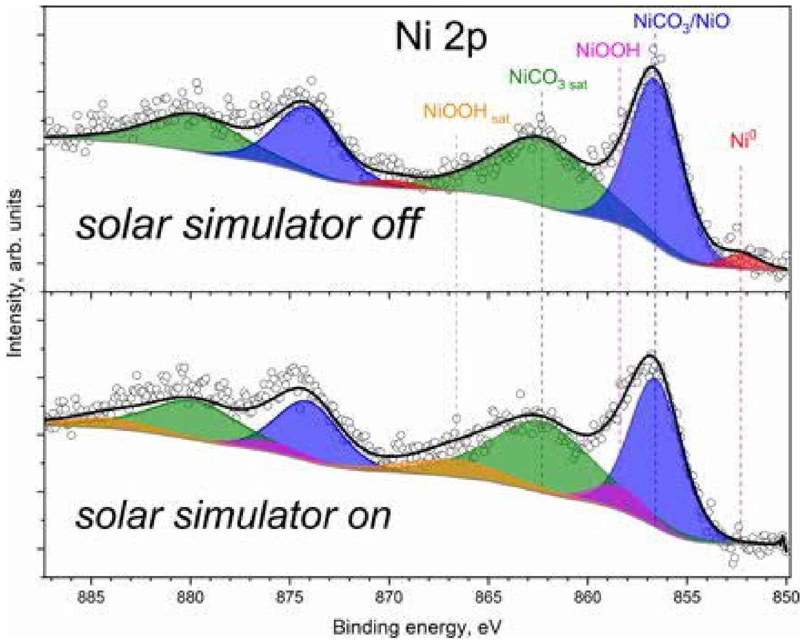
MAX IV

Ambient Pressure PhotoElectron Spectroscopy

Ability to follow the in-situ evolution of the photocatalyst surfaces with AP-XPS by irradiating the sample with sunlight-like light.

- Two light sources: solar simulator and UV lamp
  - wavelength 300-2100 cm^{-1} and 240-2500 cm^{-1}
- Tunable intensity
- Total pressure up to 20 mbar





- Ni@NiO/$NiCO_3$ was characterized under 1 mbar H_2O w/ and w/o light.
- During illumination, the metallic Ni peak vanishes, and the new peak appeared that we've assigned to NiOOH
- No X-ray beam damage effect are observed

Novel photocatalytic setup for ambient pressure X-ray photoelectron spectroscopy
Alexander Klyushin *et al.*, *submitted*

