SESAME
An overview

Andrea Lausi

With contributions by
Gihan Kamel, Messaoud Harfouche,
Mahmoud Abdellatief,
Gianluca Iori, Mustafa Fatih Genişel

Radio waves, infrared rays, visible light, ultraviolet rays, X-rays, and gamma rays are all types of electromagnetic radiation. Radio waves have the longest wavelength, and gamma rays have the shortest wavelength.

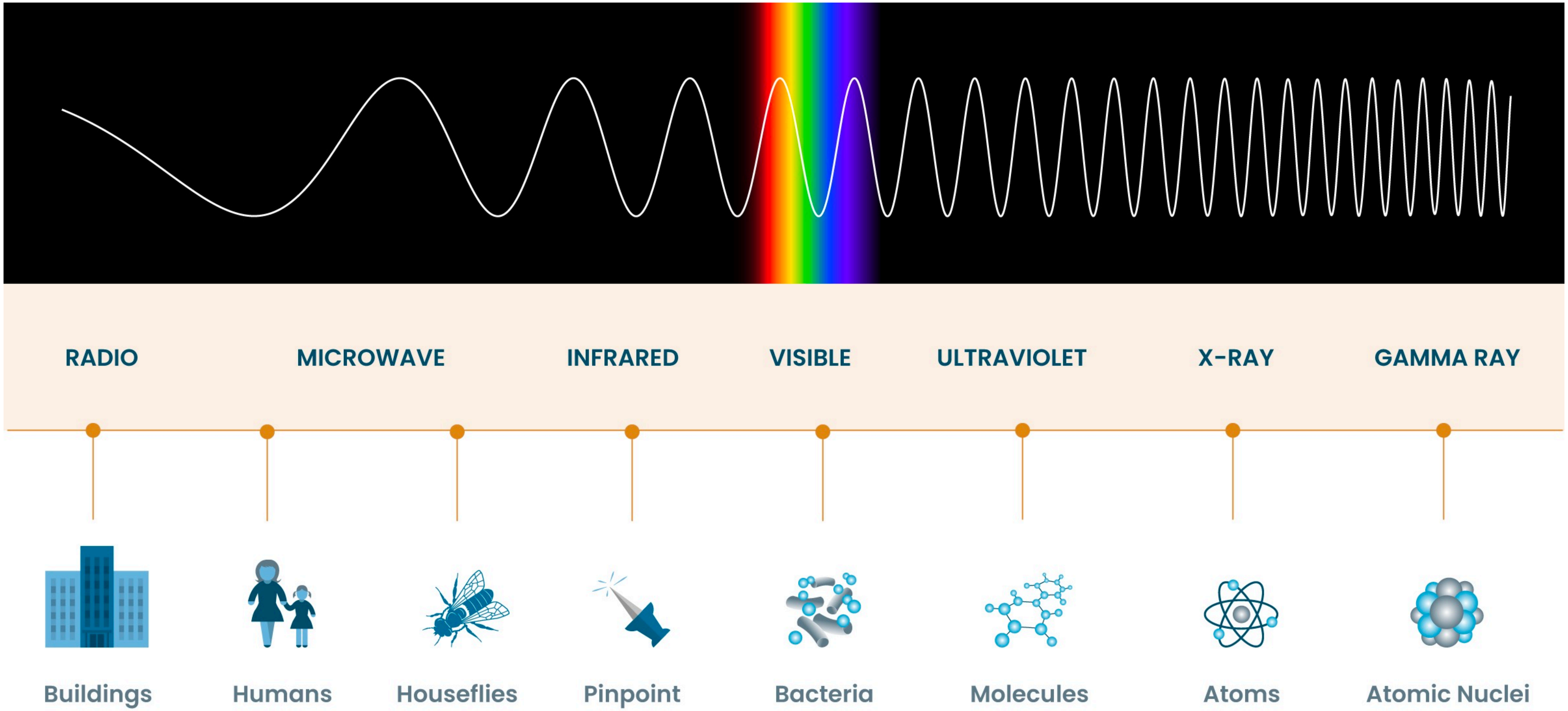
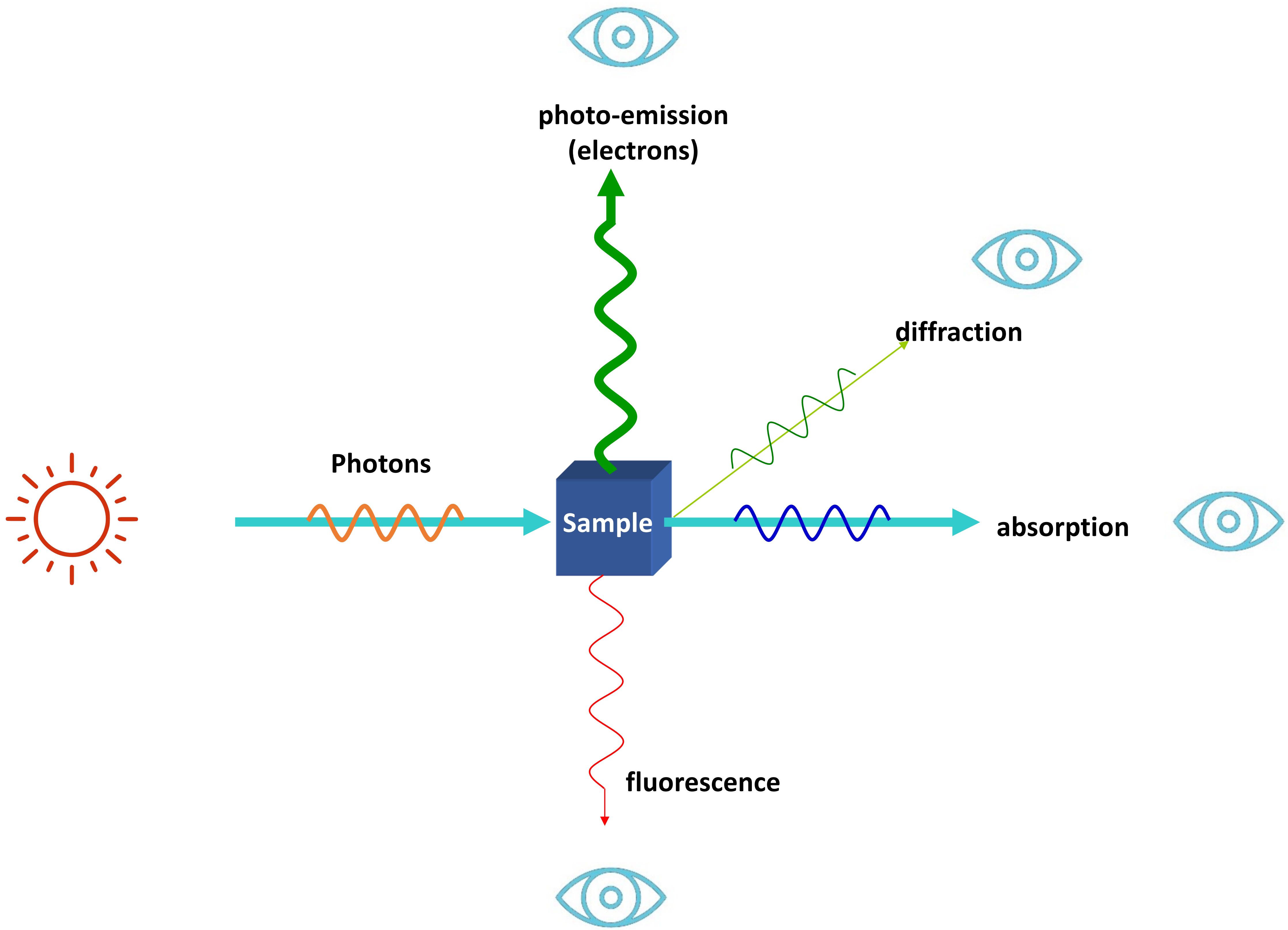
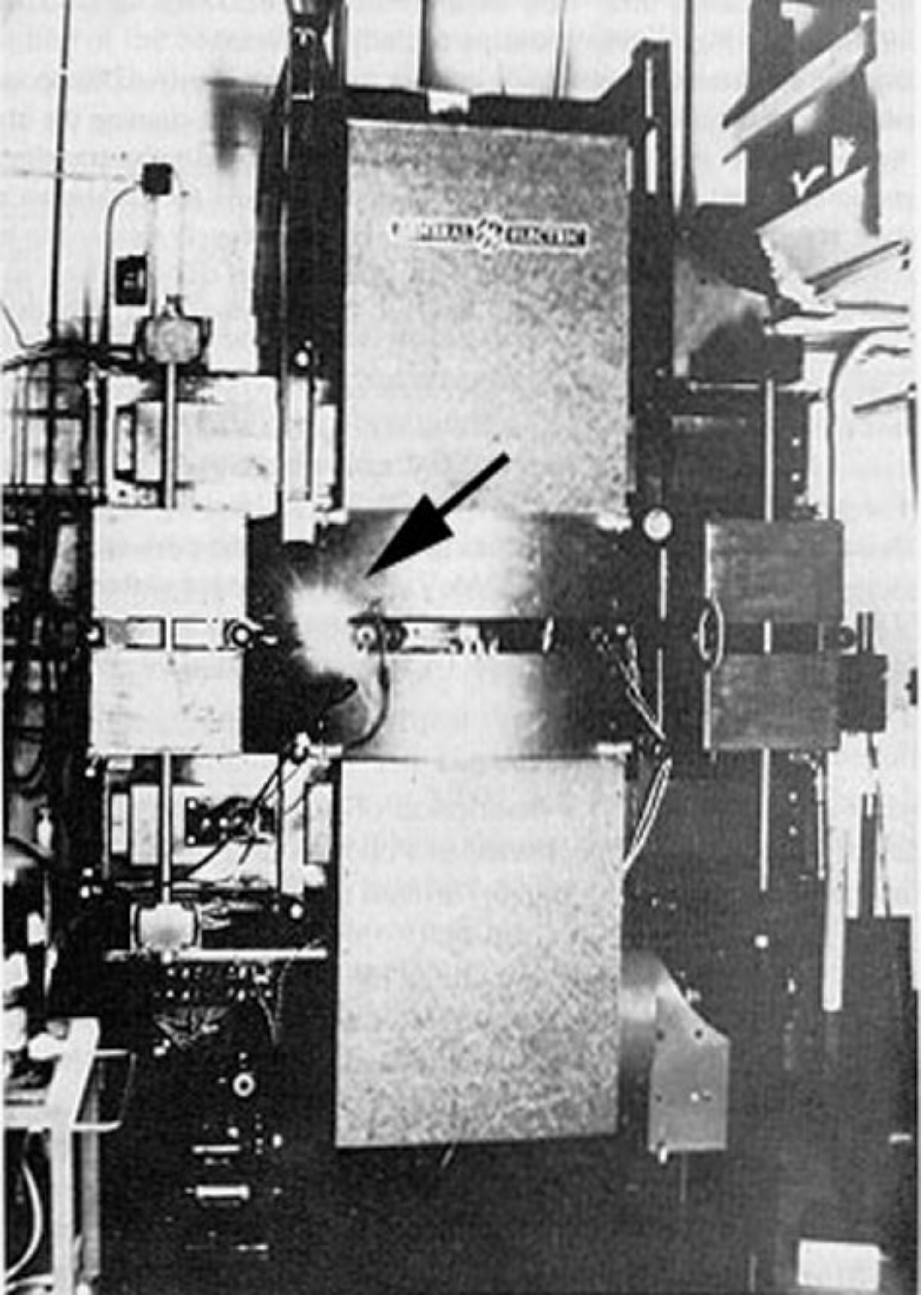


Image courtesy XFEL

Interaction of Electromagnetic Radiation with Matter





Electromagnetic radiation is emitted by charged particles when accelerated

Electromagnetic radiation emitted when the charged particles are accelerated radially (**v** ⊥ **a**) is called Synchrotron radiation

Synchrotron radiation was named after its discovery in a General Electric synchrotron accelerator built in 1946 and announced in May 1947 by Frank Elder, Anatole Gurewitsch, Robert Langmuir, and Herb Pollock in a letter entitled "Radiation from Electrons in a Synchrotron".

It is produced in the synchrotron radiation sources using bending magnets, undulators and wigglers.

1) Synchrotron Radiation covers a **Broad Spectrum** from microwaves to hard X-rays: the user can select the wavelength required for experiment

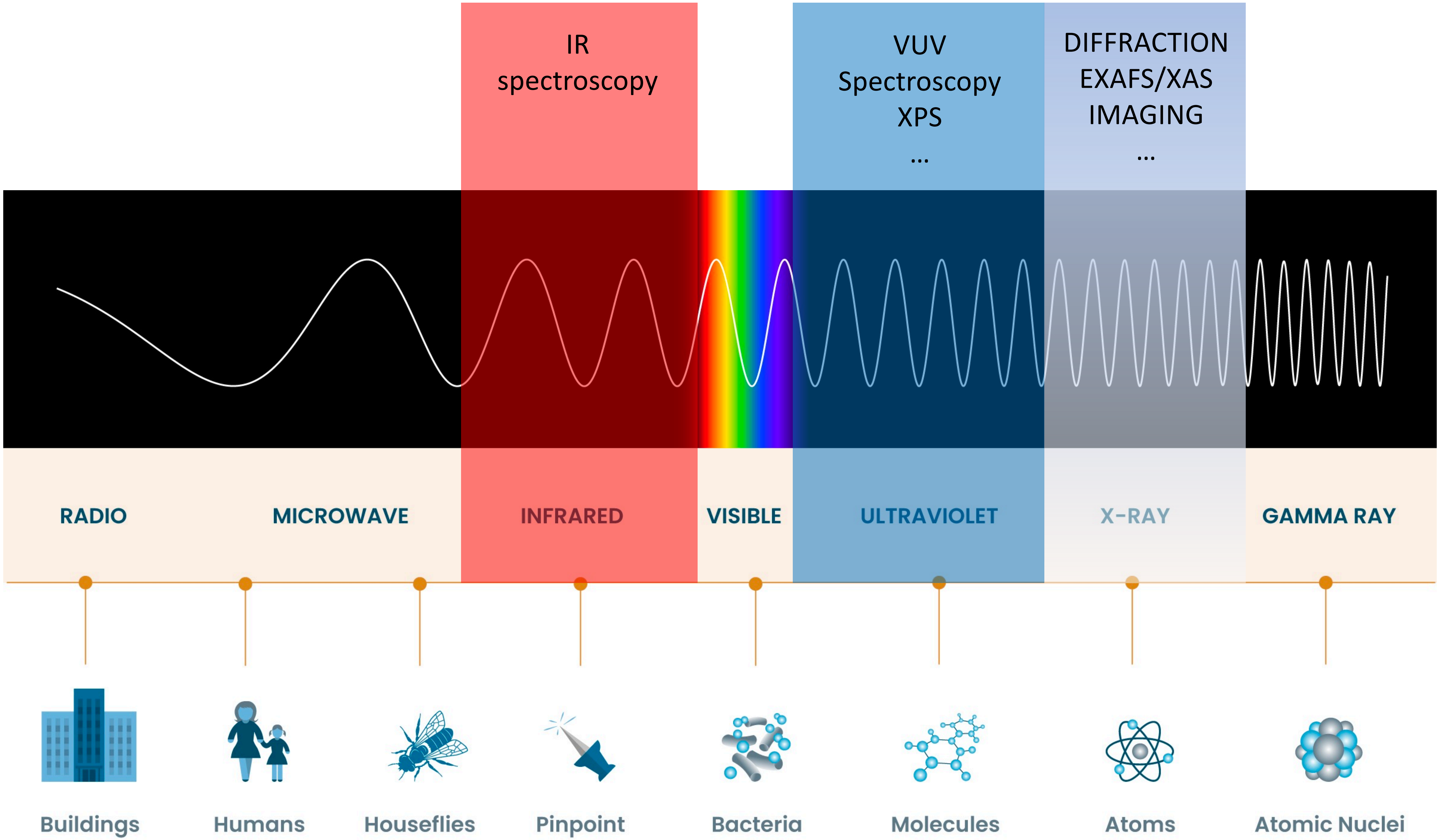
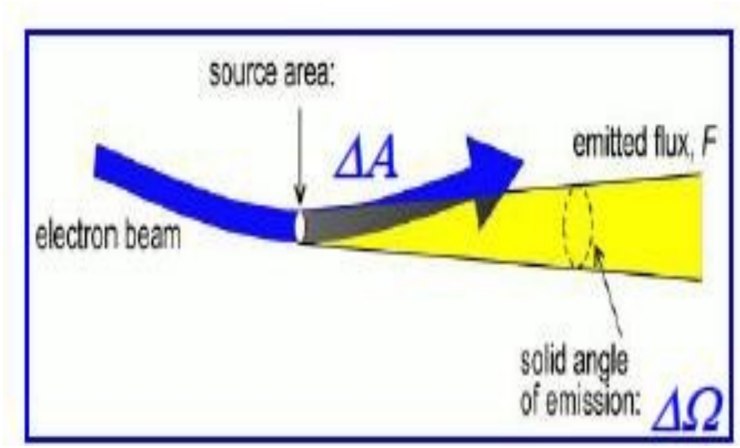
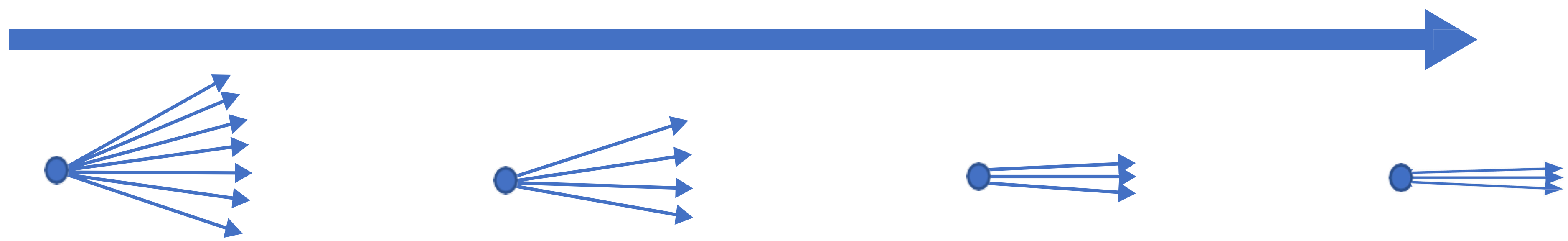


Image courtesy XFEL

2) Synchrotron Radiation is extremely **collimated**

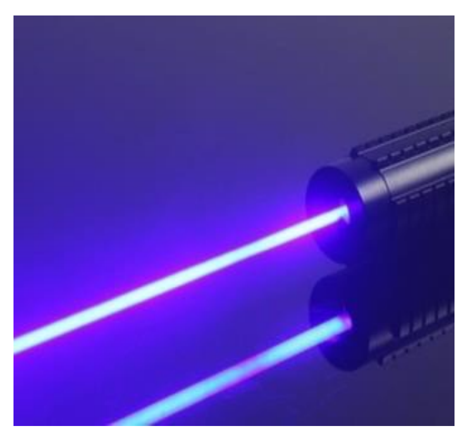


$$\text{BRILLANCE} = \frac{\text{Photon flux}}{\text{Source area x angular divergence}}$$