MAX IV

Bloch

Studying the electronic structure of surfaces and 2D materials

EH0

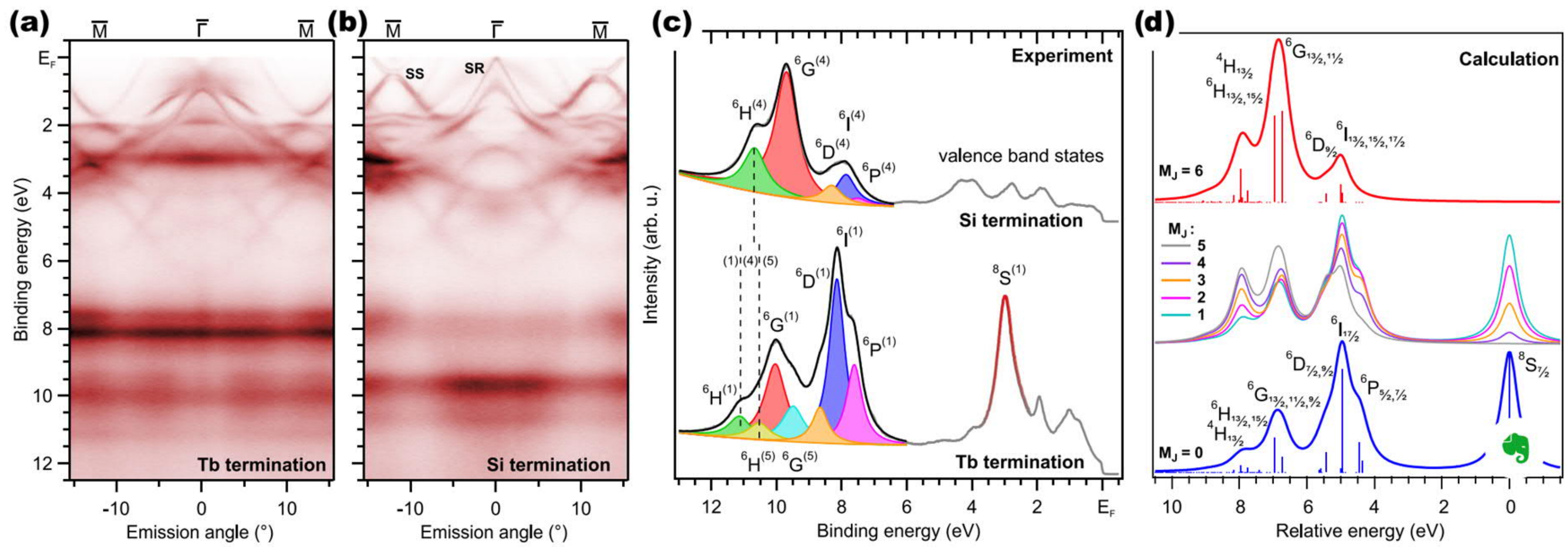


FIG. 2. ARPES spectra taken from (a) Tb and (b) Si terminated surfaces of the AFM ordered $TbRh_2Si_2$ crystal at $T = 21$ K along the $\overline{M} - \overline{\Gamma} - \overline{M}$ direction of the surface Brillouin zone (SBZ). (c) Normal-emission PE spectra obtained by integration over the angle range of $\pm5^\circ$ from the data shown in [(a),(b)]. (d) Theoretical normal-emission $4f$ PE spectra for different single-M_J ground states calculated using Eq. (7). The numbers in brackets denote atomic layers from which the signal comes.

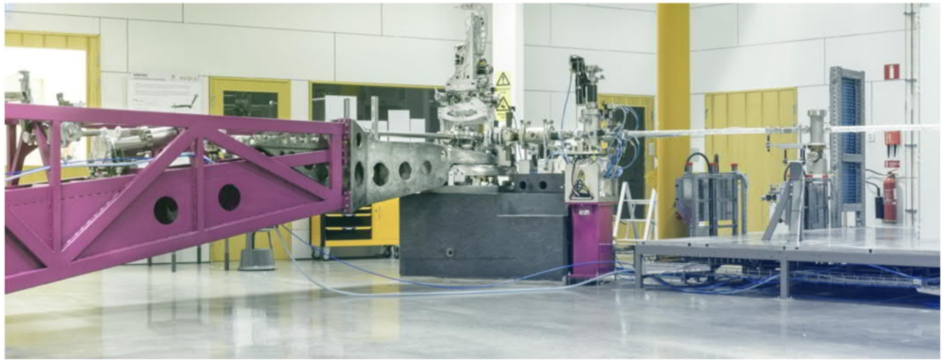
Crystal electric field and properties of 4f magnetic moments at the surface of the rare-earth compound TbRh2Si2
Tarasov et al., Phys. Rev. B 106, 155136 (2022)

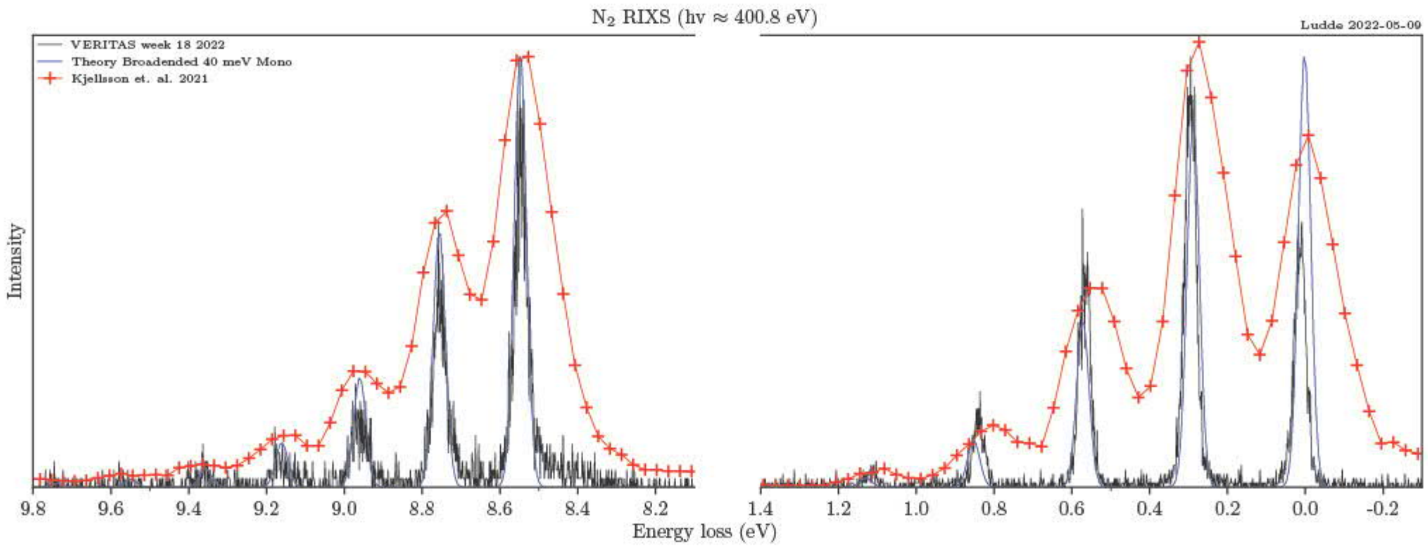
EH0 Det är en liten elefant på den högra grafen, ska det vara det?
Emelie Hilner, 2022-11-16T20:51:48.244