HALOGEN LAMP


TORCH

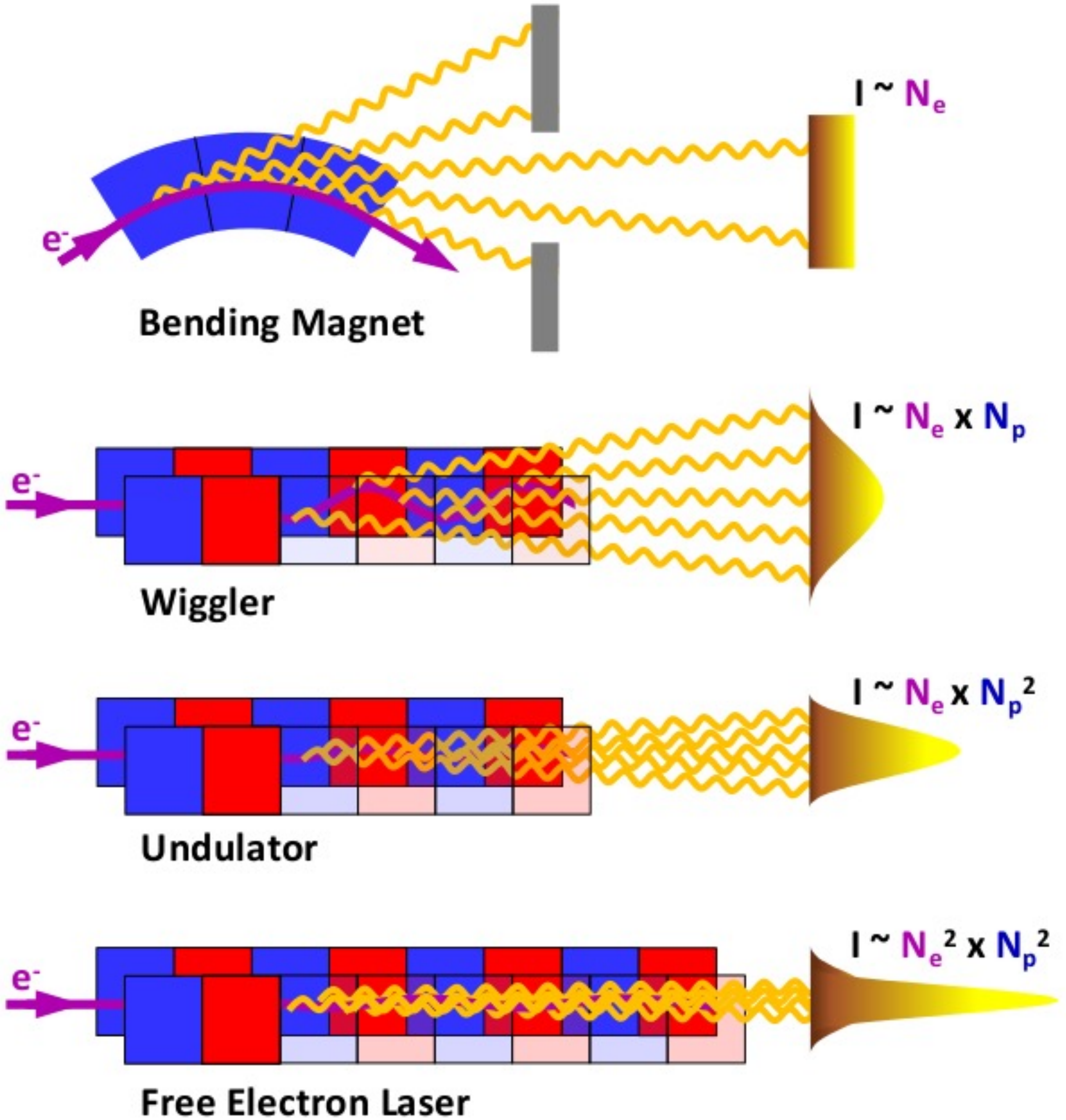

LASER

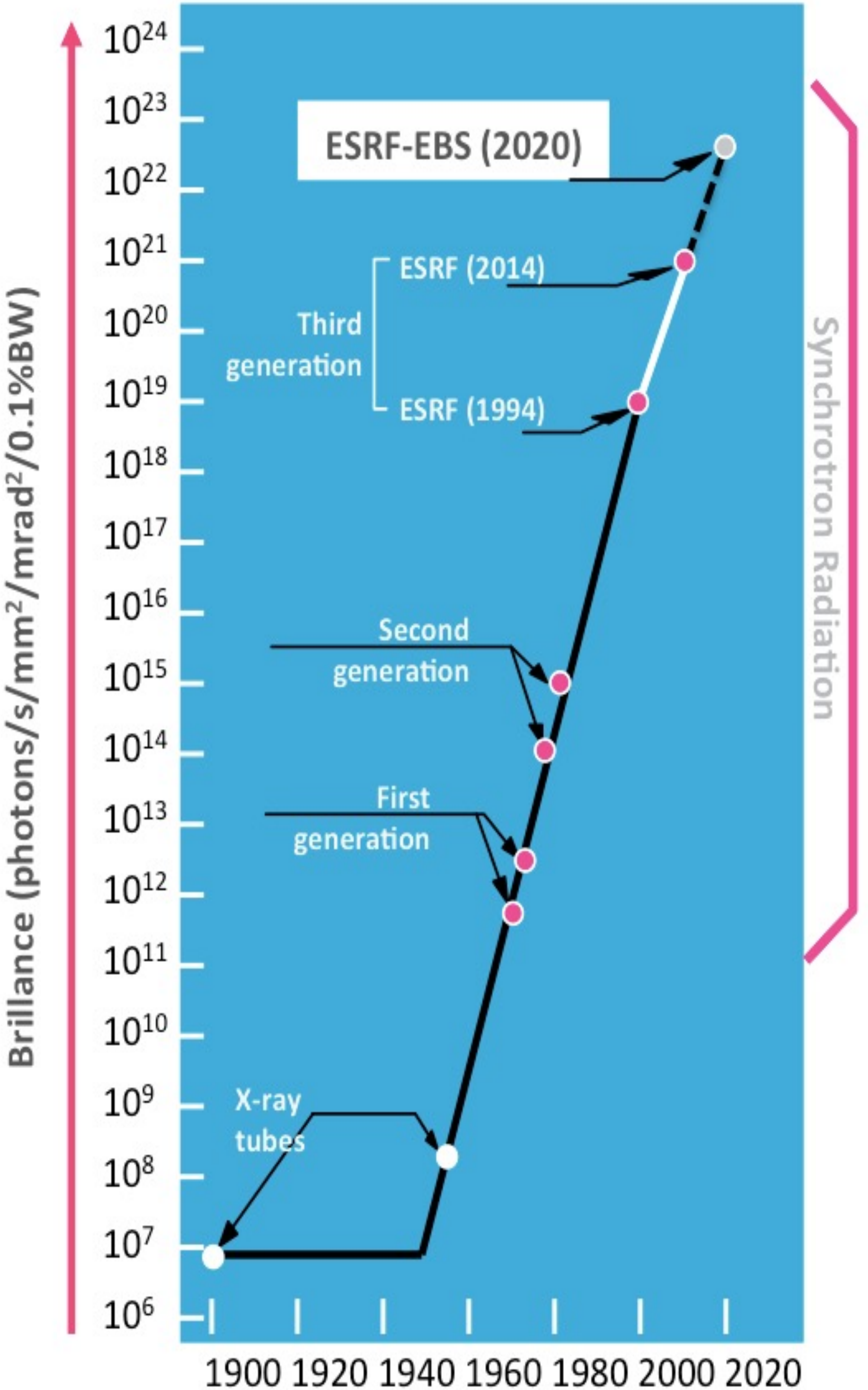

SYNCROTRON RADIATION

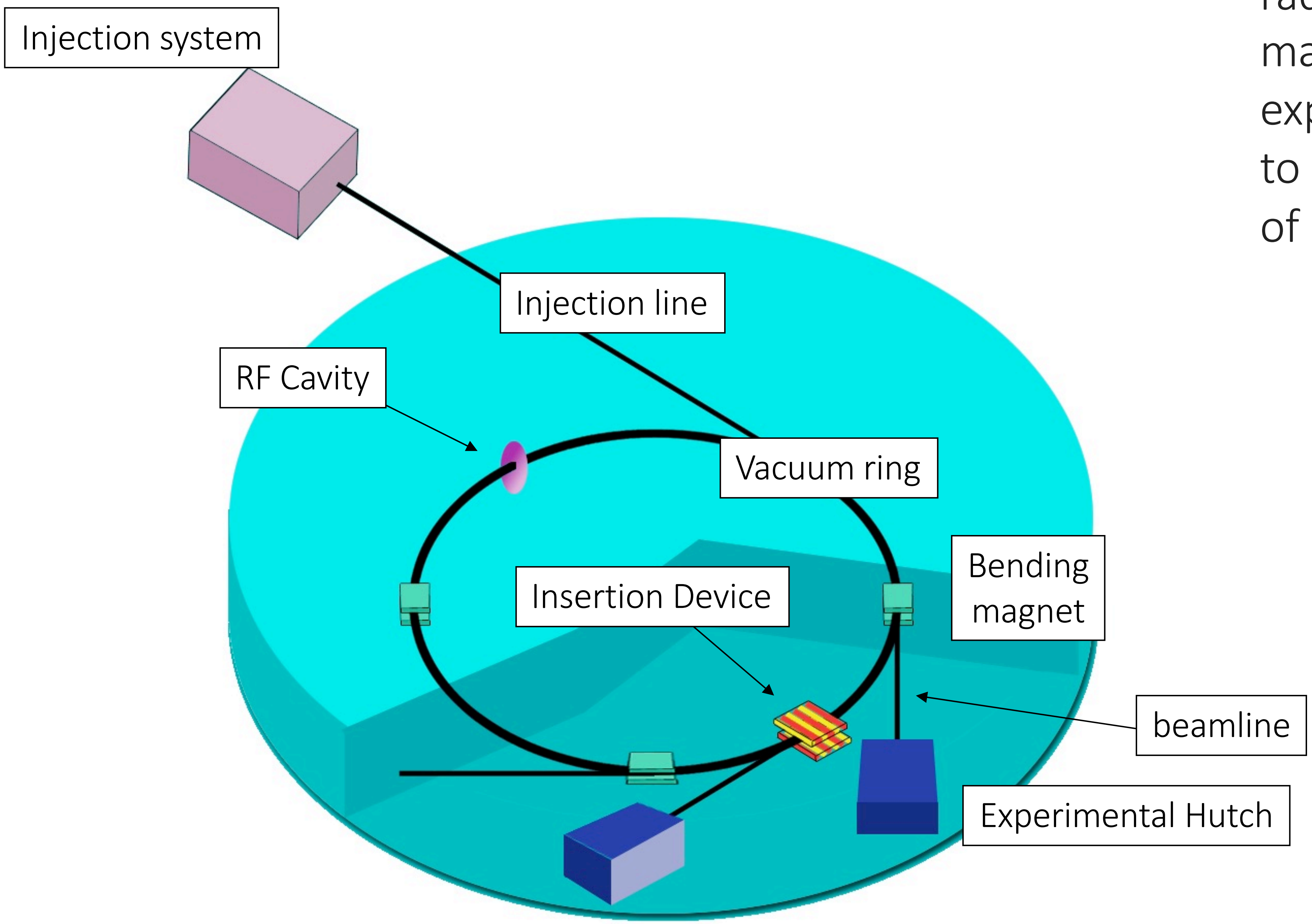
Collimation: Conventional Sources vs Syncrotron Ligth

Courtesy M. Cestelli Guidi

Synchrotron Radiation can be **taylored** to the experiment needs



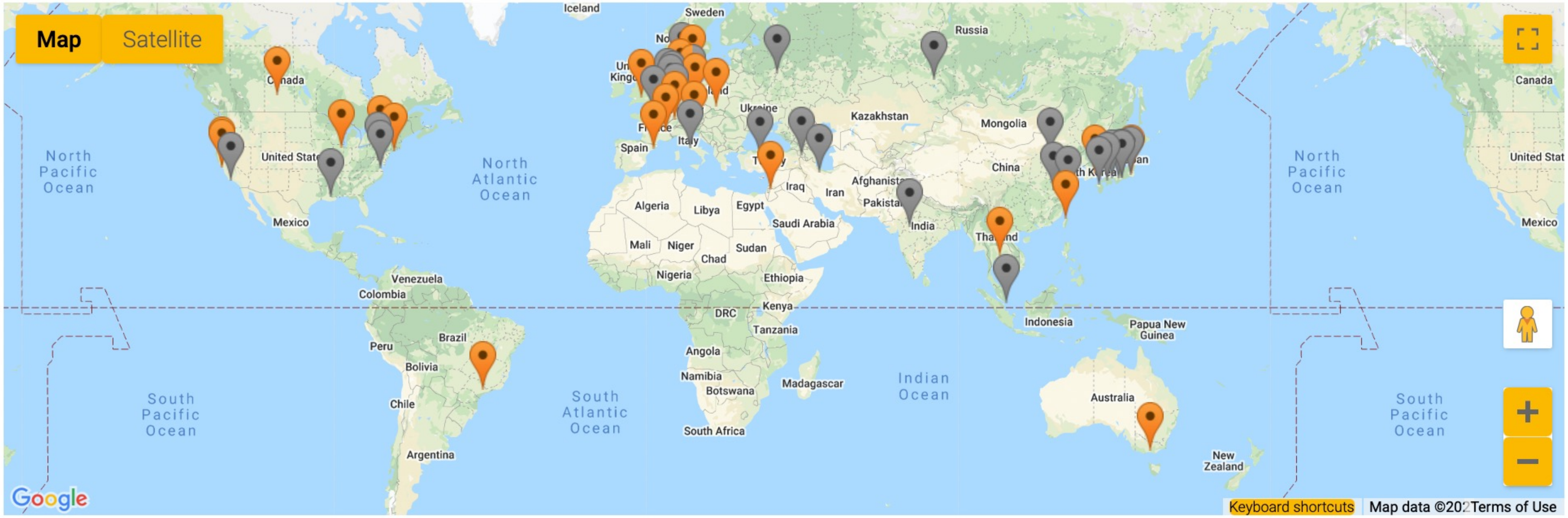




One single synchrotron radiation source can host many different sources, exploited in different ways to cover a wide spectrum of applications.

Light sources of the world

There are more than 50 light sources in the world (operational, or under construction). This page lists all the members of the lightsources.org collaboration.



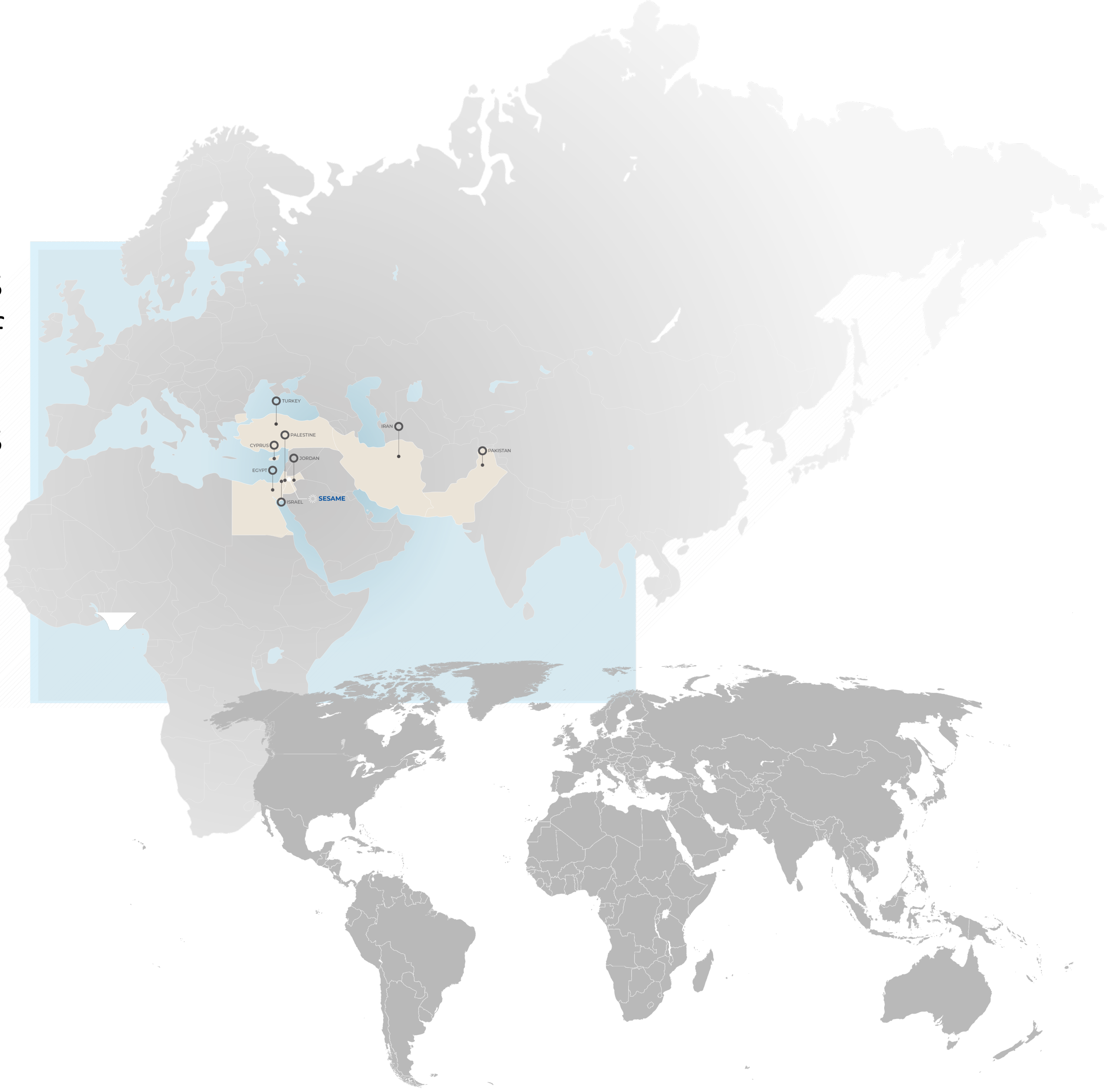
Orange pins on the map represent members of the lightsources.org collaboration.
If your facility is not listed below and you wish to join our collaboration, please contact our *project manager* .

SESAME is located in Allan, NW of Amman, the capital of Jordan

United Nations
Educational, Scientific and
Cultural Organization

- SESAME is a cooperative venture by scientists and governments of the region set up on the model of CERN (European Organization for Nuclear Research) although it has very different scientific aims.
- It was developed under the auspices of UNESCO (United Nations Educational, Scientific and Cultural Organization) following the formal approval given for this by the Organization's Executive Board (164th session, May 2002).

SESAME is composed of Members and Observers



SESAME is composed of Members and Observers

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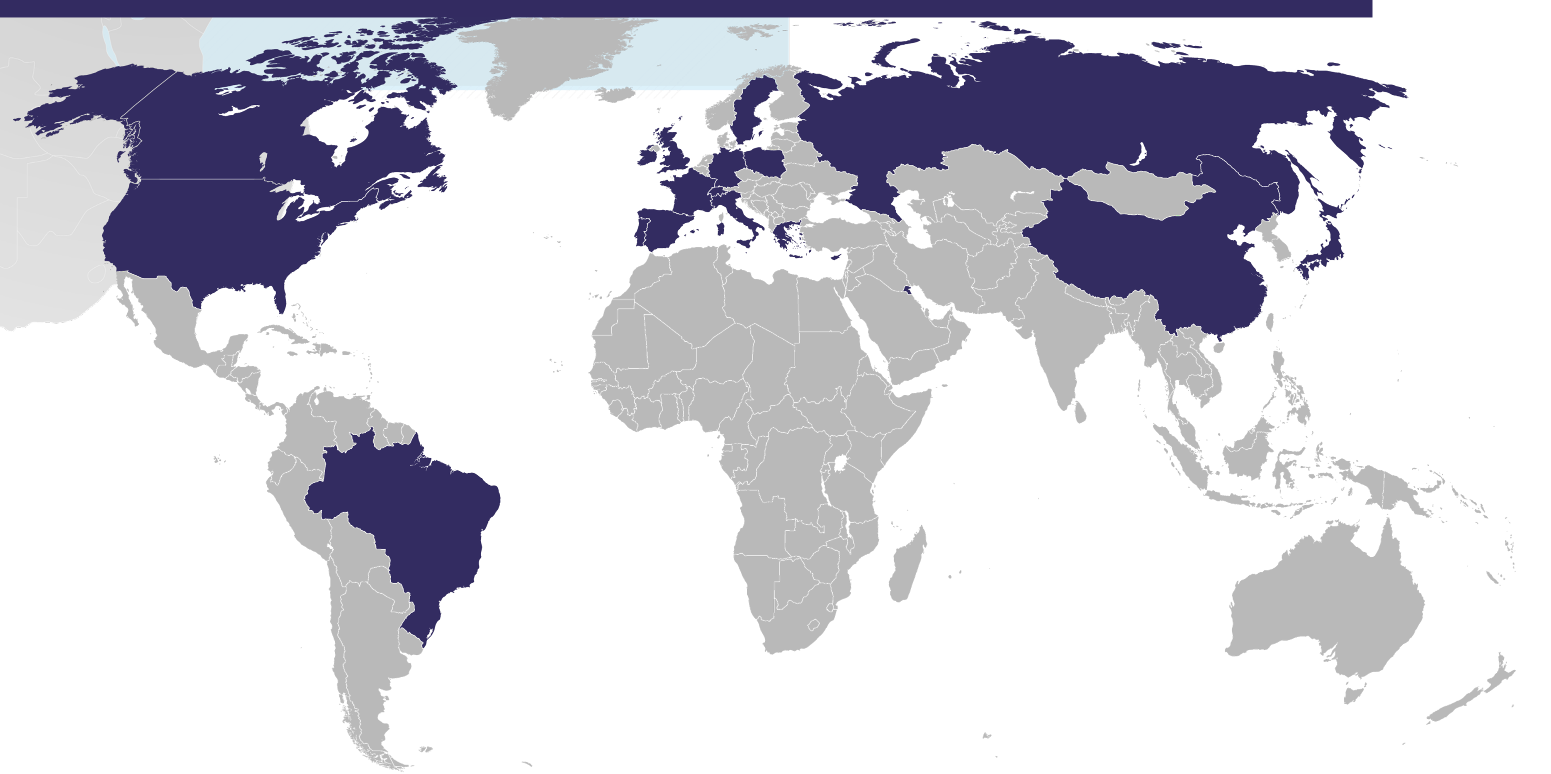
Brazil, Canada, CERN, China, the European Union, France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russian Federation, Spain, Sweden, Switzerland, the United Kingdom, United Arab Emirates, and the United States of America.

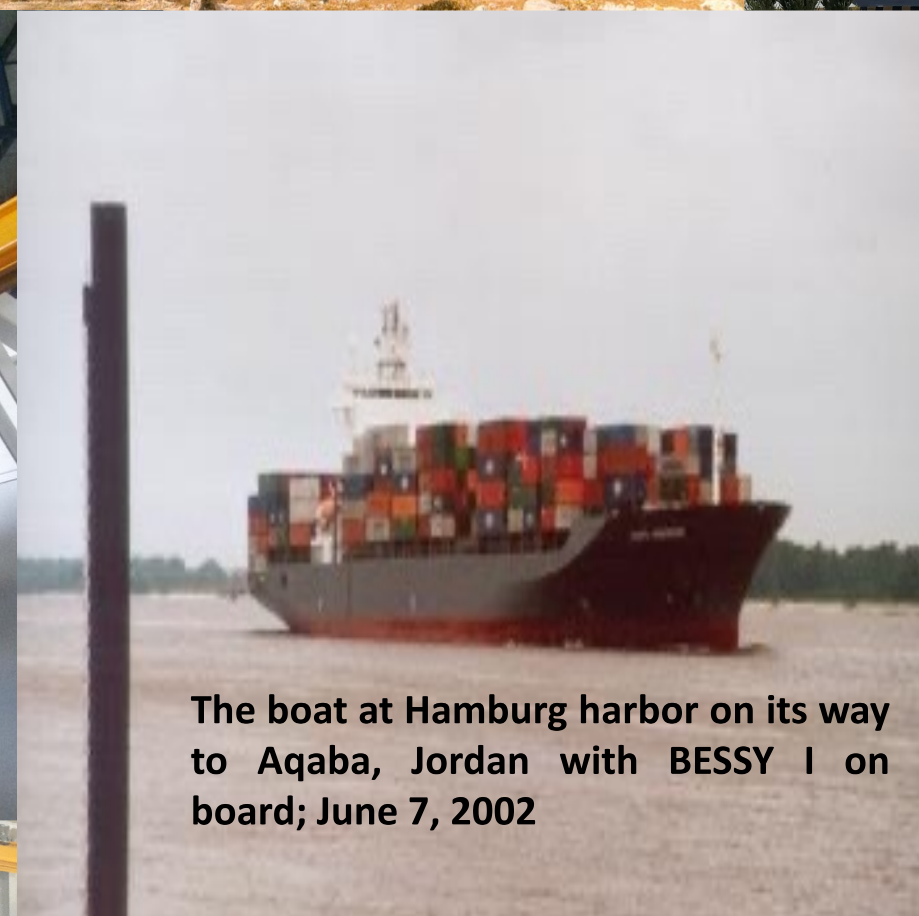


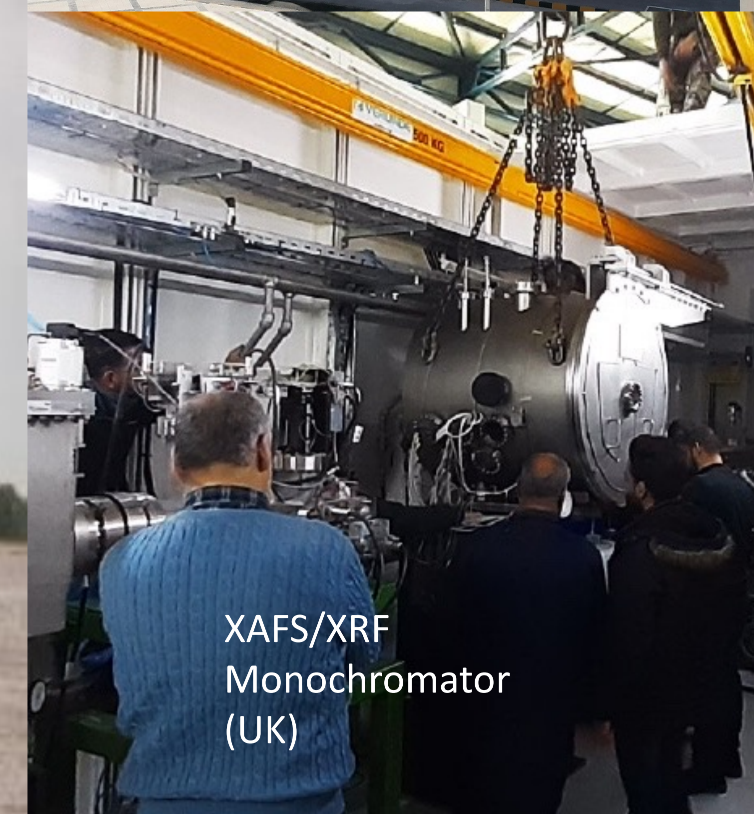
SESAME received much support from observers. Examples are…


Solar Power Plant (EU)

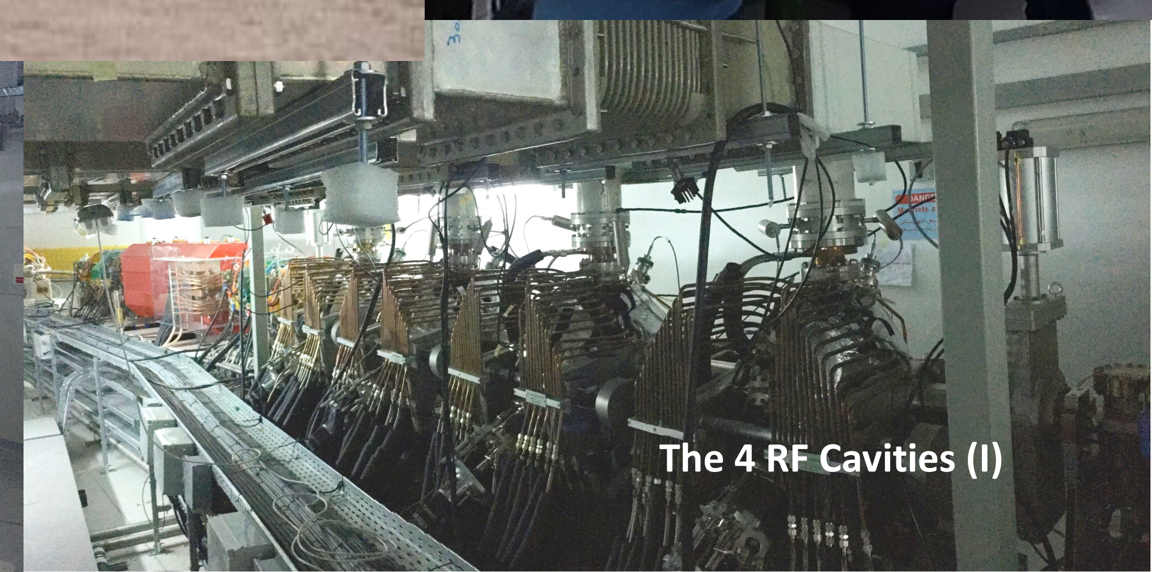

Sergio Fubini Guest-House (I)


Rossendorf Beamline (D)


The boat at Hamburg harbor on its way to Aqaba, Jordan with BESSY I on board; June 7, 2002


XAFS/XRF Monochromator (UK)


Material Science Beamline (CH)


The 4 RF Cavities (I)

Synchrotron-light sources allow research in many areas, e.g. biology, physics, chemistry, archaeology, medicine, material science, environmental science, arts, …
They are ideal facilities for building scientific capacity.

International collaboration is the obvious way to share the cost of building and maintaining a large-scale scientific infrastructure such as a synchrotron-light source.

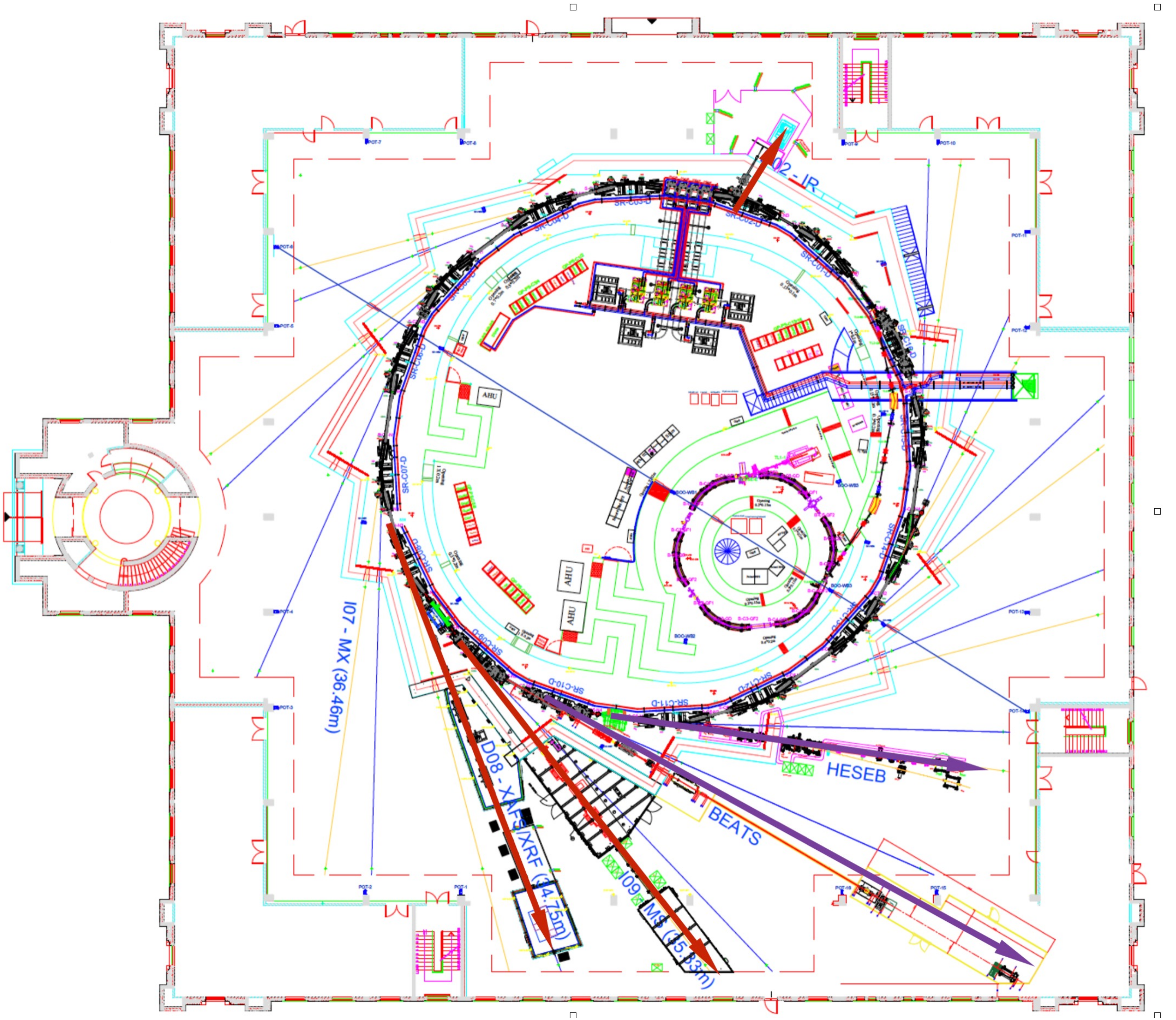
Synchrotron-light sources are user facilities: scientists will typically go there two or three times a year for a few days to carry out experiments in collaboration with other scientists.

SESAME Opening Ceremony, May 16, 2017

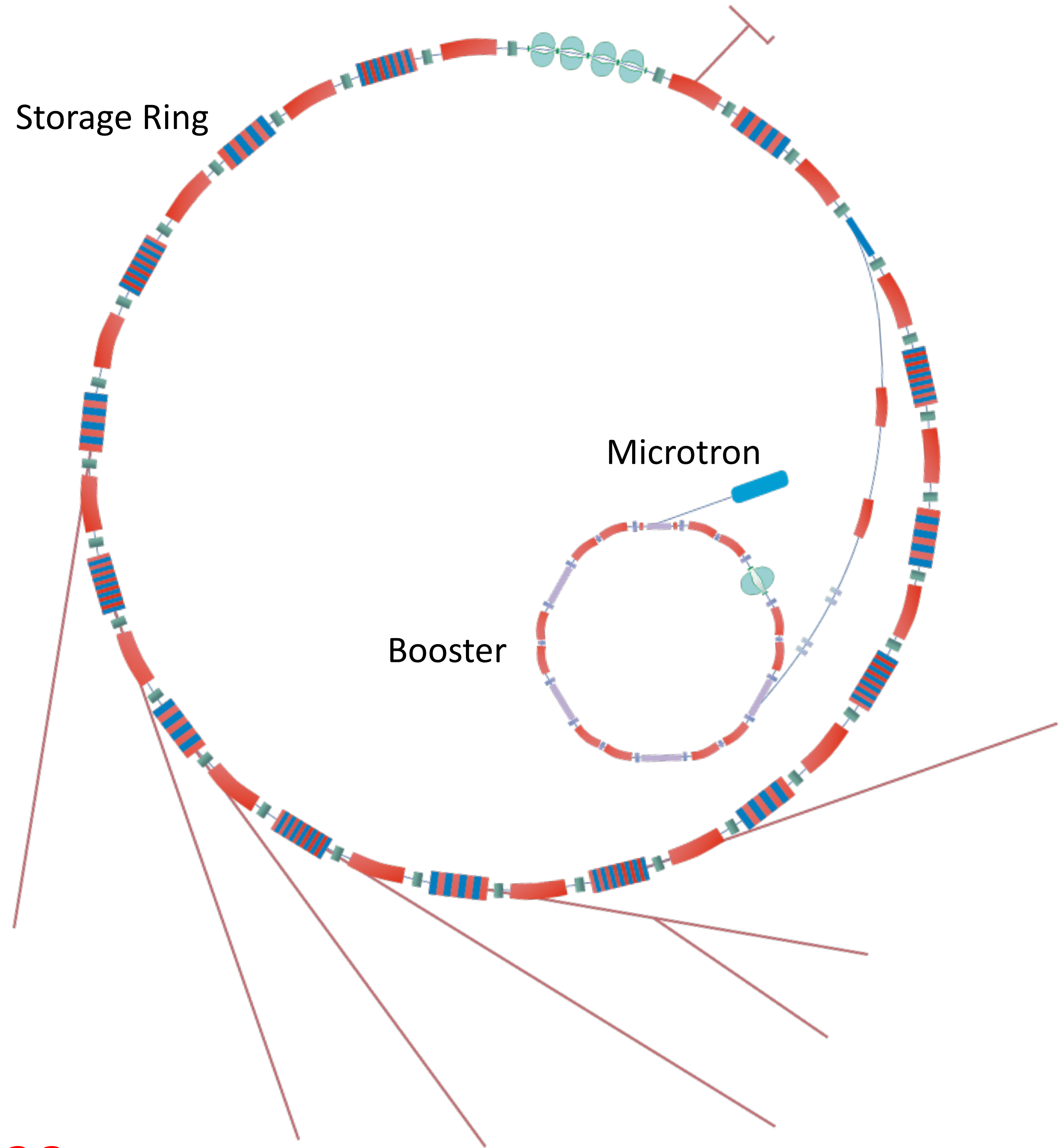
His Majesty King Abdullah II following the opening of SESAME, flanked by Heads of the delegations of the SESAME Members and Directors of International Organisations that have supported SESAME. To the King's left, HRH Princess Sumaya of Jordan, who headed the Jordanian delegation, and Fabiola Gianotti, Director General of CERN; to the right, Irena Bokova, Director-General of UNESCO, and Carlos Moedas, European Commissioner for Research, Science and Innovation.


SESAME
INTERNATIONAL RESEARCH CENTER

SESAME layout



SESAME layout



SESAME storage ring parameters

Energy (GeV) 2.5
Current (mA) 400
Circumference (m) 133.2
Natural emmitance (nmrad) 26

Three Beamlines in Operation

Number of proposals received for the IR (2018-2021), XAFS-XRF (2018-2021) and MS (2020-2021) beamlines:

Belgium	1
Colombia	1
Cyprus	18
Egypt	75
France	1
Germany	2
Iran	56
Israel	8
Italy	8
Jordan	38
Kenya	3
Malaysia	1
Malta	1
Mexico	1
Pakistan	47
Palestine	12
Qatar	3
South Africa	1
Sweden	1
Turkey	45
United Arab Emirates	2
United Kingdom	1
TOTAL	**326**
TOTAL ACCEPTED	**177**

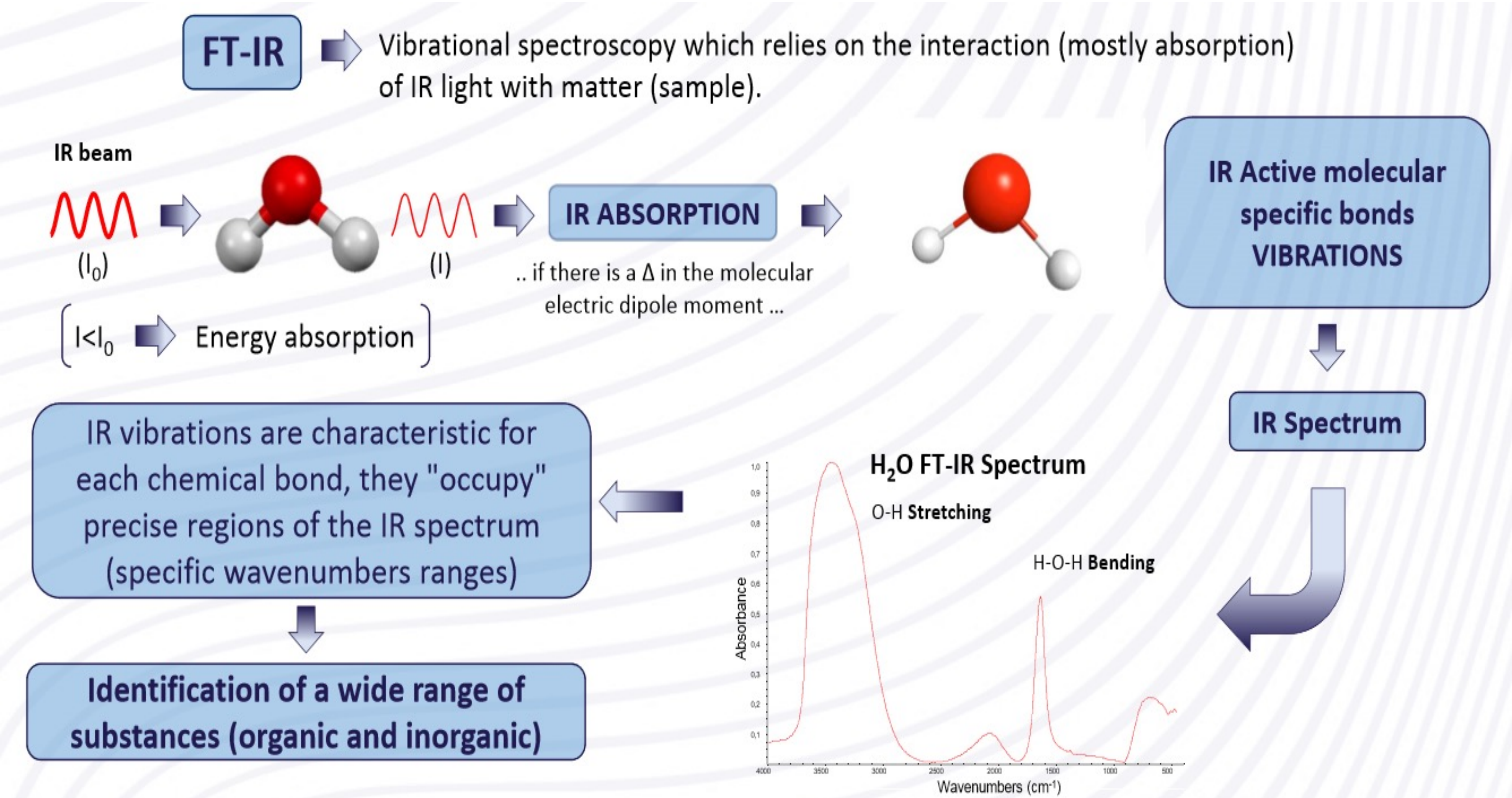
Three Beamlines under Construction

BEATS – BEAmline for Tomoghraphy at SESAME (2022)

HESEB – Helmholtz-SESAME Beamline (2022)

TXPES – Turkish X-ray PhotoEmission Spectroscopy Beamline (2023)

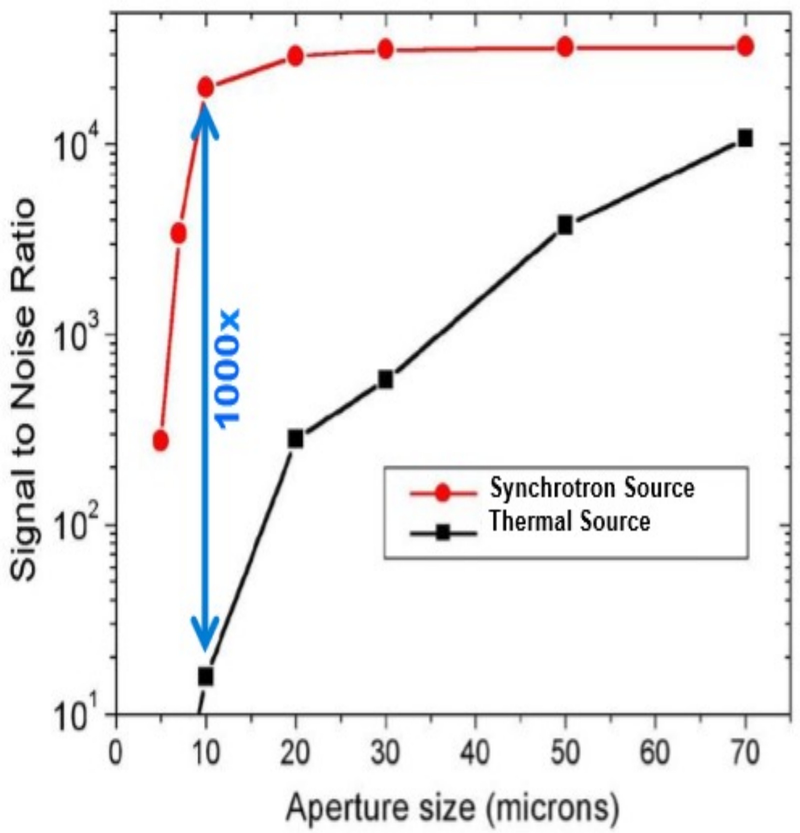
FT-IR Spectroscopy



Adapted from: Alvise Vianello, Jes Vollertsen Aalborg University, Denmark

SR Advantages over thermal sources

Synchrotron IR is 1000x *brighter* than a conventional blackbody source

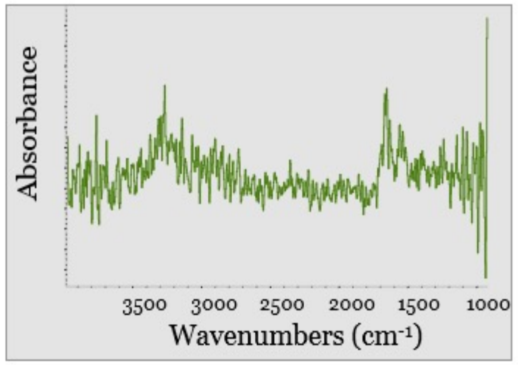


Advantages

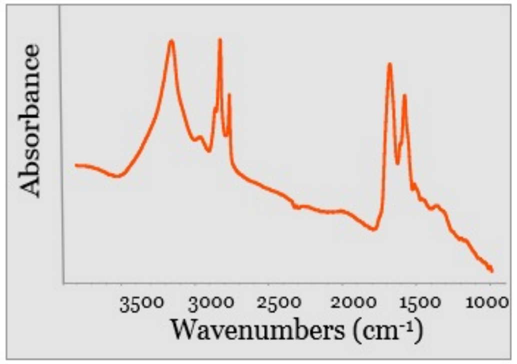
- Diffraction-limited spot sizes for microscopy (2-10 μm)
- Superior collimation for high spectral resolution
- Smaller samples
- Better signal to noise ratios
- Faster data acquisition

Holman et al., Spectroscopy - An International Journal 17(2-3), 139-159 (2003).

Globar: 6x6 μm^2
1000 scans = 500s

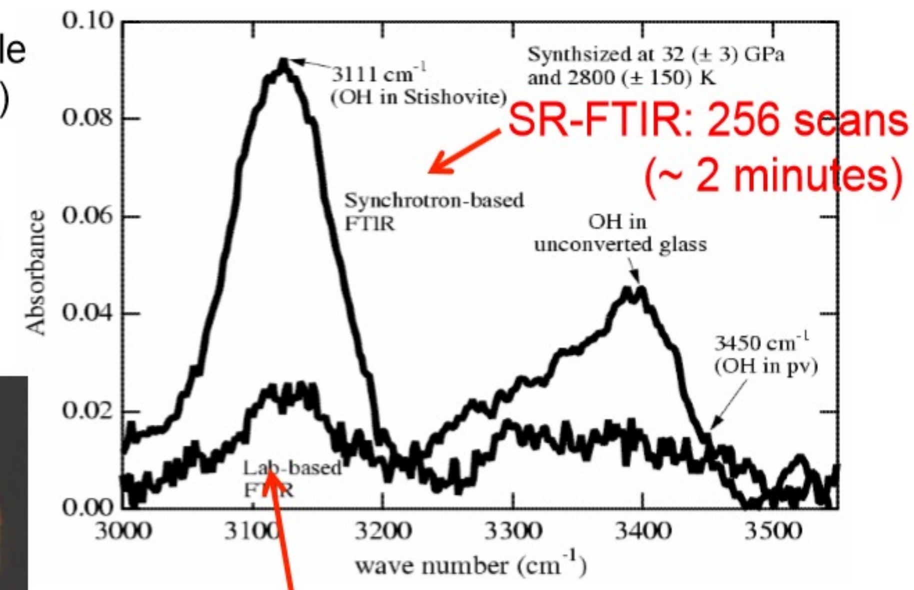


Synchrotron: 6x6 μm^2
32 scans = 16 s

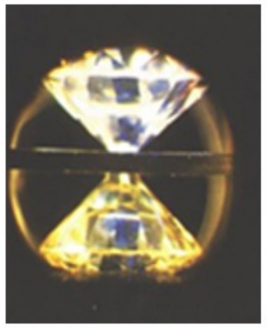


From Paul Dumas, SOLEIL

Mineral sample (ocean basalt) in diamond anvil cell at high pressure (32 GPa)



Lab FTIR: 60,000 scans averaged (~ 16 hours averaging!)



Panero, Benedetti, Jeanloz

BM02 - Infrared Beamline, IR

Gihan Kamel

Ahmed Refaat

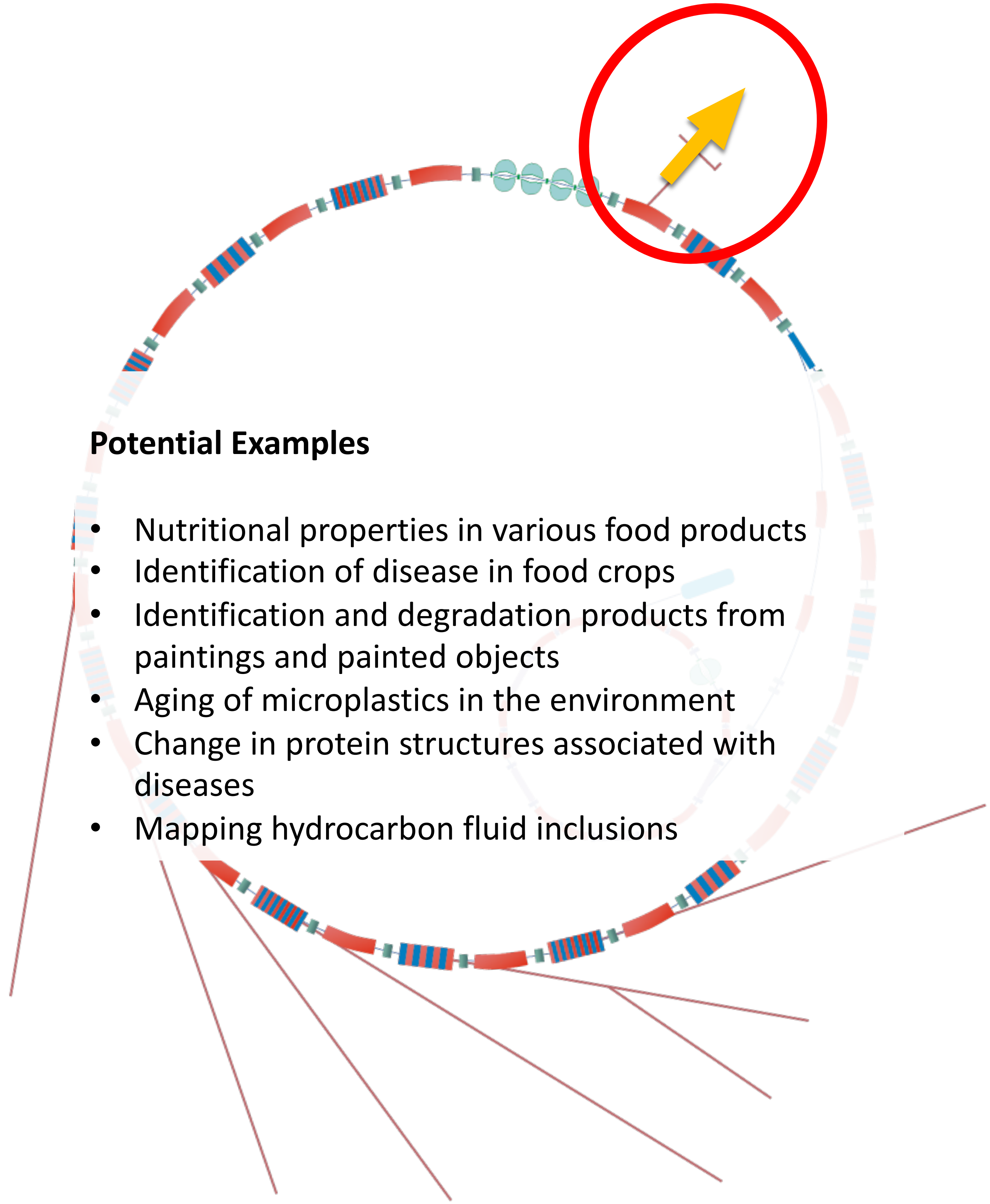
Operational since November 2018

infrared spectroscopy and microscopy

Source – Bending magnet

Experimental station – Bruker© Vertex 70v FTIR Spectrometer equipped with internal DLaTGS and MCT detectors. The spectrometer is coupled to Hyperion 3000 IR-microscope equipped with 15x for transmission/reflection, ATR, and grazing incidence angle IR objectives..