OK0 0 Hej, nej den kommer nog från mjukvaruplatformen som jag glömt namnet på. Strunt samma.
Olof Karis, 2022-11-17T06:39:00.501

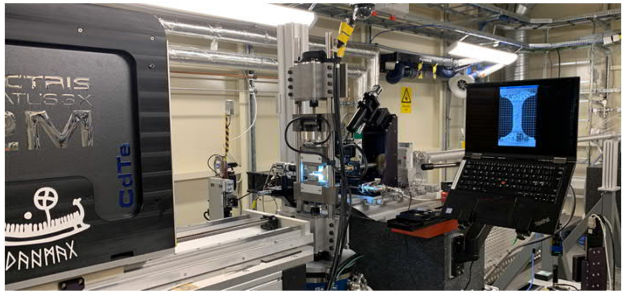
Veritas – Commissioning Results

Investigating fundamental excitations in correlated materials and vibrational excitations in molecular systems

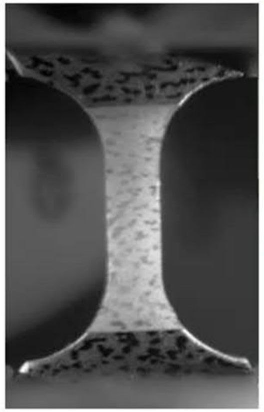


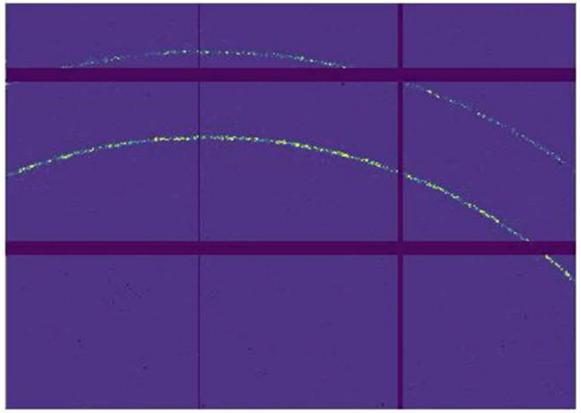


In-situ x-ray diffraction of deformation of TRIP steel

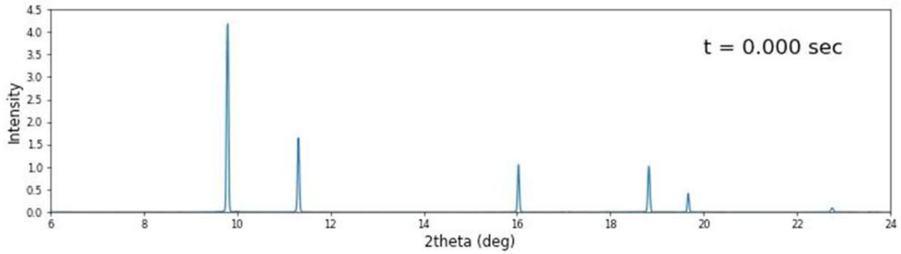


- Transformation induced plasticity or TRIP steels are used in many applications due to their outstanding combination of strength and ductility