Sample Type – Fiber, Liquid, Powder, Solid.



Potential Examples

- Nutritional properties in various food products
- Identification of disease in food crops
- Identification and degradation products from paintings and painted objects
- Aging of microplastics in the environment
- Change in protein structures associated with diseases
- Mapping hydrocarbon fluid inclusions

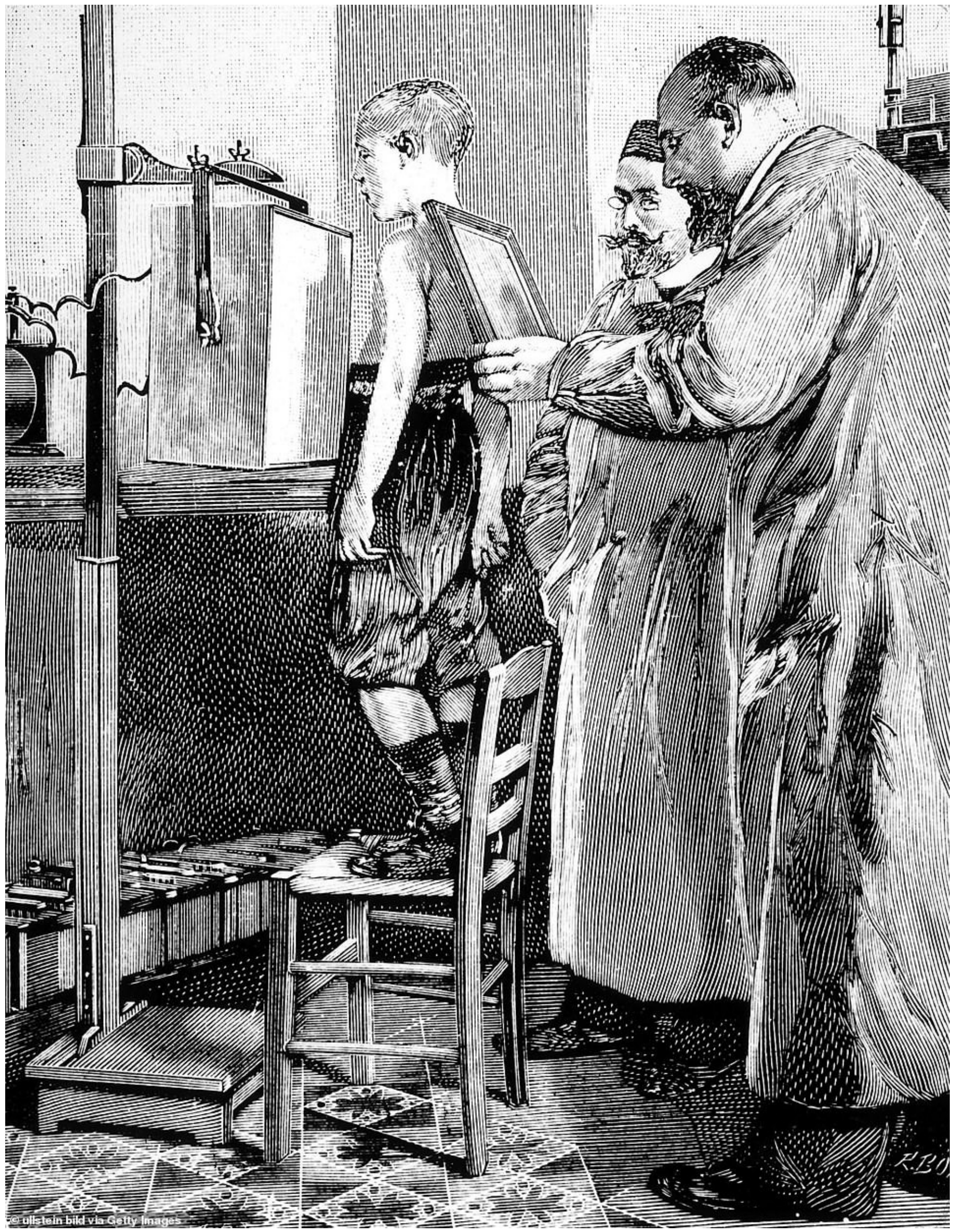
Stage II and experimental setup

February 15th, 2022

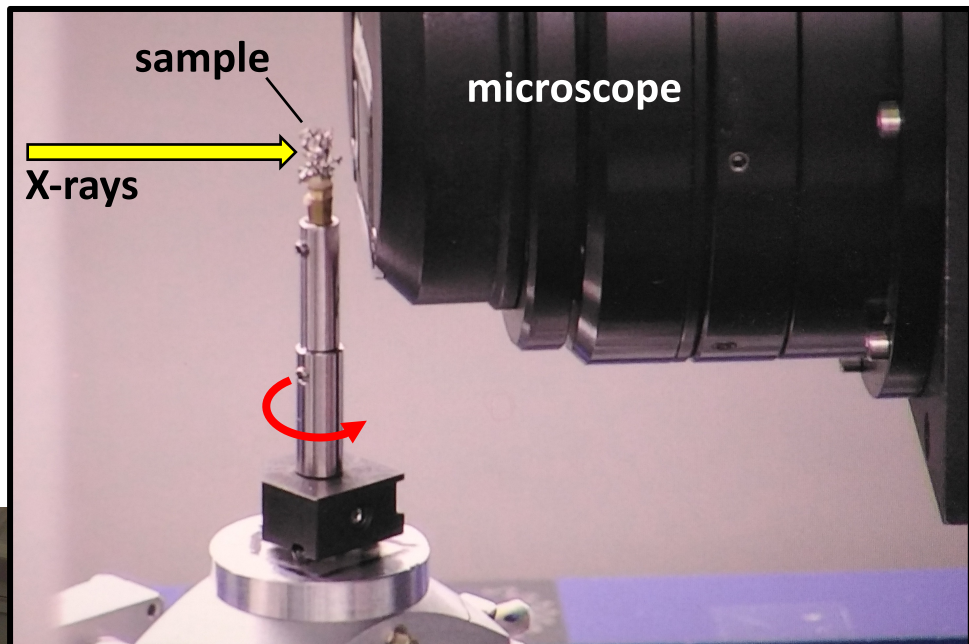
ITALIAN AMBASSADOR TO JORDAN FABIO CASSESE INAUGURATES THE NEW LABORATORY FOR CULTURAL HERITAGE AND THE INCLUSION OF SESAME IN INFN-CHNET

INFN
CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

X-rays

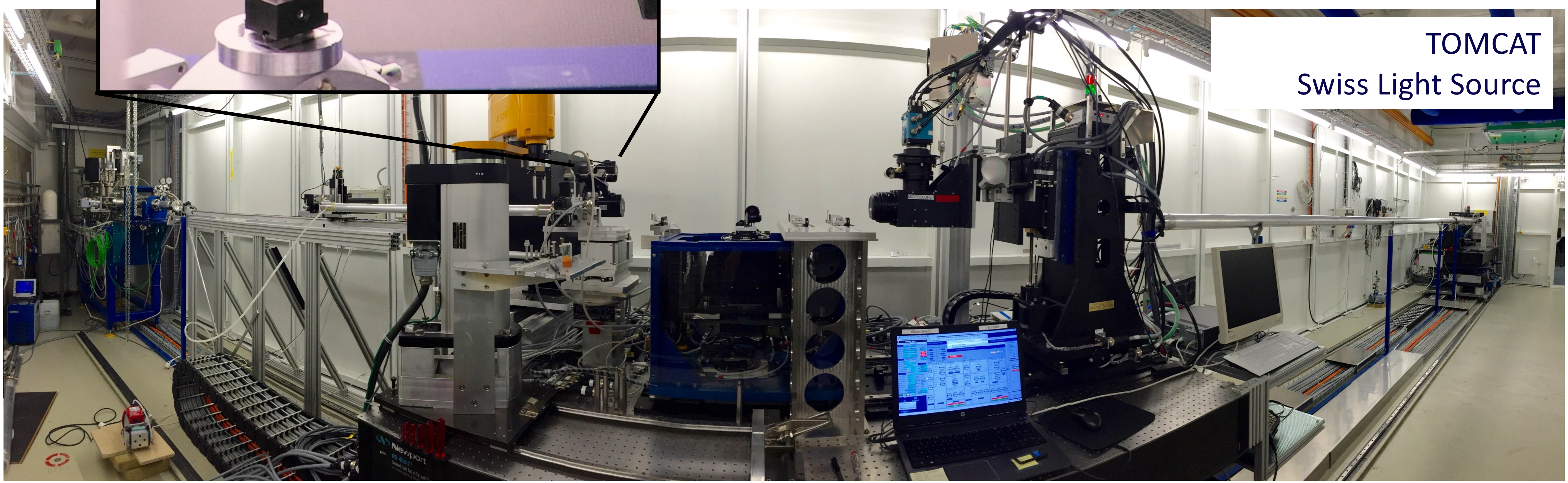


X-ray computed tomography

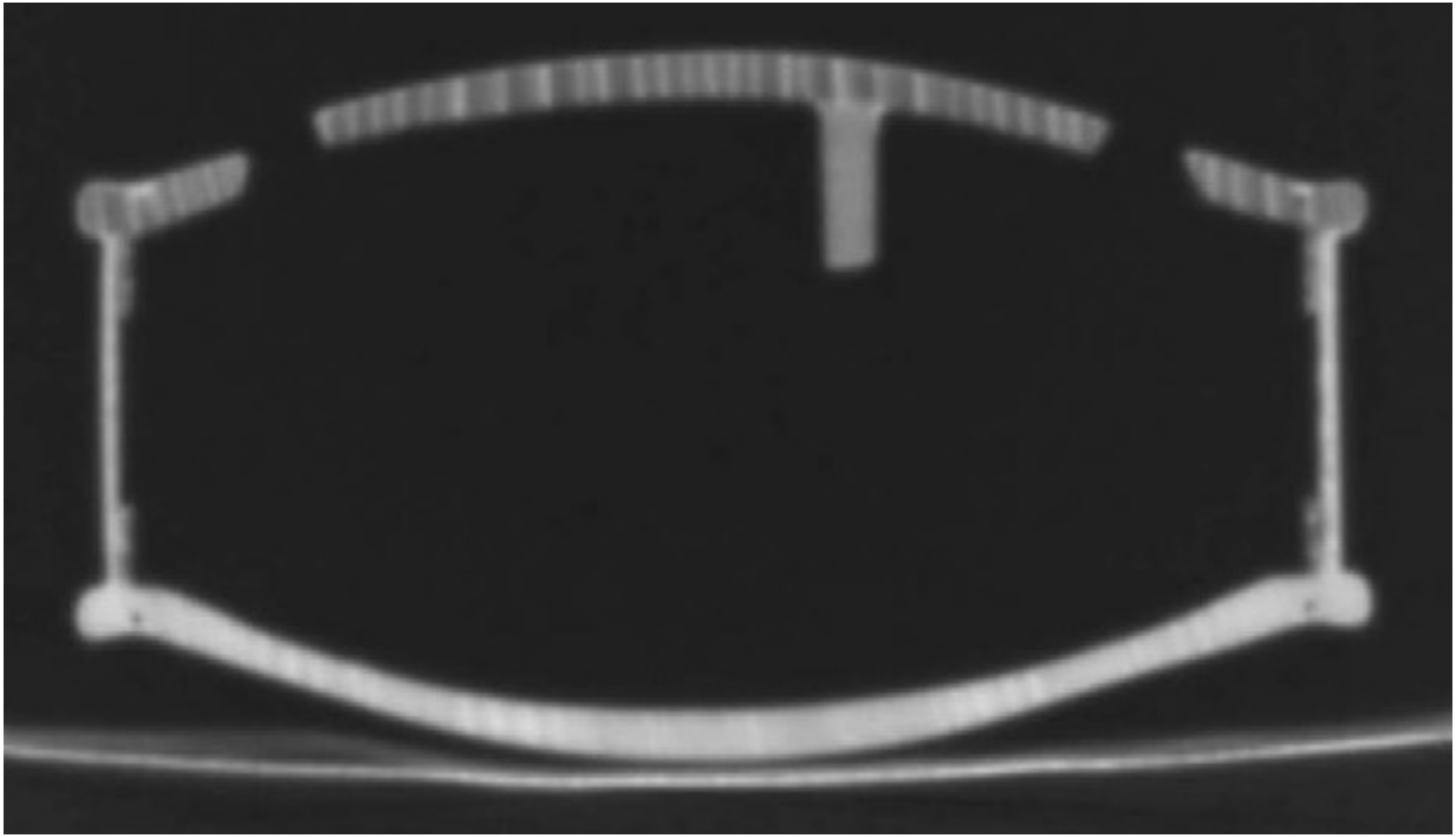


First Computed Tomography scan
EMI Scanner (1971)

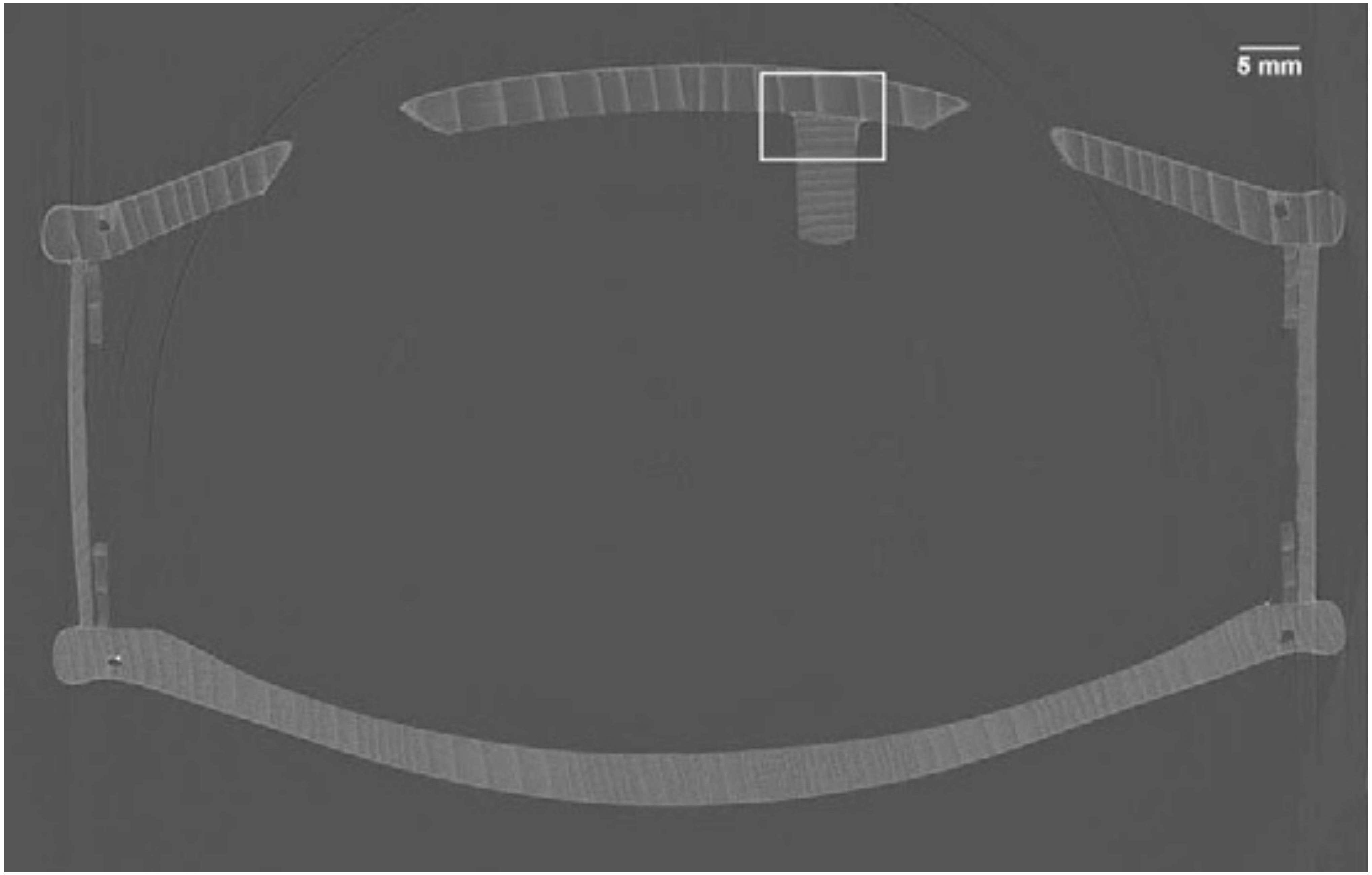
Nobel prize for CT in 1979
Hounsfield & Cormack

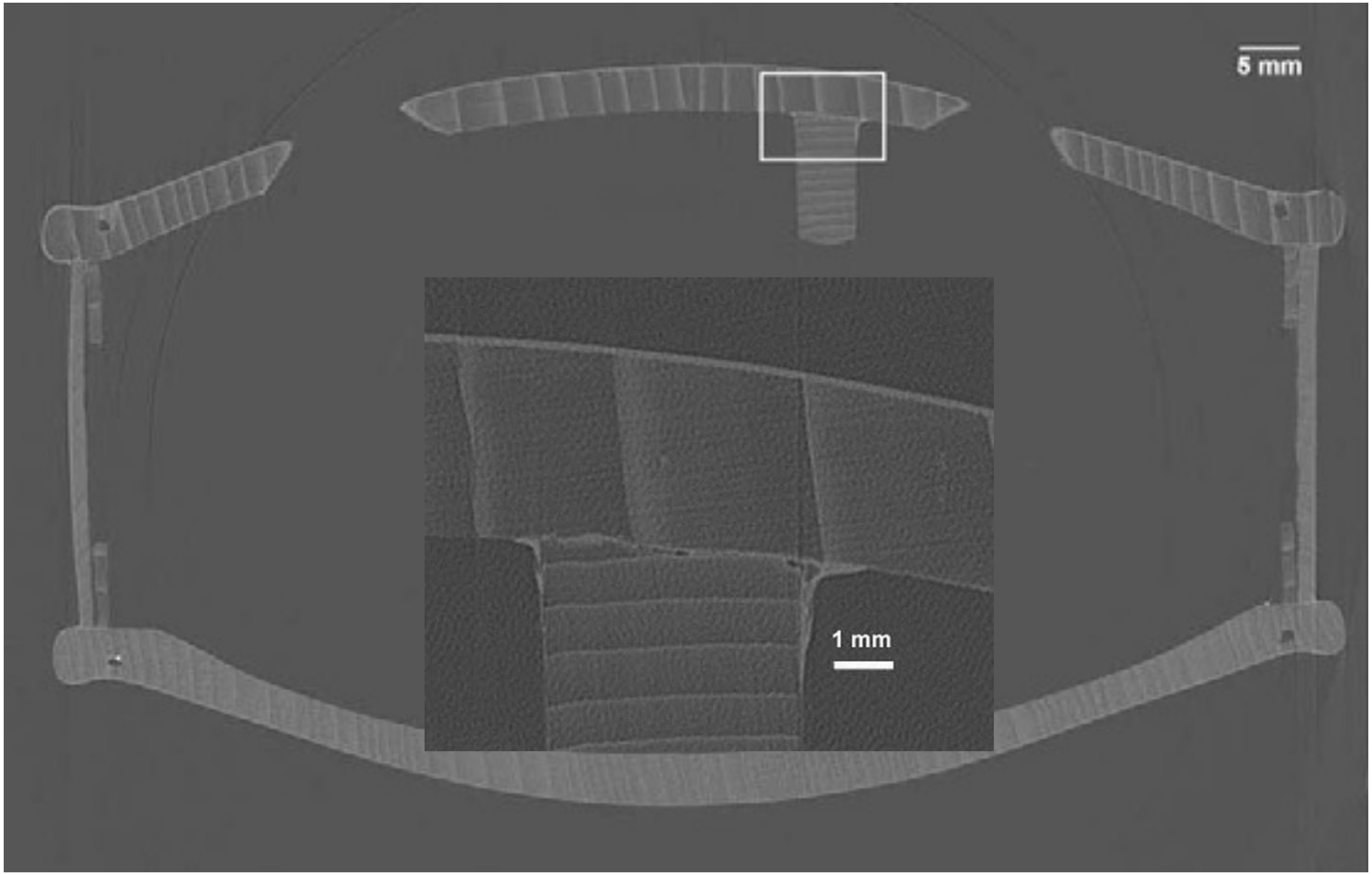


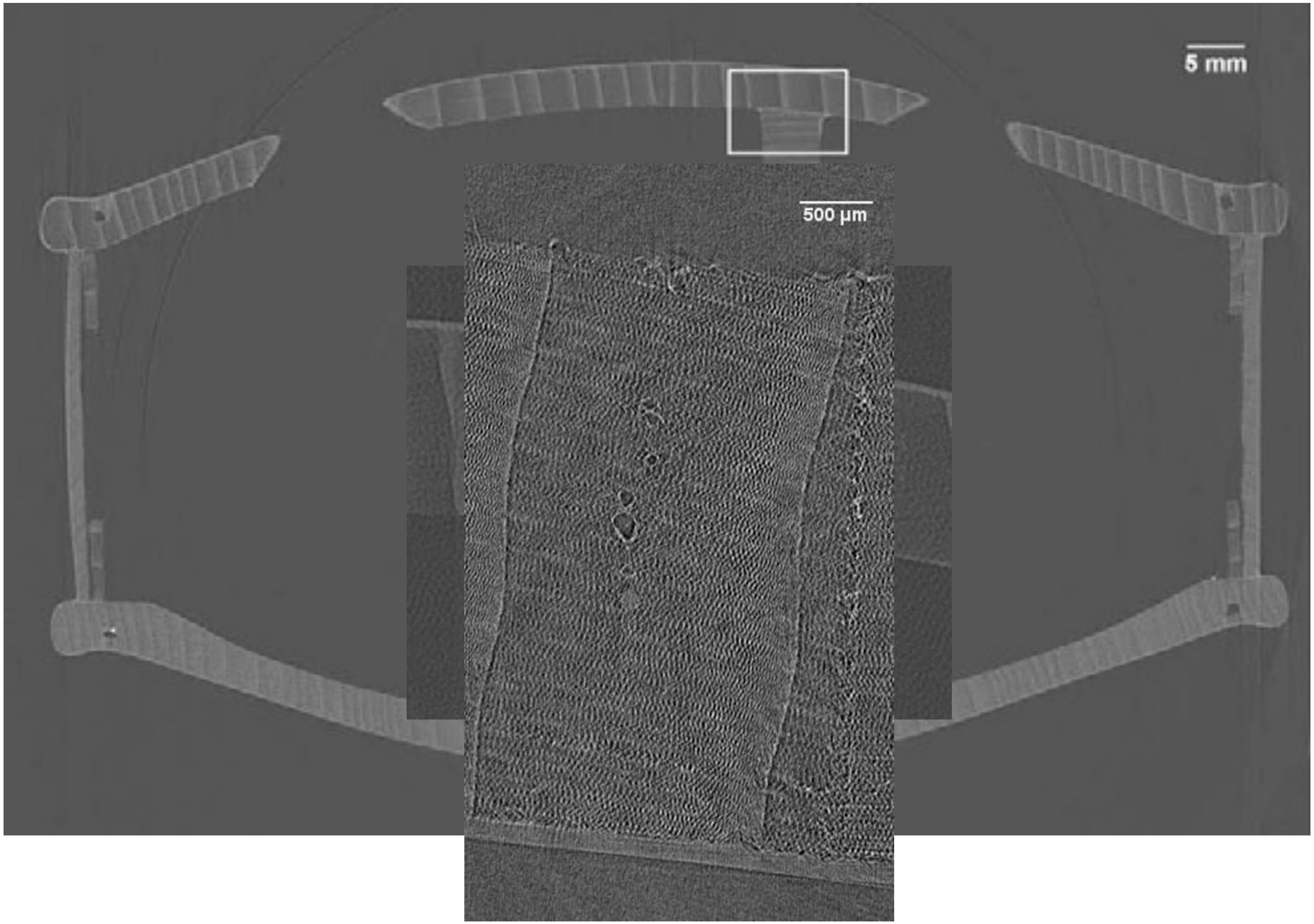
https://www.psi.ch/en/sls/tomcat/endstations



N. Sodini et al. / Journal of Cultural Heritage 13S (2012) S44–S49


5 mm


5 mm
1 mm



N. Sodini et al. / Journal of Cultural Heritage 13S (2012) S44–S49

ID10 – BEAmline for Tomography at SESAME, BEATS

Axel Kaprolat, ESRF   Gianluca Iori, SESAME

Operational 2022

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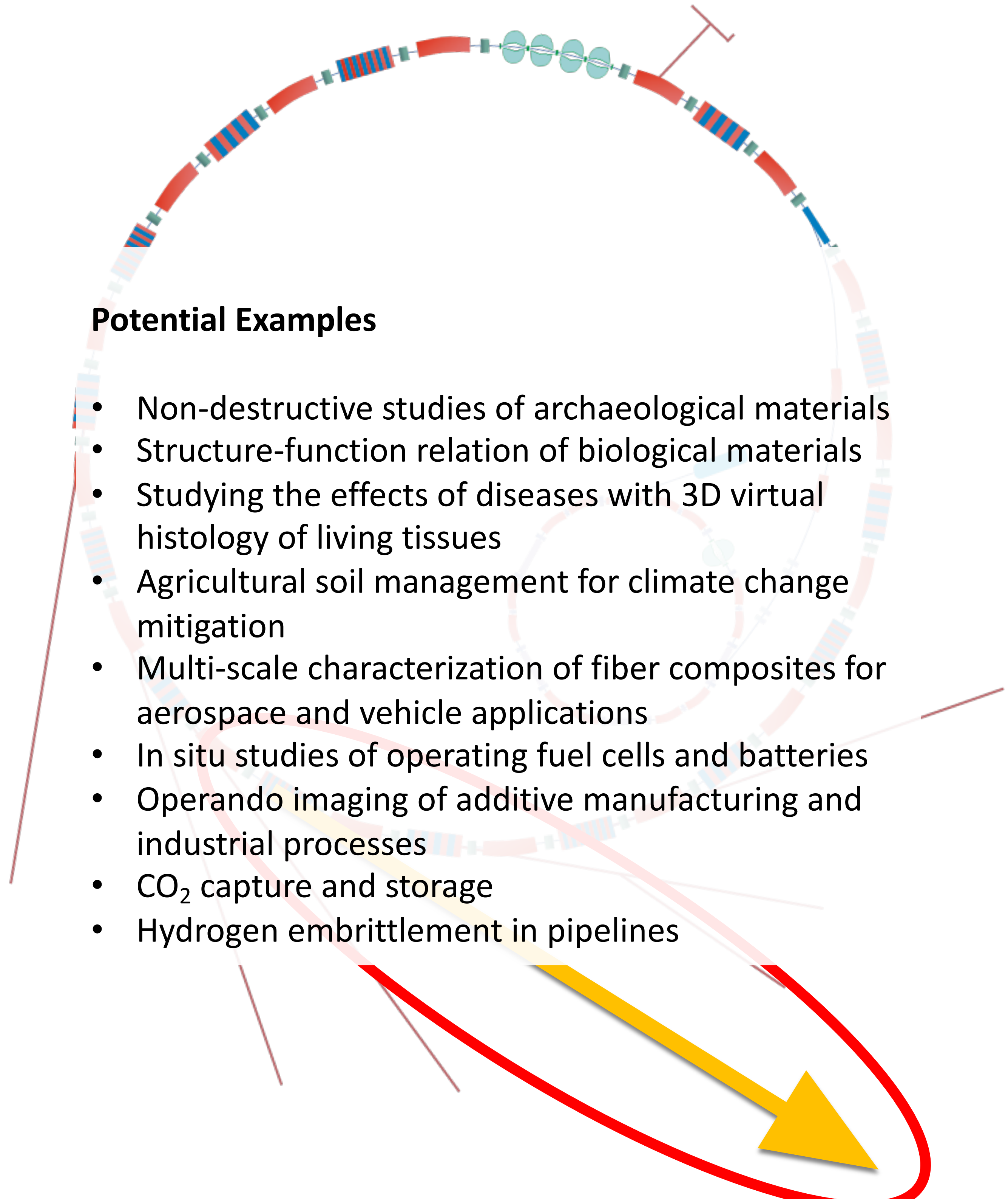
A new beamline for TOMOGRAPHY

6 M Euro funding (EU)

X-ray source: 3-pole wiggler, 3T, E_c= 12.4 keV

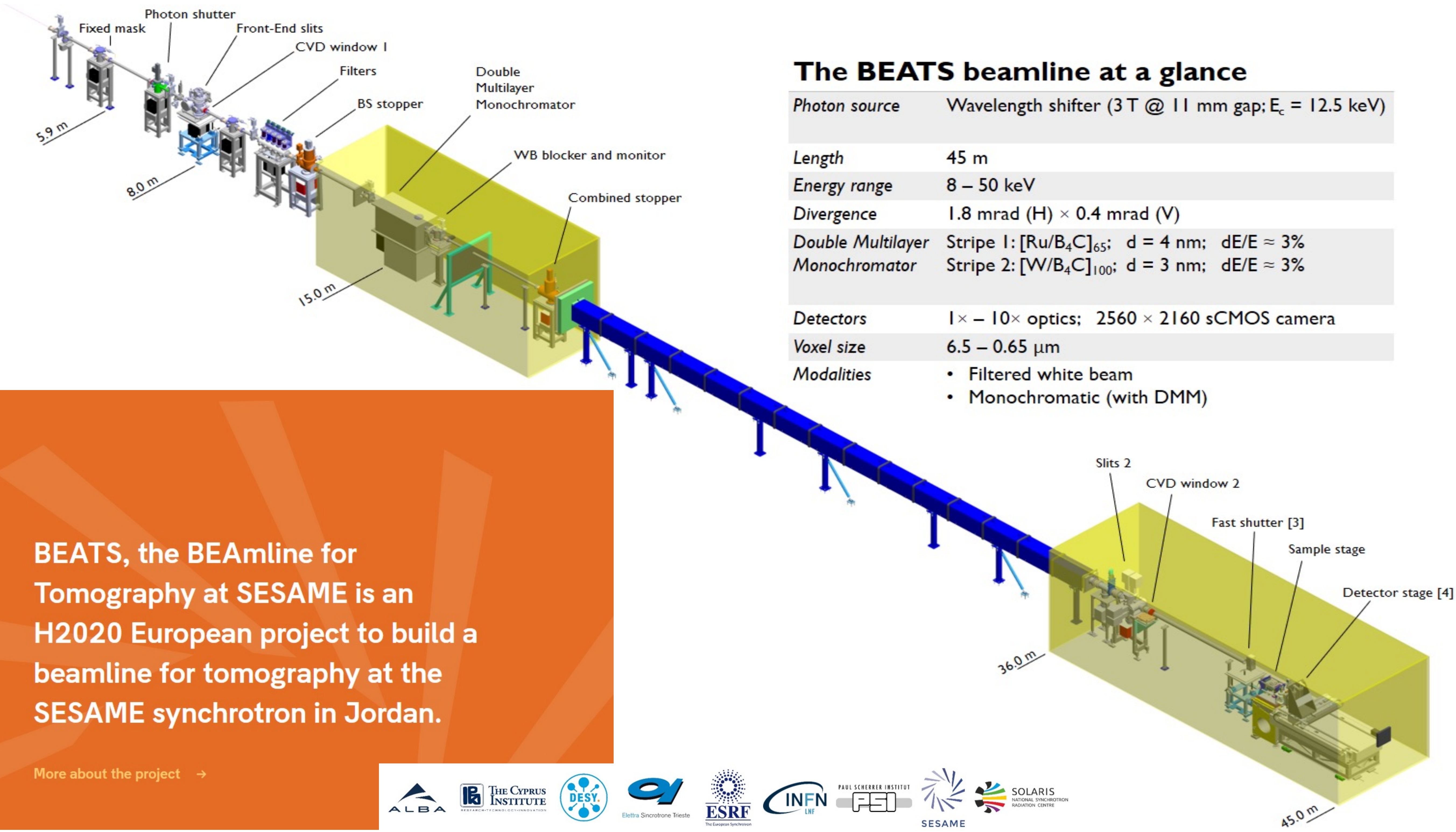
User community build-up workshops

Funded by the EU's H2020
framework programme under
grant agreement n°822535



Potential Examples

- Non-destructive studies of archaeological materials
- Structure-function relation of biological materials
- Studying the effects of diseases with 3D virtual histology of living tissues
- Agricultural soil management for climate change mitigation
- Multi-scale characterization of fiber composites for aerospace and vehicle applications
- In situ studies of operating fuel cells and batteries
- Operando imaging of additive manufacturing and industrial processes
- CO_2 capture and storage
- Hydrogen embrittlement in pipelines



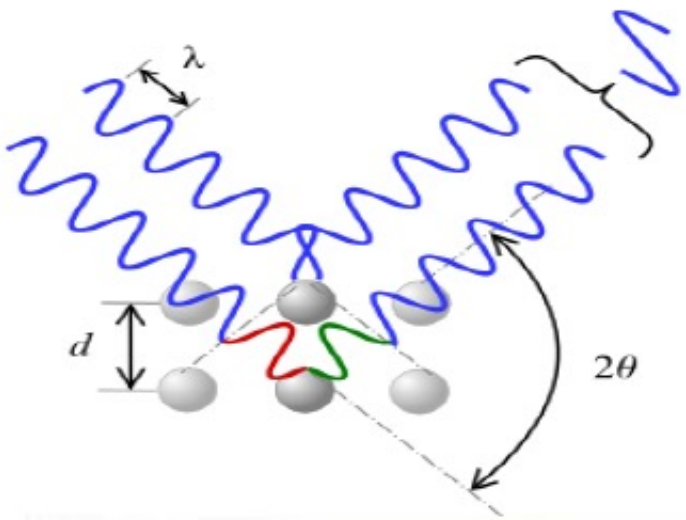
The BEATS beamline at a glance

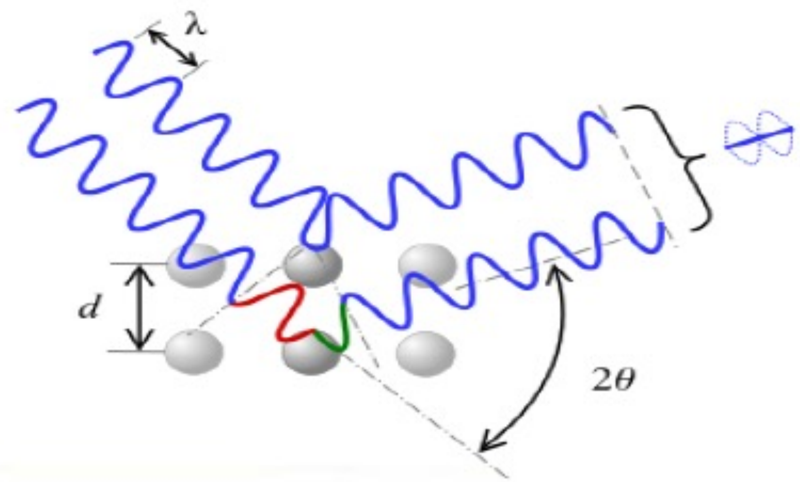
Photon source	Wavelength shifter (3 T @ 11 mm gap; E_c = 12.5 keV)
Length	45 m
Energy range	8 – 50 keV
Divergence	1.8 mrad (H) × 0.4 mrad (V)
Double Multilayer Monochromator	Stripe 1: $[Ru/B_4C]_{65}$; d = 4 nm; dE/E ≈ 3% Stripe 2: $[W/B_4C]_{100}$; d = 3 nm; dE/E ≈ 3%
Detectors	1× – 10× optics; 2560 × 2160 sCMOS camera
Voxel size	6.5 – 0.65 μm
Modalities	• Filtered white beam • Monochromatic (with DMM)

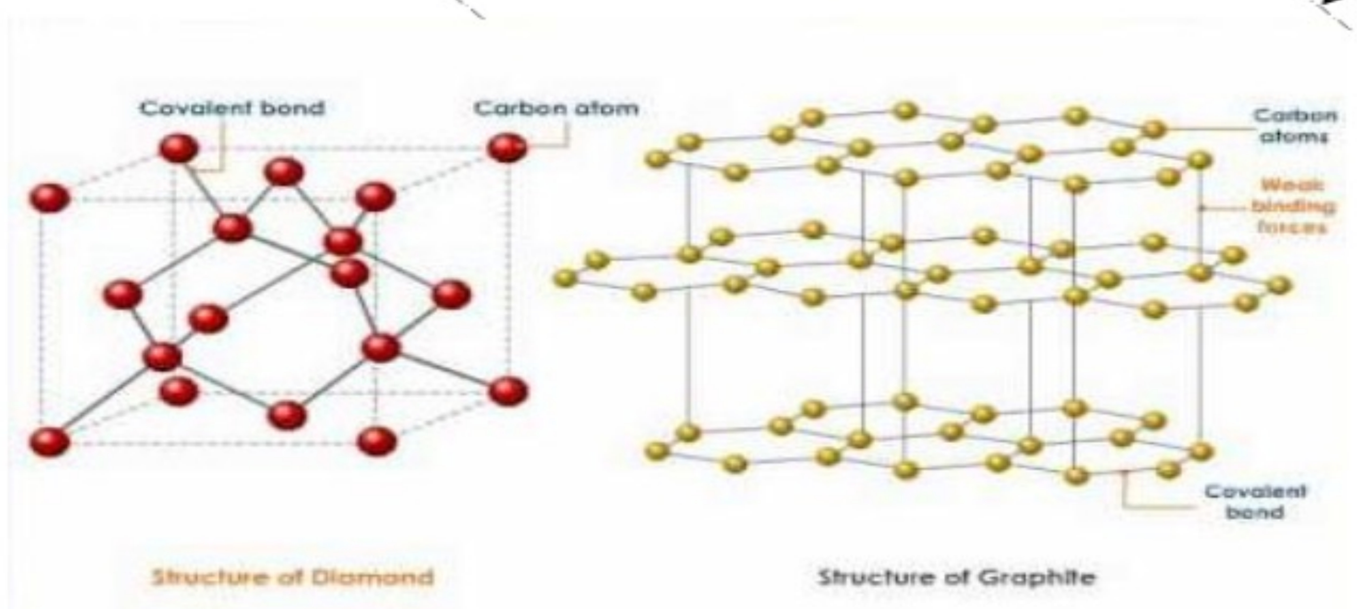
BEATS, the BEAmline for Tomography at SESAME is an H2020 European project to build a beamline for tomography at the SESAME synchrotron in Jordan.

More about the project →

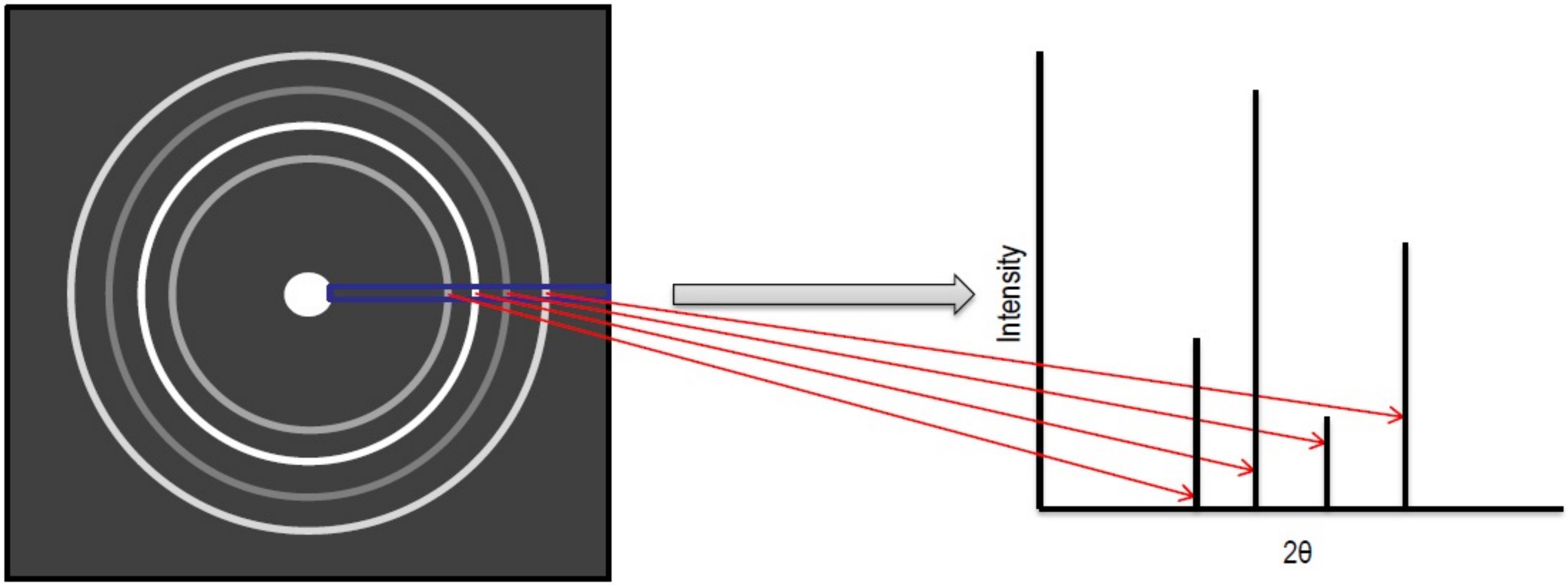
X ray diffraction - <u>Crystallographic structure</u>







$$n \lambda = 2 d \sin\theta$$ Bragg law



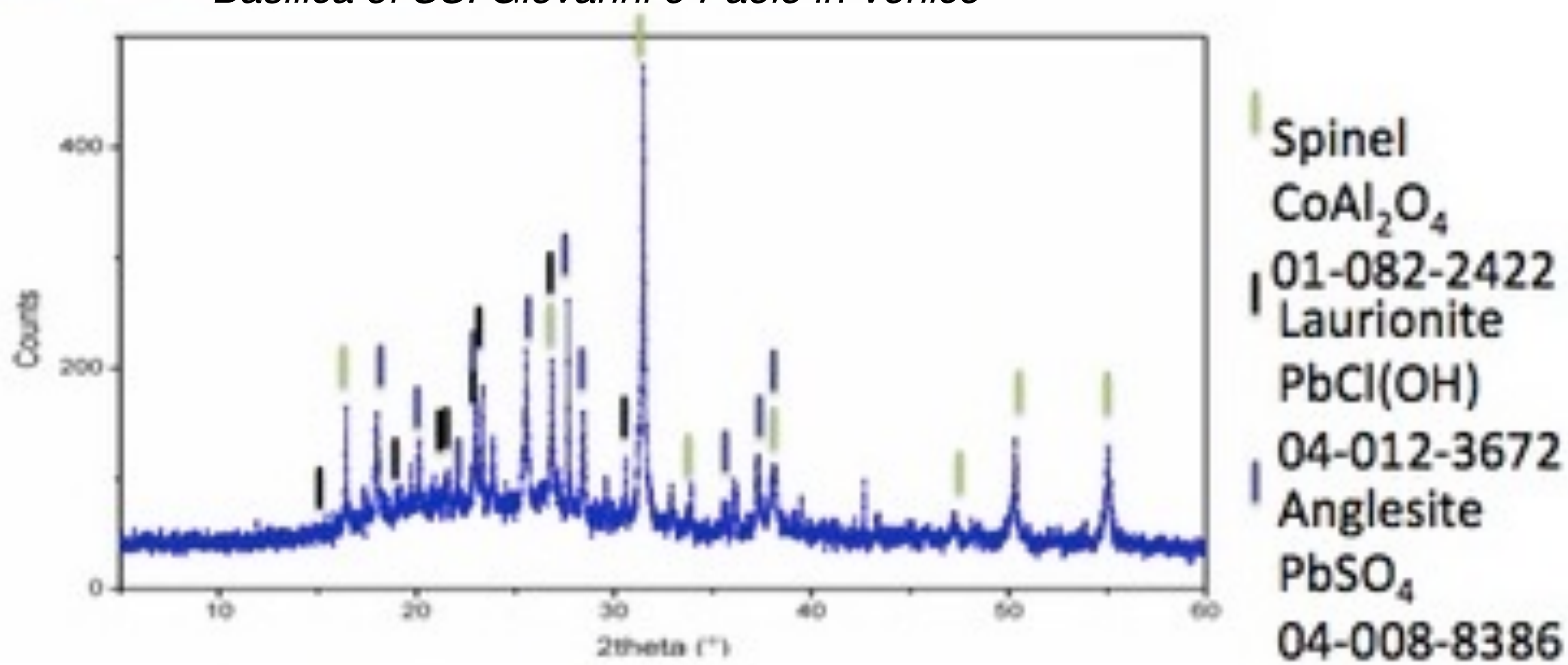
Diffraction pattern main parameters

- Peaks positions : fingerprint of material structure
- Peaks Intensities : solve the structure at atomic level
- Peaks shapes : Micro-structure information (crystal size- lattice strain)

MAIN ADVANTAGES OVER LABRATORY SOURCES

High Intensity
Highly collimated
Peak shape can be calculated

Basilica of SS. Giovanni e Paolo in Venice



Plaisier, J.R. et al *The X-ray diffraction beamline MCX at Elettra: A case study of non-destructive analysis on stained glass* (2017) Acta IMEKO, 6 (3), pp. 71-75