- Adiabatic heating upon fast deformation of TRIP steel drives phase transitions – and changes the properties of the material



- Using strain rates up to 1 s^{-1} and 250 Hz XRD data we observed the details of the austenite to martensite phase that transform

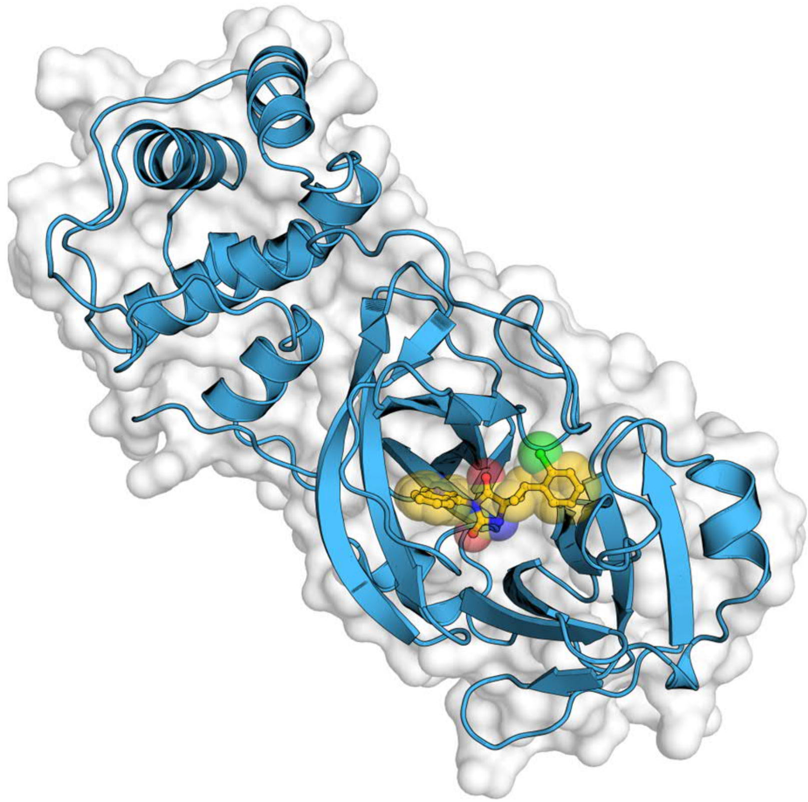
PI: M. Hokka, Tampere U.

Slow motion video
– the real experiment is 5 times faster

MAX IV

Towards an antiviral drug against SARS CoV-19

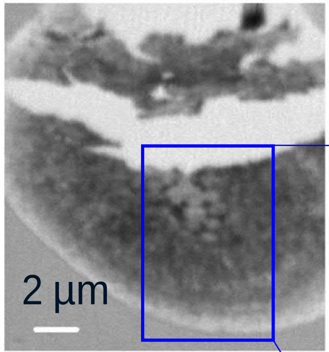
- Part of SciLifeLab and KAW:s national program on COVID-19 research
- Inhibitor bound to protein involved in virus assembly studied at BioMAX (FragMAX)



https://maxiv-legacy.maxiv.lu.se/news/from-virtual-screens-to-promising-inhibitors-of-coronaviruses-an-effort-to-develop-an-antiviral-drug-to-treat-covid-19/
https://www.scilifelab.se/capabilities/pandemic-laboratory-preparedness/pandemic-response/covid-19-research-program/