ID09 – Powder diffraction Beamline (Materials Science), MS

Mahmoud Abdellatief

Operational since December 2020
Powder diffraction

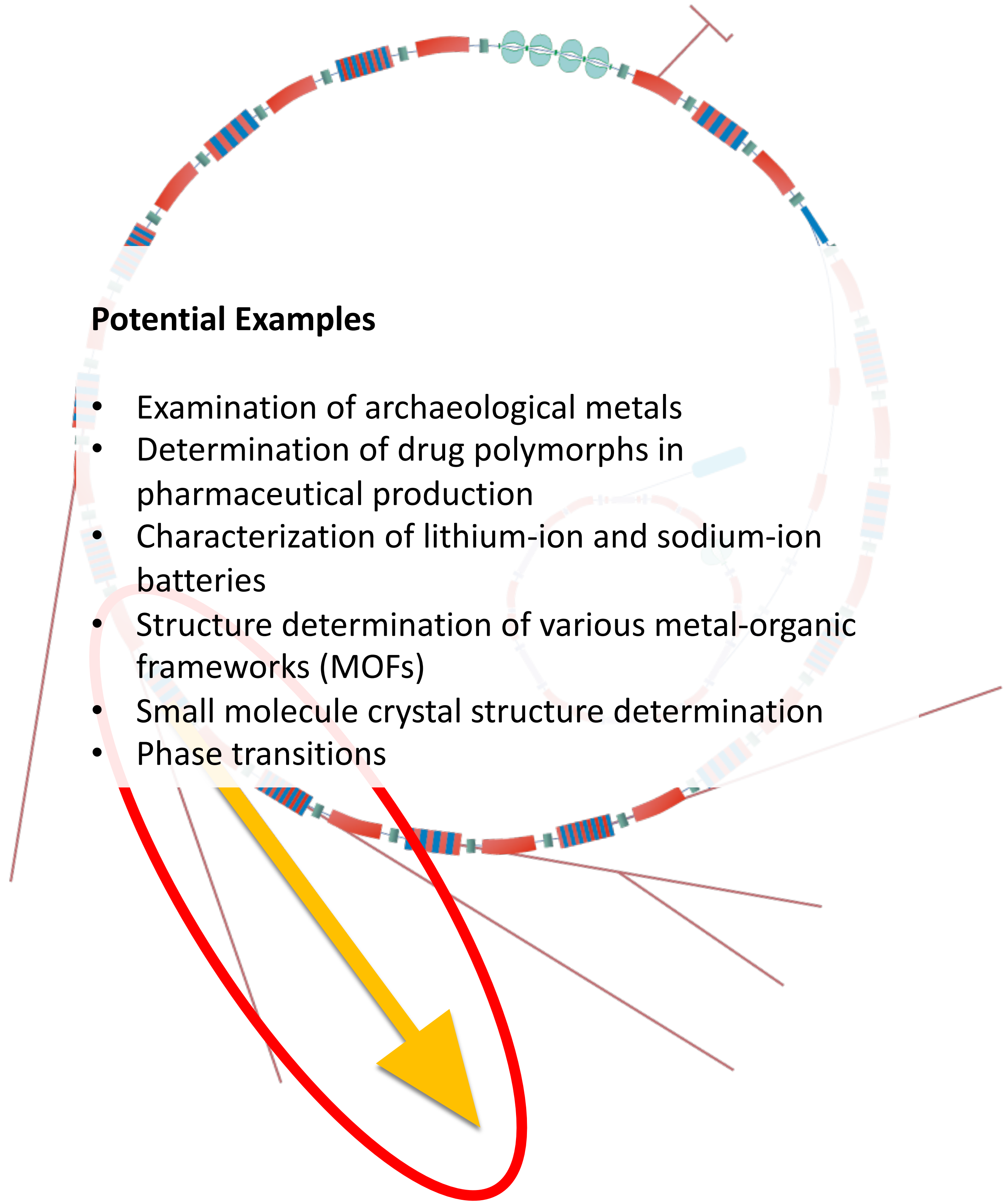
Source – Multipole wiggler

Experimental station – 2-circle diffractometer, with motorised translation stage to align the capillary to the spinner.

Sample environment – Hot Blower (RT to 1300 K) and Cryo Stream (100 K to RT)

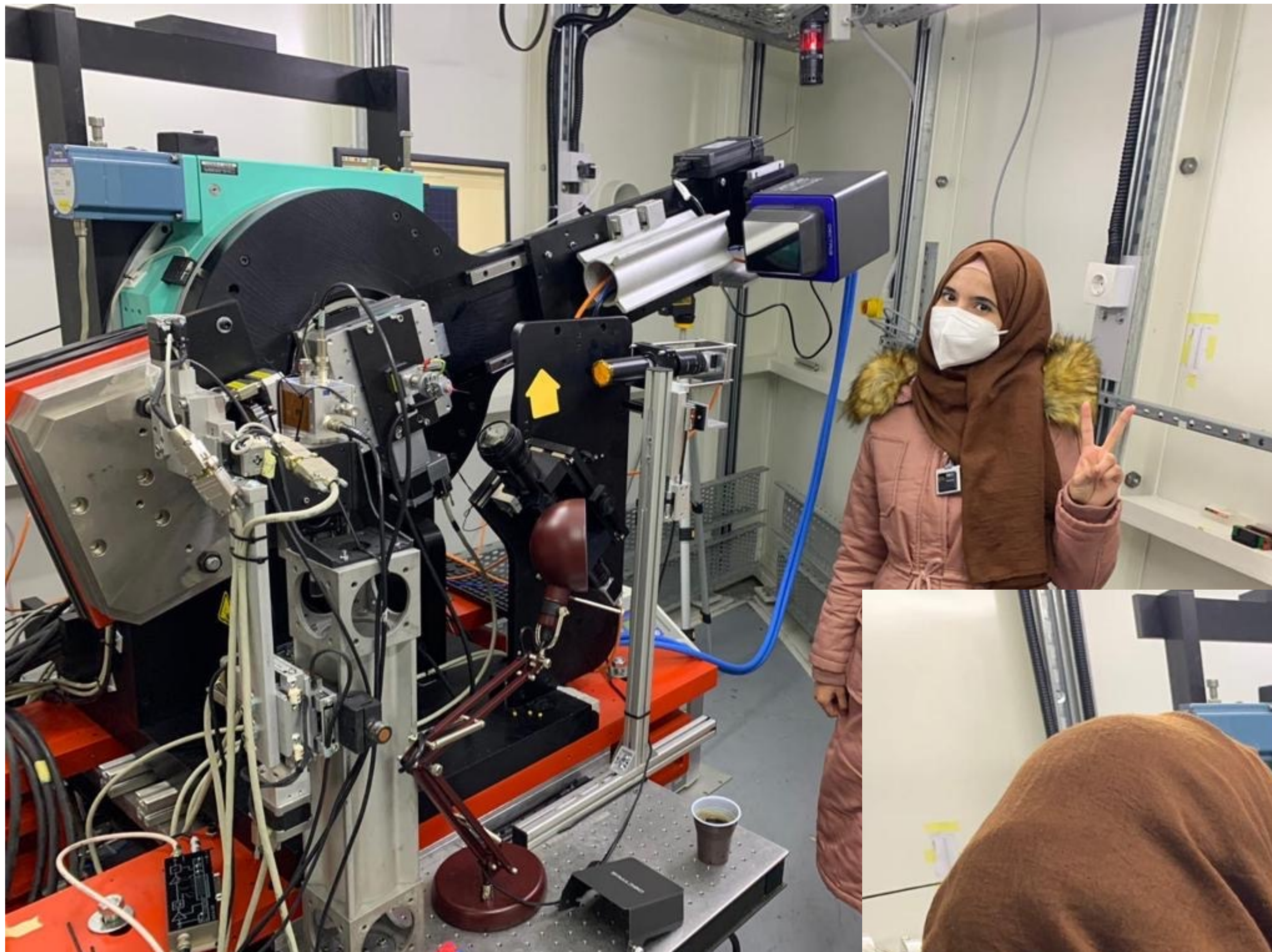
Detector – Dectris Pilatus 300K

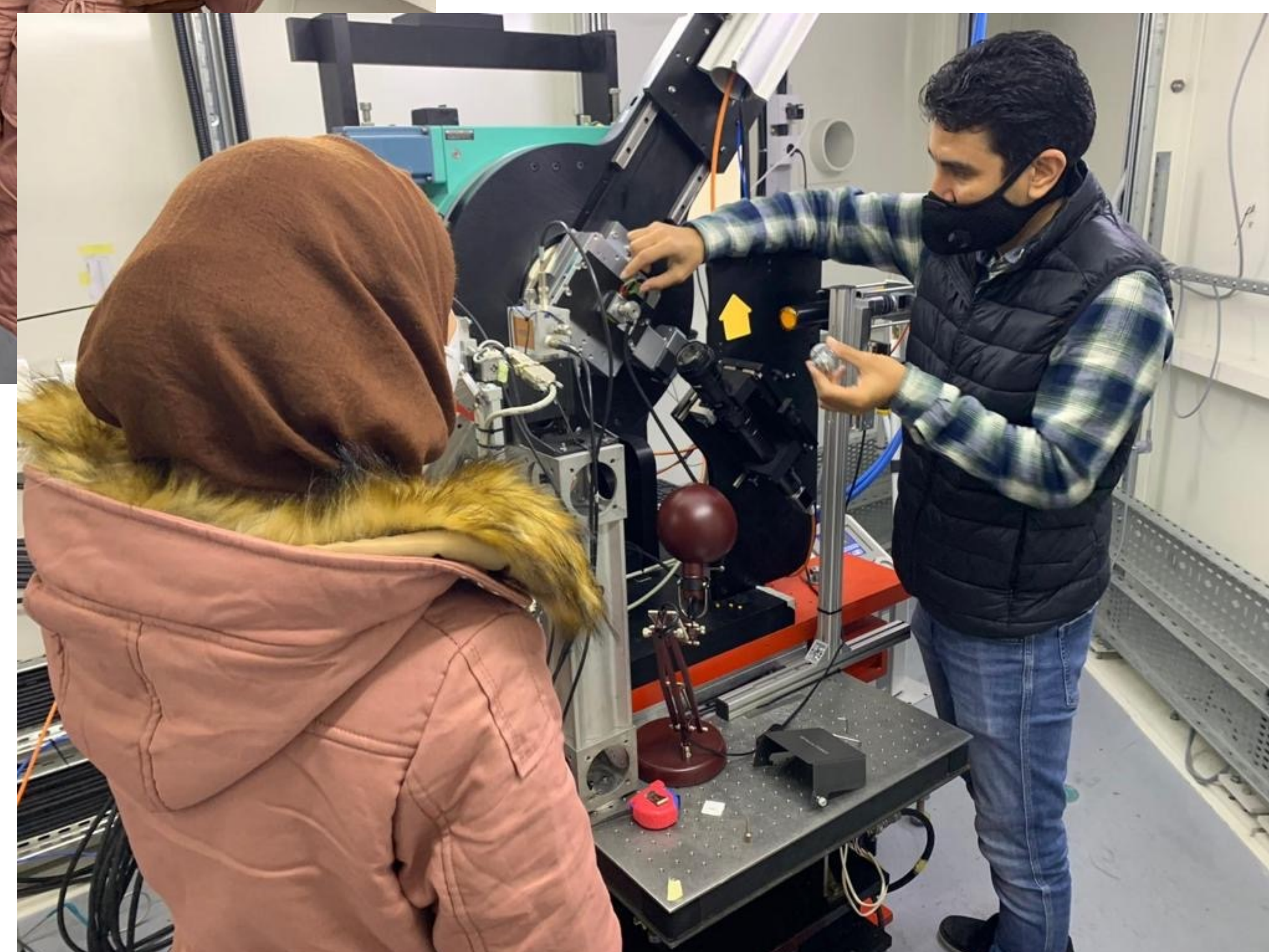
Sample Type –Powder in Capillary. (Flat sample geometry will be available in 2022)



Potential Examples

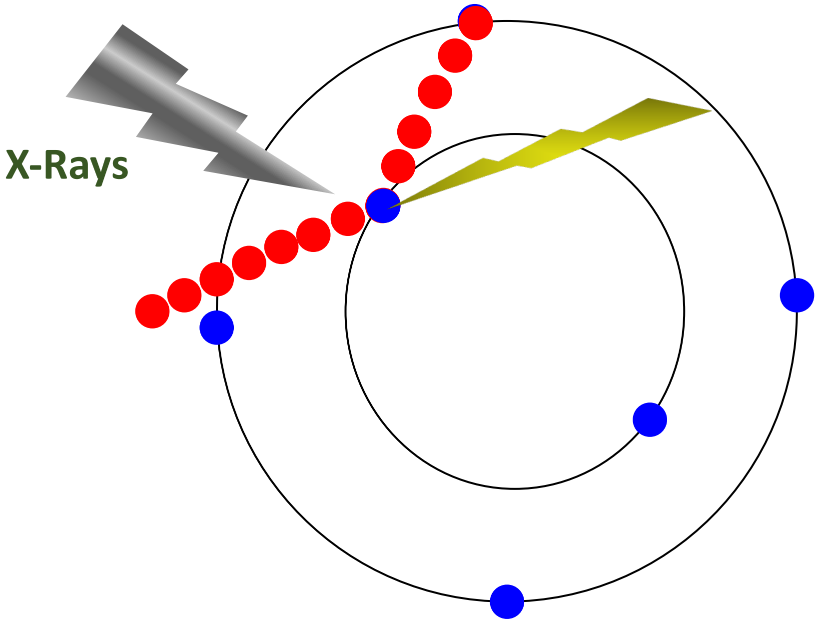
- Examination of archaeological metals
- Determination of drug polymorphs in pharmaceutical production
- Characterization of lithium-ion and sodium-ion batteries
- Structure determination of various metal-organic frameworks (MOFs)
- Small molecule crystal structure determination
- Phase transitions



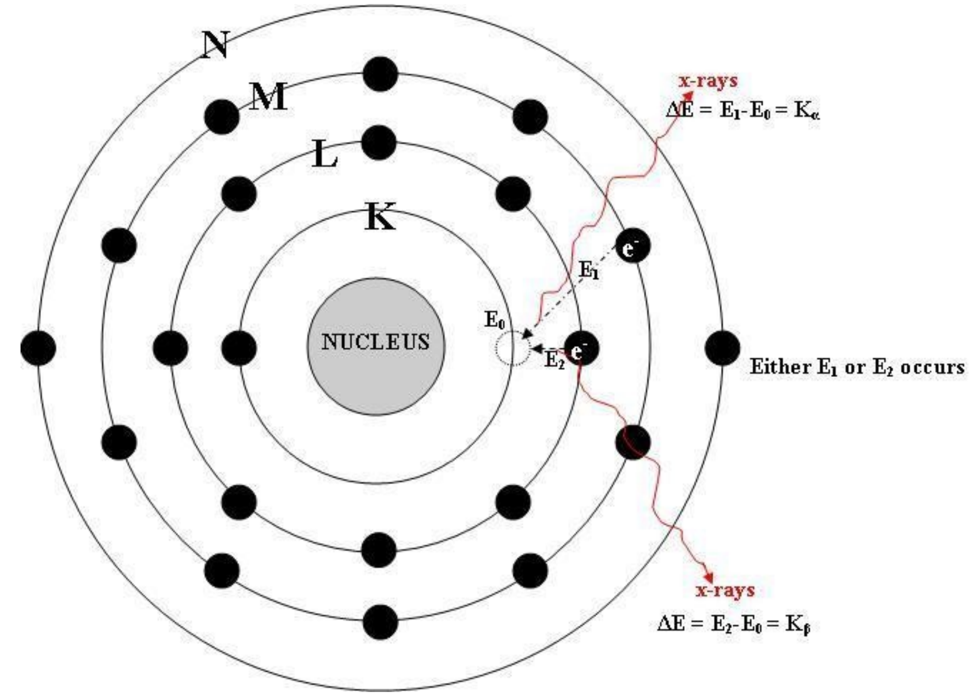


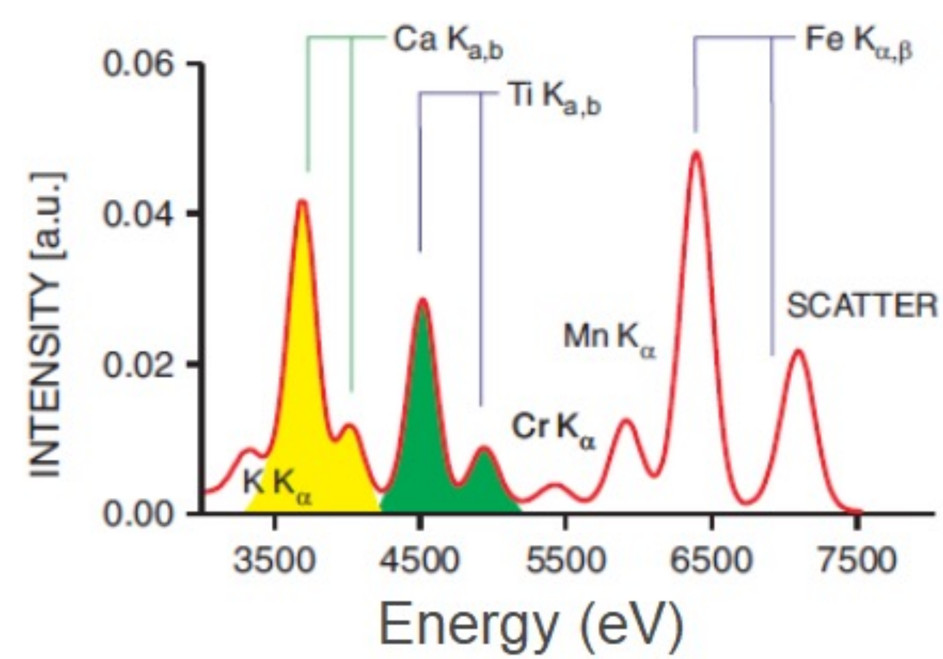
MS is the third beamline of SESAME to start full user operation
22 December, 2020

X ray fluorescence – Elemental analysis

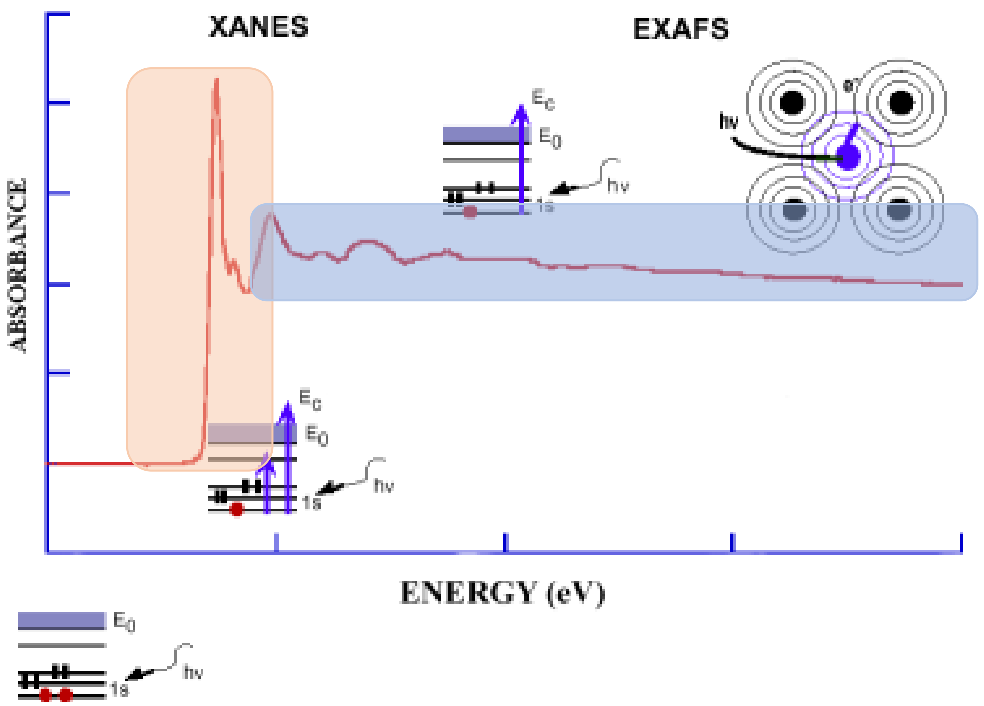


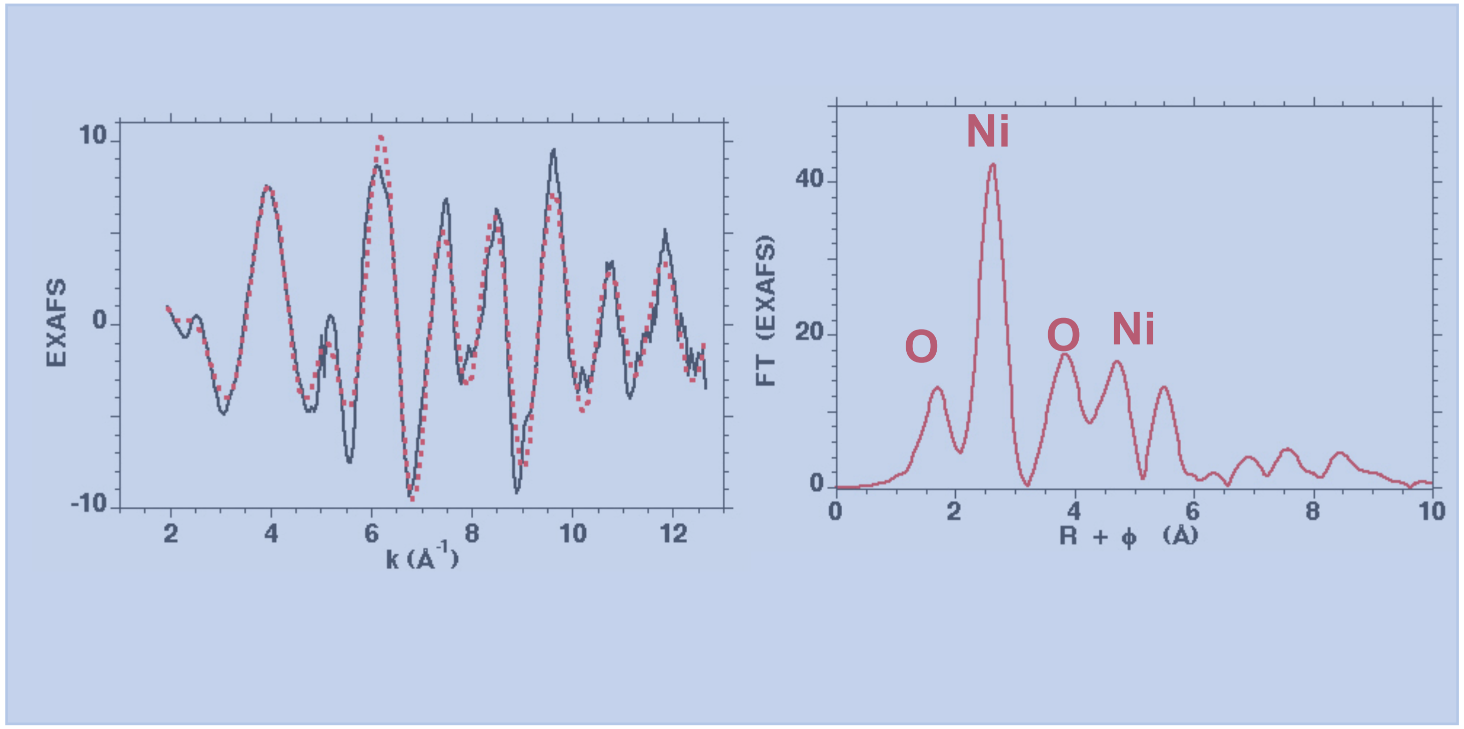
XRF

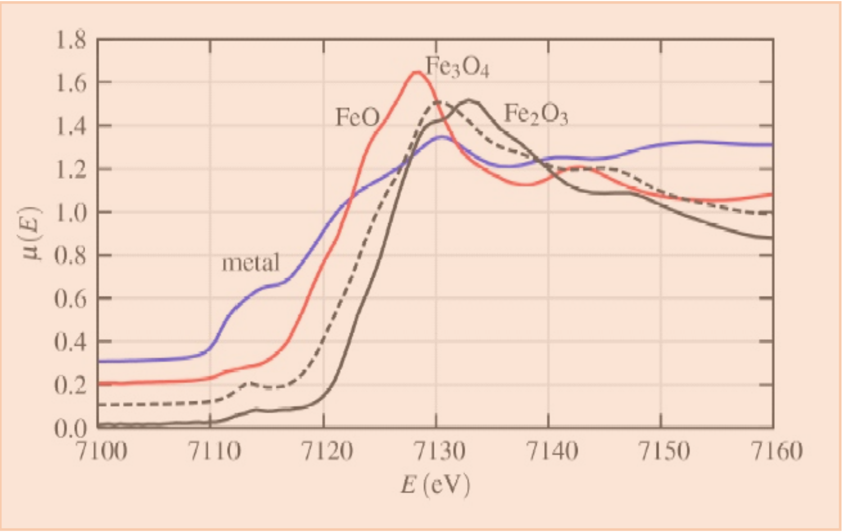




- **Energy→ e- ejection from the continuum shell**
- **Electron from higher shell will fill the empty place**
- **Emission of X-Rays (photo-electron)**



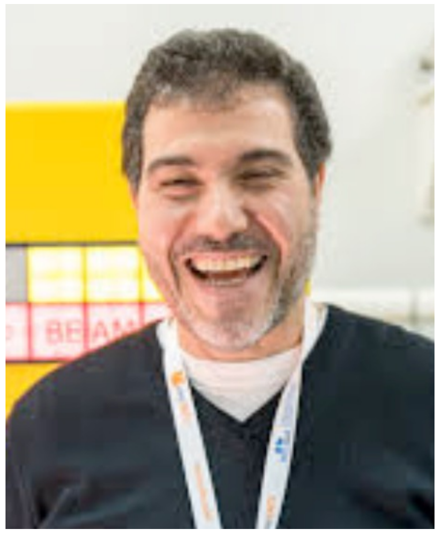




- Radial distribution of atoms around the photo-absorber (bond distance, number and type of neighbors)

- Oxidation state
- Coordination chemistry of the absorbing atom
- Orbital occupancy

BM08 – XAFS/XRF



Messaoud Harfouche

Latif Ullah Khan

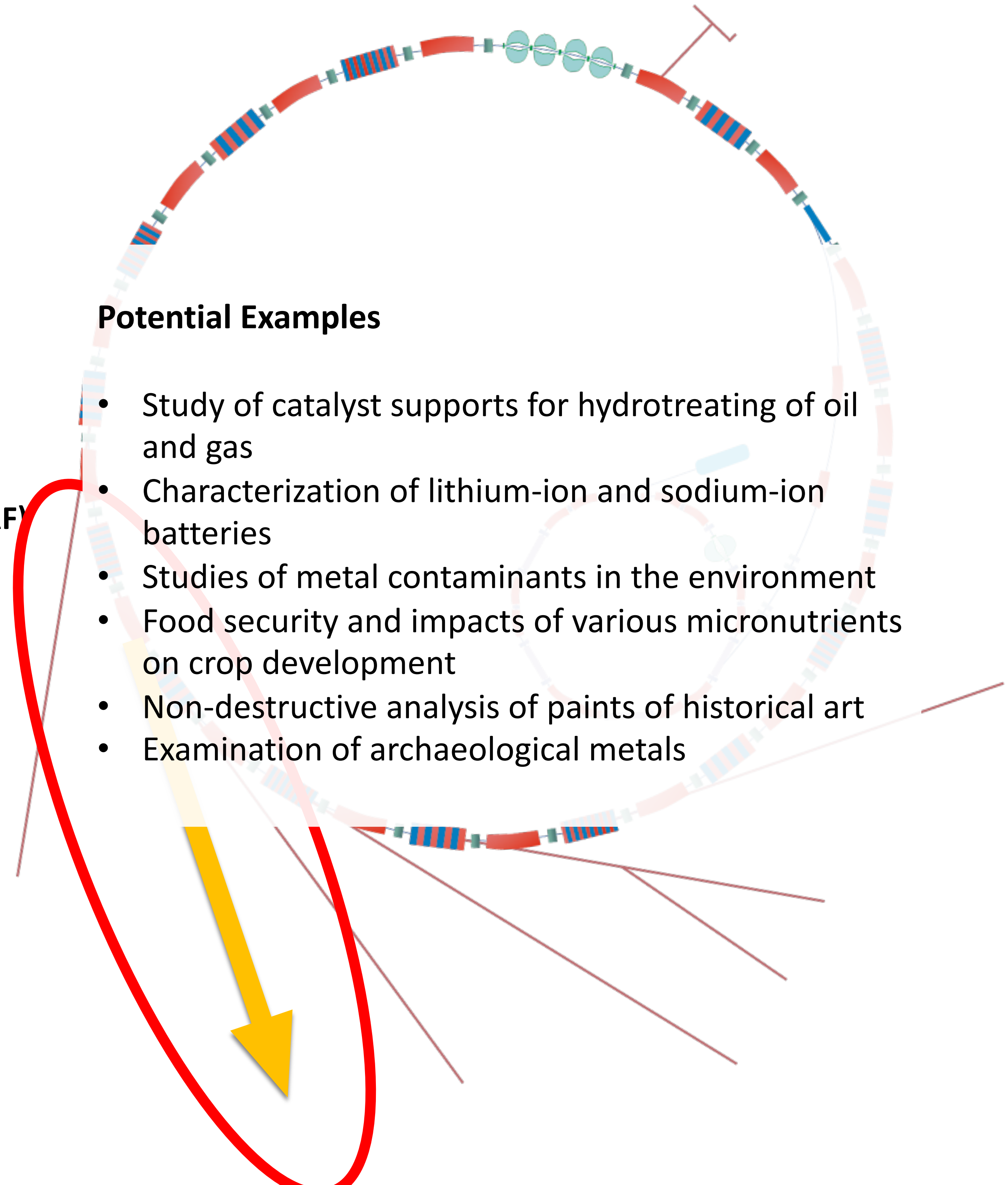
Operational since July 2018

X-ray Absorption Fine Structure/X-ray Fluorescence (XAFS/XRF)

Source – Bending magnet

Experimental station – optical table with 6 axis of freedom and used as support for different detectors as well as for the sample manipulator and other sample. Detectors comprise Ion Chambers and X-Ray Fluorescence detectors (KETEK single element silicon drift detector and INFN 64 element silicon drift detector)

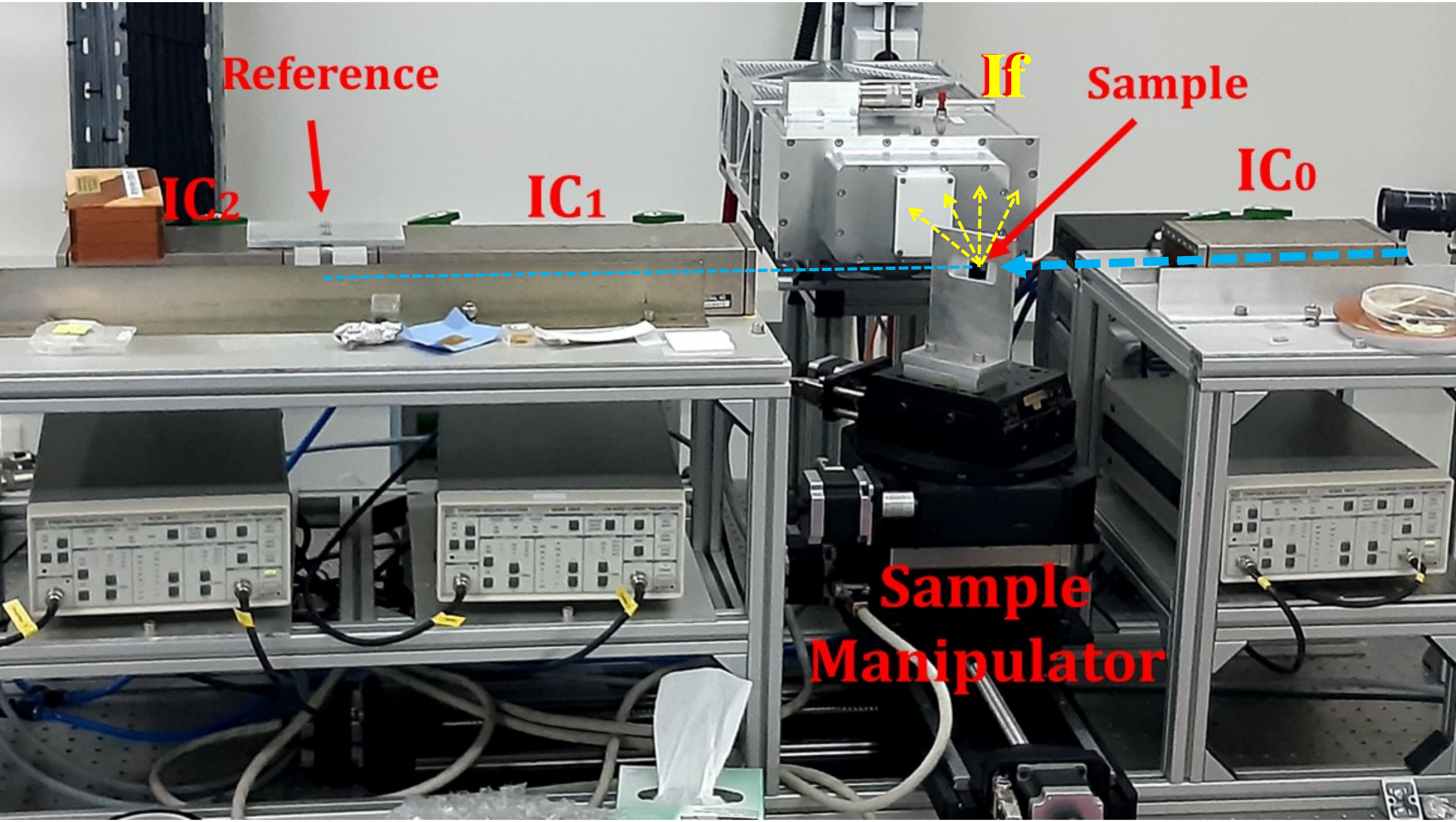
Sample Type – Crystal, Amorphous, Powder, Gel, Liquid, Gas



Potential Examples

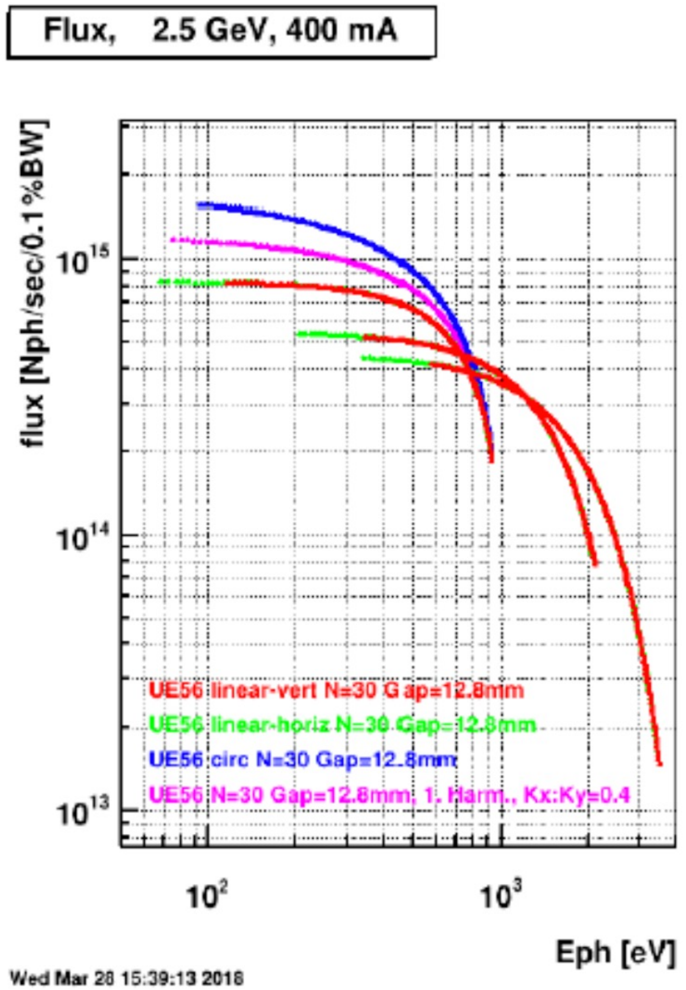
- Study of catalyst supports for hydrotreating of oil and gas
- Characterization of lithium-ion and sodium-ion batteries
- Studies of metal contaminants in the environment
- Food security and impacts of various micronutrients on crop development
- Non-destructive analysis of paints of historical art
- Examination of archaeological metals

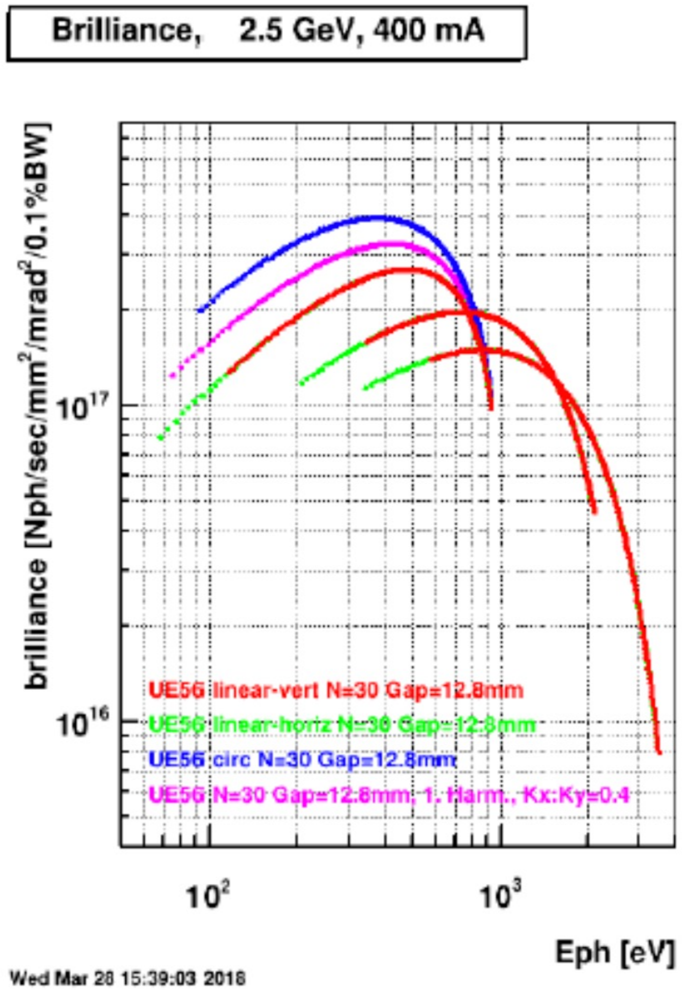
Beamline Experimental Setup

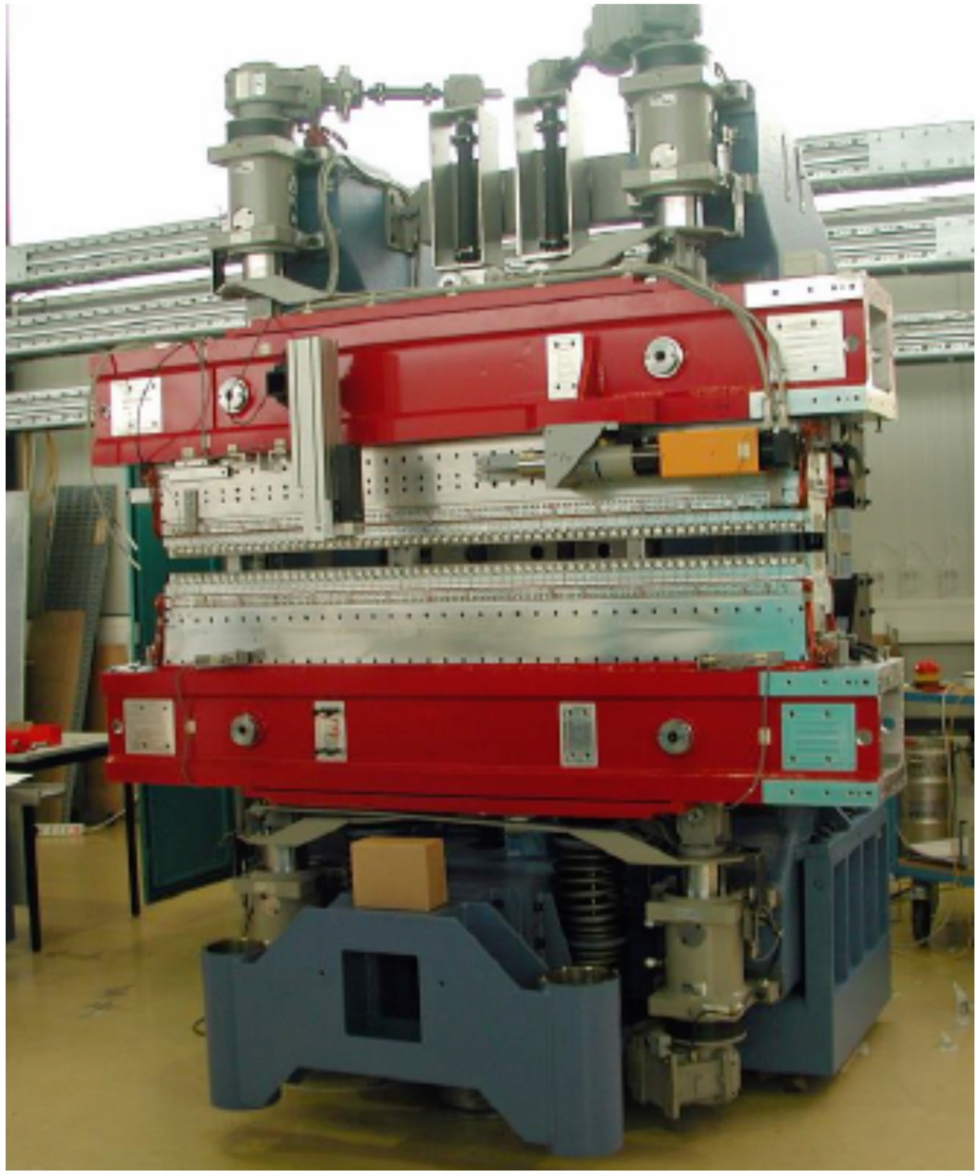


HESEB Beamline

Undulator UE56 with variable polarization





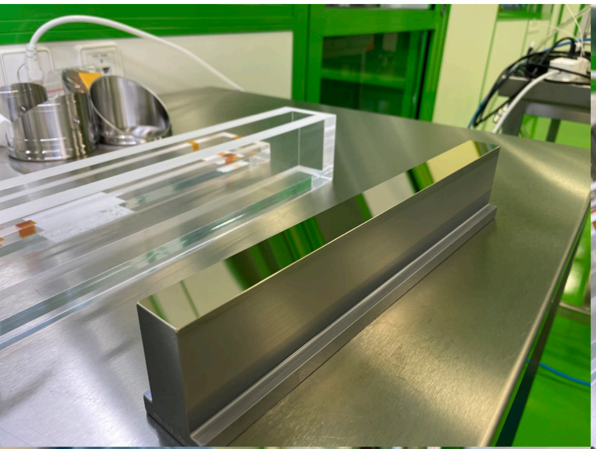


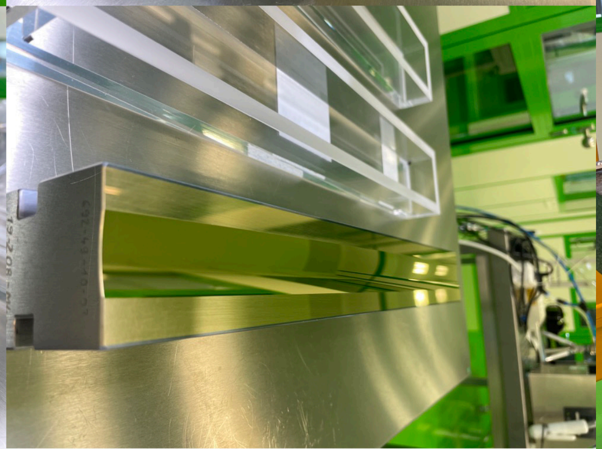
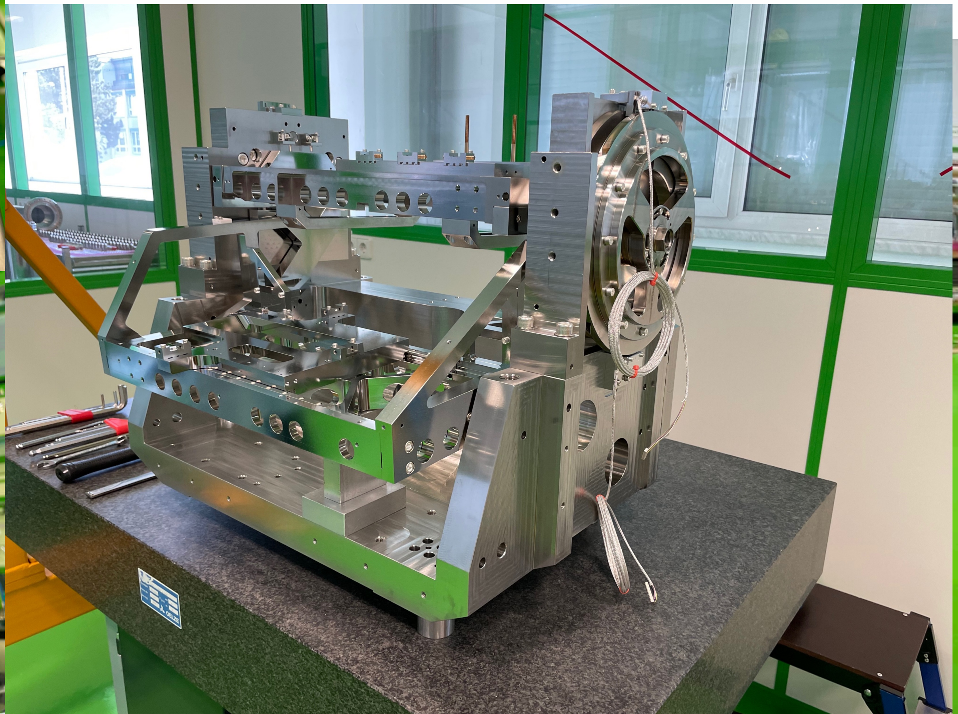
Advanced Planar Polarized Light Emitter