MAX IV

Sagitta-Otolith ($CaCO_3$ fish ear bones) in cod larva



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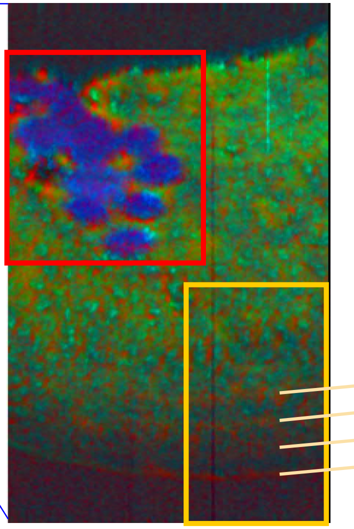
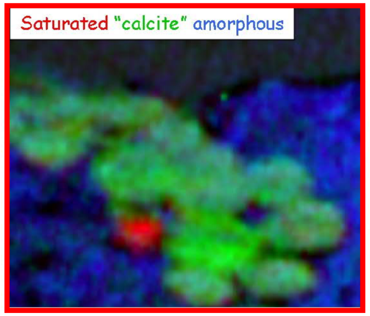
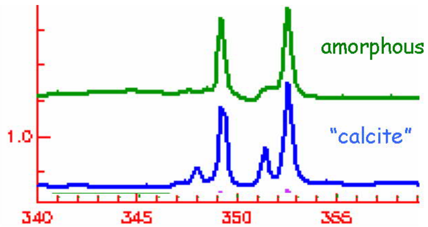
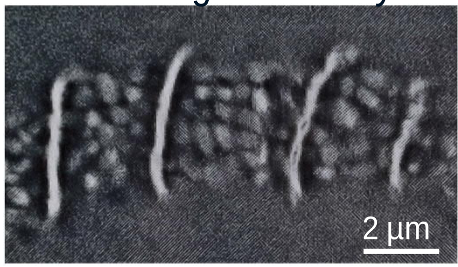