Source refurbished
Delivery March 2022

HESEB

Beamline and front-end under construction
Delivery November 2021

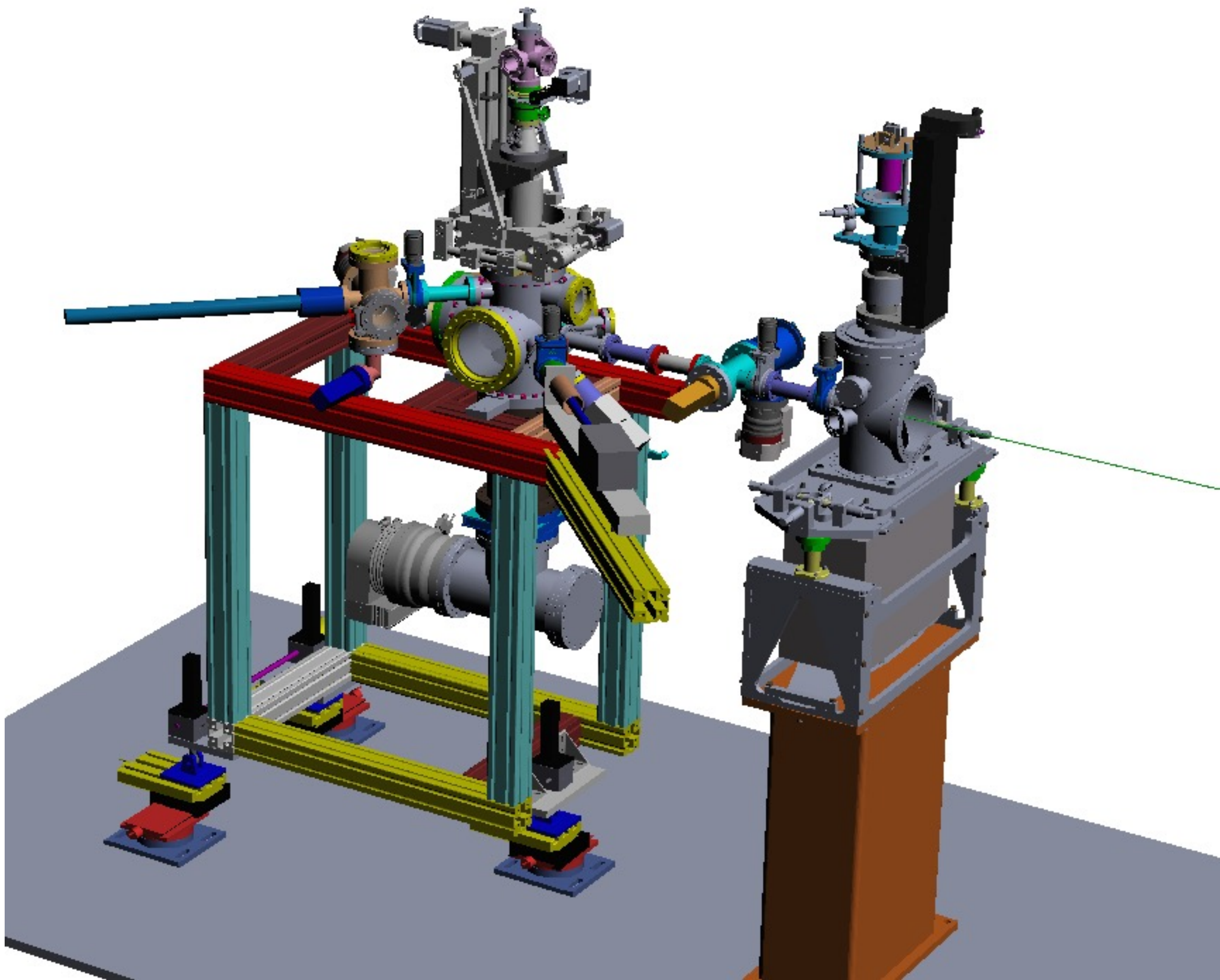



Installation of SESAME's HESEB soft X-ray beamline
08 February, 2022

Properties of HESEB End Station

- Fluorescence Detector (XRF)
- Total Electron Yield measurement
- LN_2 Cooling
- Sample Heating
- E-Beam Cleaning
- Partial Pumping
  - Measurement at low vacuum at He atmosphere (for archeology studies)



ID11 – Helmholtz-SESAME Beamline, HESEB

Wolfgang Eberhard

Mustafa Fatih Genişel

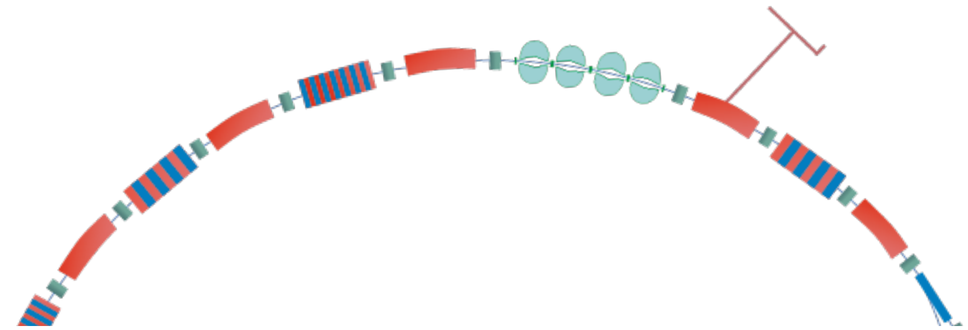
Operational 2022

A new soft X-ray beamline dedicated to enable advanced photoemission/spectroscopy experiments

Based on a variable polarization undulator

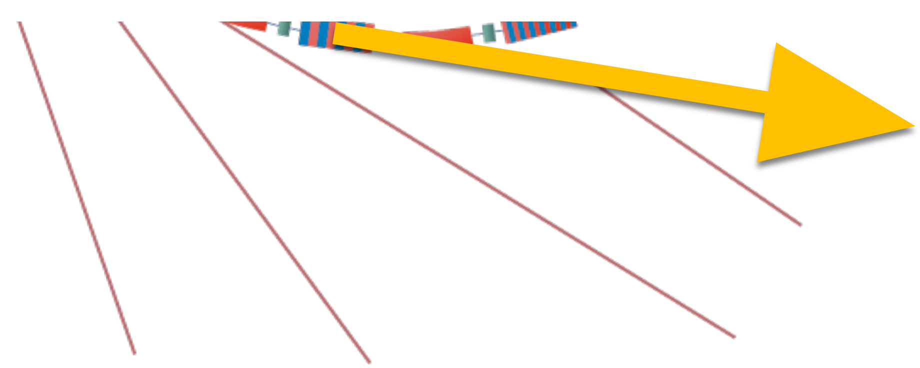
Kick-off meeting in January 2019 at DESY

3.9 M Euro funding secured (Helmholtz Institute)



Potential Examples

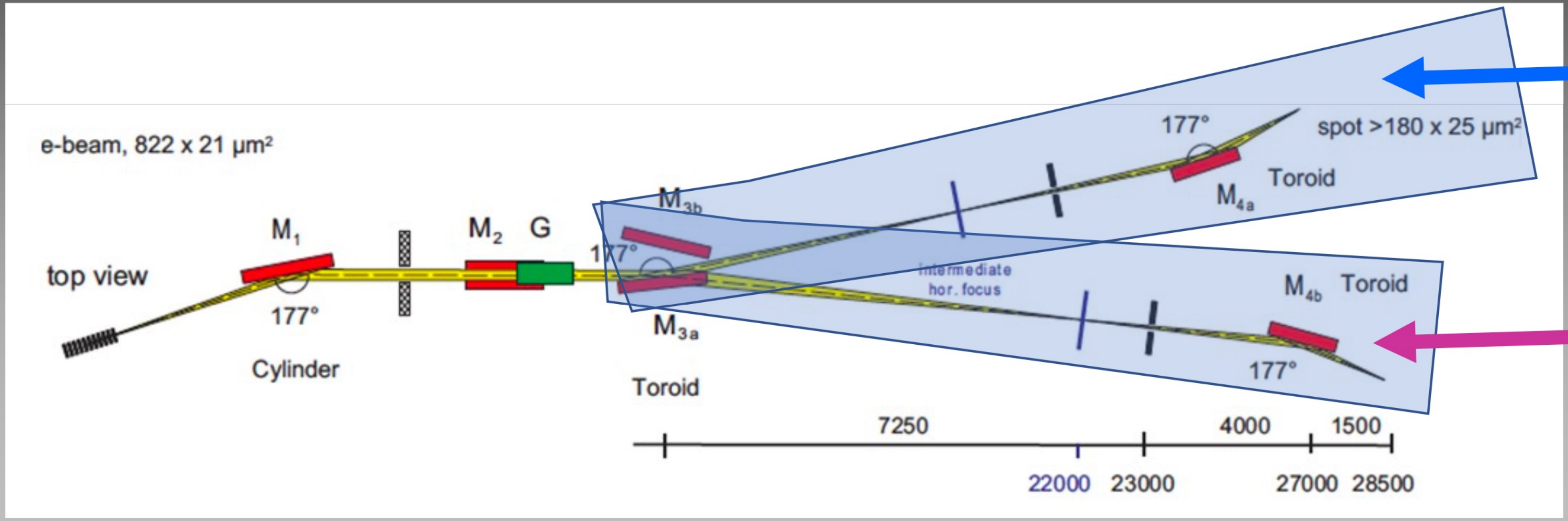
- Absorption spectroscopy with polarized soft X-rays
- Magnetic dichroism in the X-ray region (CMXD)
- Spectroscopy of catalysts under process conditions
- Spectroscopy of battery electrodes under operational conditions
- Non-destructive studies of archaeological materials (e.g. Characterisation and Conservation of Paintings on Walls and Sculpture from Nabataean Petra)



New beamline initiatives

TXPES

Complementarity of TXPES & HESEB Beamlines



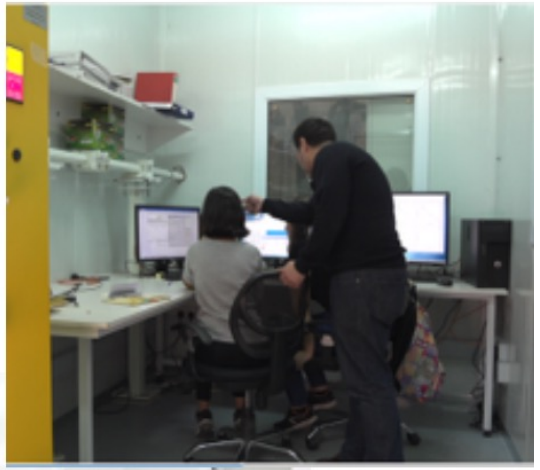
HESEB Beamline

TXPES Beamline

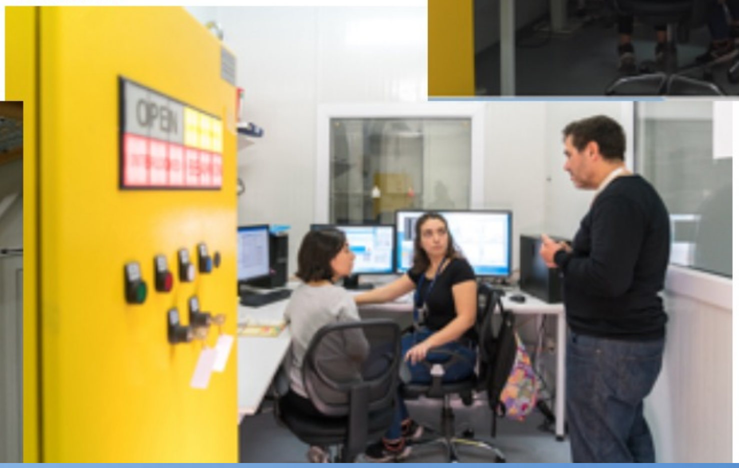
HOW TO BECOME A USERS OF SESAME

SESAME is open to users intending to publish their scientific results. Proposals are submitted in calls that remain open for two months. After submission, the beamline coordinators assess the technical feasibility of the experiment proposed and the security services evaluate the potential risk involved.
Feasible proposals are then evaluated and ranked by SESAME international Proposal Review Committee.
Best ranked proposals are allocated according to the number of available beamtime.

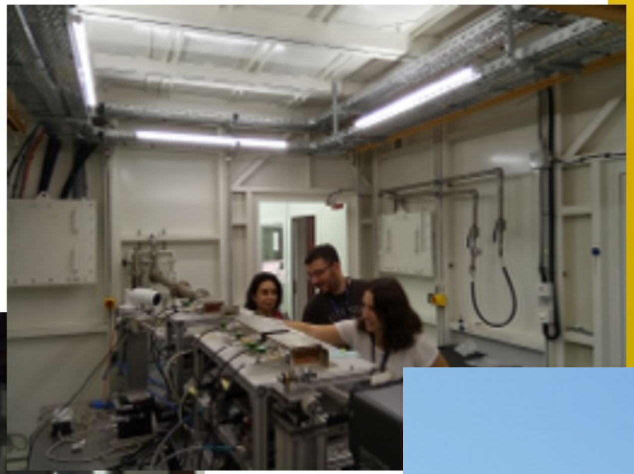
Analyzing data



Making plans & collecting good data



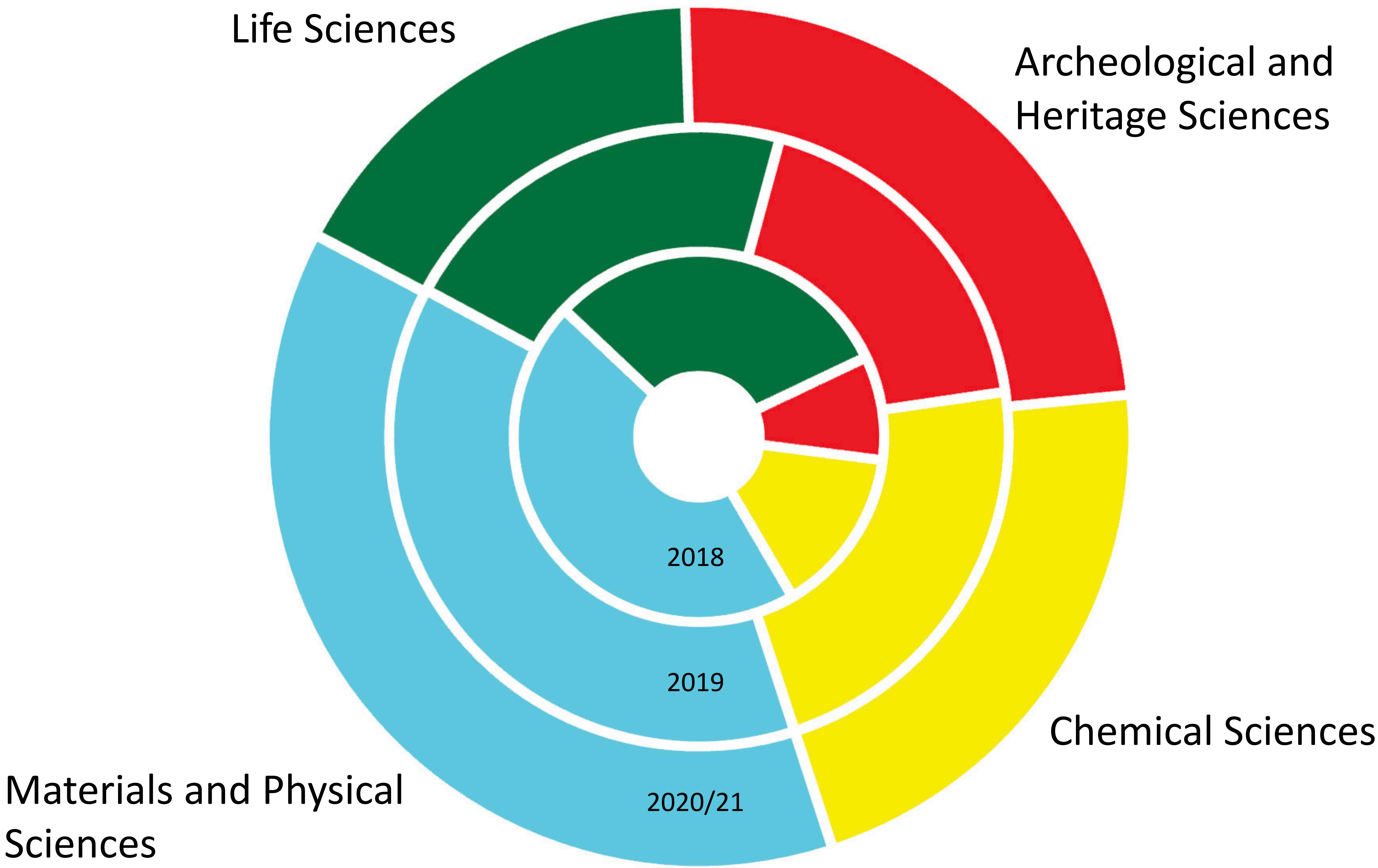
Mounting samples



Preparing Samples

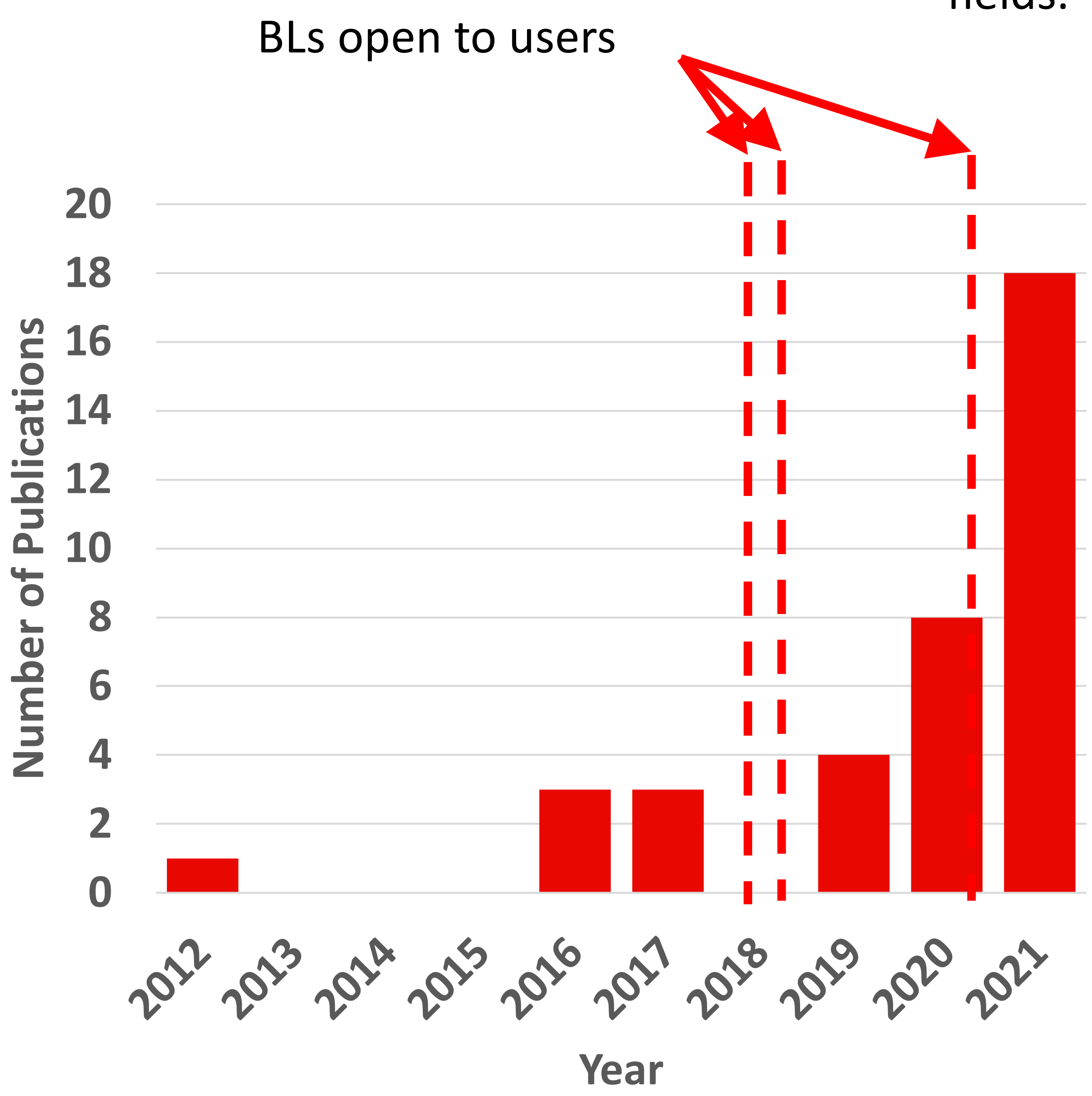
Step-by-step assistance to users

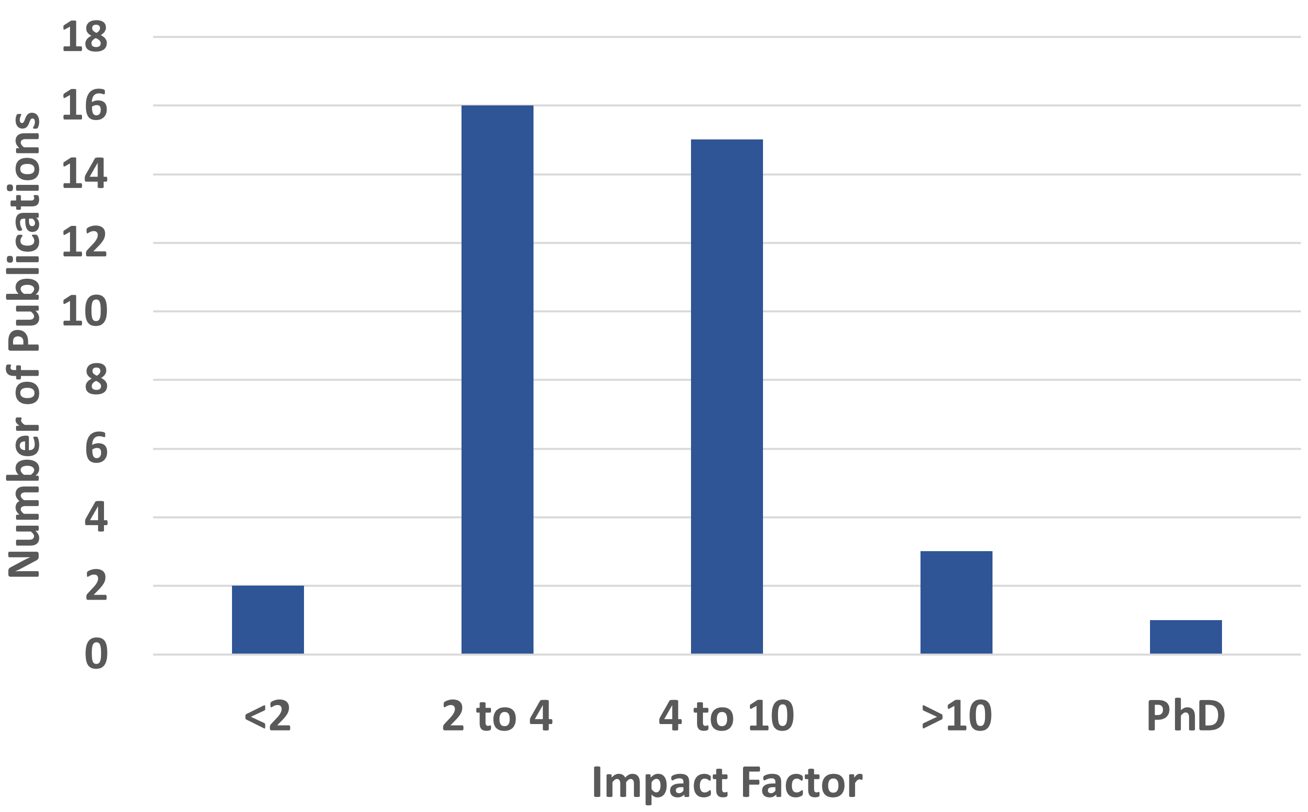
4 Proposal Review Subcommittees



Publications

SESAME is continuing to grow with 151 requests for beamtime received in 2020 including all its Members. Scientific work has led to 37 peer-review publications with an average scientific impact factor of 4.7 and the work is typically published in the top 40% of journals in their respective fields.





Thank you!