CORE

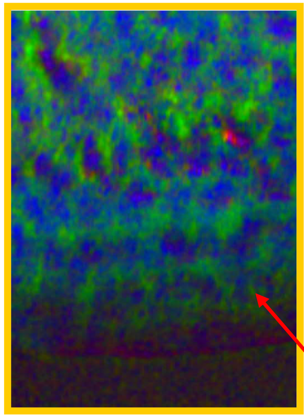


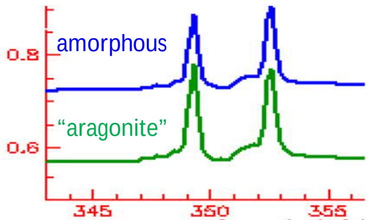


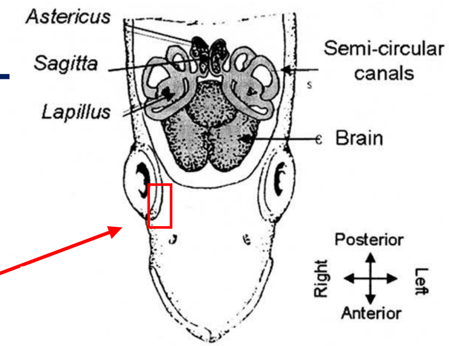
Bonus: edge of the eye

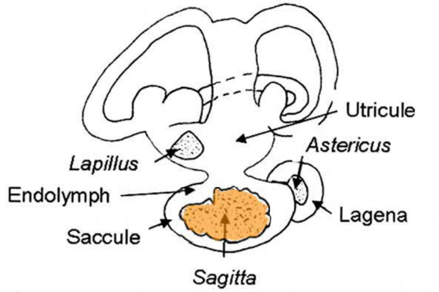


EDGE







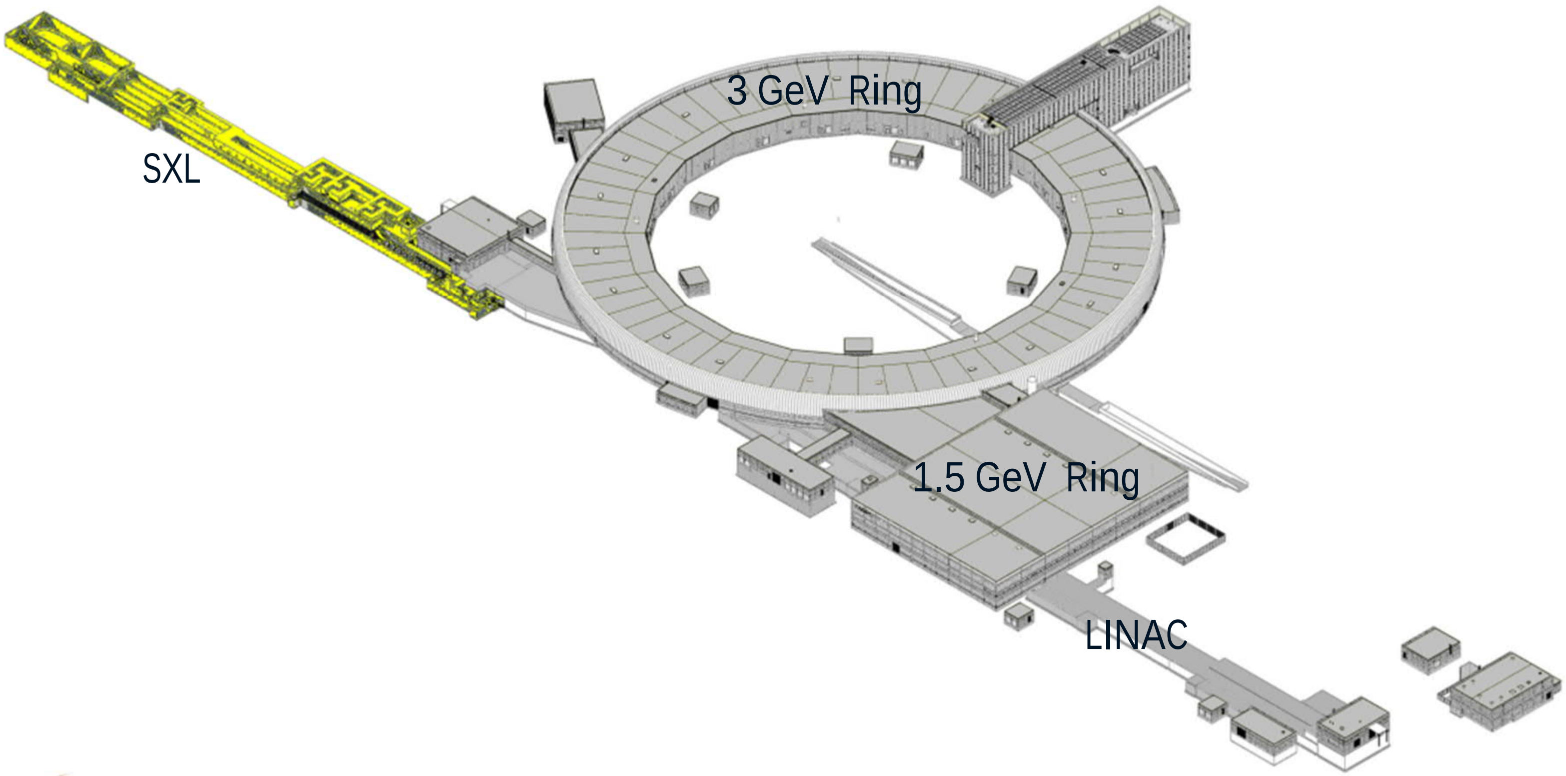


Goal: explore ability of STXM to characterise early day rhythm in the growth of otoliths ($CaCO_3$ structures in fish ear) in 6d old cod fish larva.

Yvette Heimbrand, Karen Limburg (SLU); Bryan Falcones Olarte (LU)
Adam Hitchcock (McMaster University) &
Karina Thånell

SXL: A Soft X-ray Laser @ MAX IV

- A user-driven initiative and internationally competitive facility
- Capitalizes on existing infrastructure to open research opportunities that are not possible at any other beamline at MAX IV



SXL in the international context

Facility	SXL	SwissFEL	Fermi	FLASH	SXFEL Shanghai	XFEL	PAL	LCLSI	LCLSII	SACLA
Max electron Energy [GeV]	3.0	5.9	1.5	1.25	1.6	17.5	10	14.3	14.3	8.5
Wavelength range [nm]	1 5	0.1 7	4 100	4 90	1.2 12	0.05 4.7	0.0 86	0.1 4.4	0.054. 7	0.06 0.3
Photons/pulse	$8x10^{10}$ $4x10^{13}$	10^{13}	10^{13} 10^{14}	$3x10^{13}$	10^{11} 10^{13}	10^{12}	10^{11} 10^{12}	10^{13}	10^{12} 10^{13}	$4x10^{11}$
Peak Brilliance [ph/s/mm^2/mrad^2/0.1%BW]	10^{32} $4x10^{33}$	10^{33}	10^{31}	10^{31}		$5x10^{33}$	10^{33}	10^{33}	$2x10^{31}$	10^{33}
Rep. Rate [Hz]	100	100	10 50	5000	10 50	27000	60	120	10^6	60

Data adapted from X-ray FEL Science: The International Perspective by Massimo Altarelli, London 2019