Overview of SESAME and opportunities in cultural heritage

Andrea Lausi

SESAME

light but a short line with extension in the plane of the orbit.

The light emitted from the beam is polarized with the electric vector parallel to the plane of the electron orbit. It disappears as the observer rotates a piece of Polaroid before the eye through ninety degrees. An investigation of the spectral distribution of the energy is in progress and will be reported.

This work has been supported by the Office of Na... ...ch under contract N5ori–178.

...nko and I. Pomeranchuk, Phys. Rev. 65, 343 (...
...tt, Phys. Rev. 69, 87 (1946).
...v. Sci. Inst. 17, 6 (1946).
...hys. Rev. 70, 798 (1946).

Radiation from Electrons in a Synchrotron

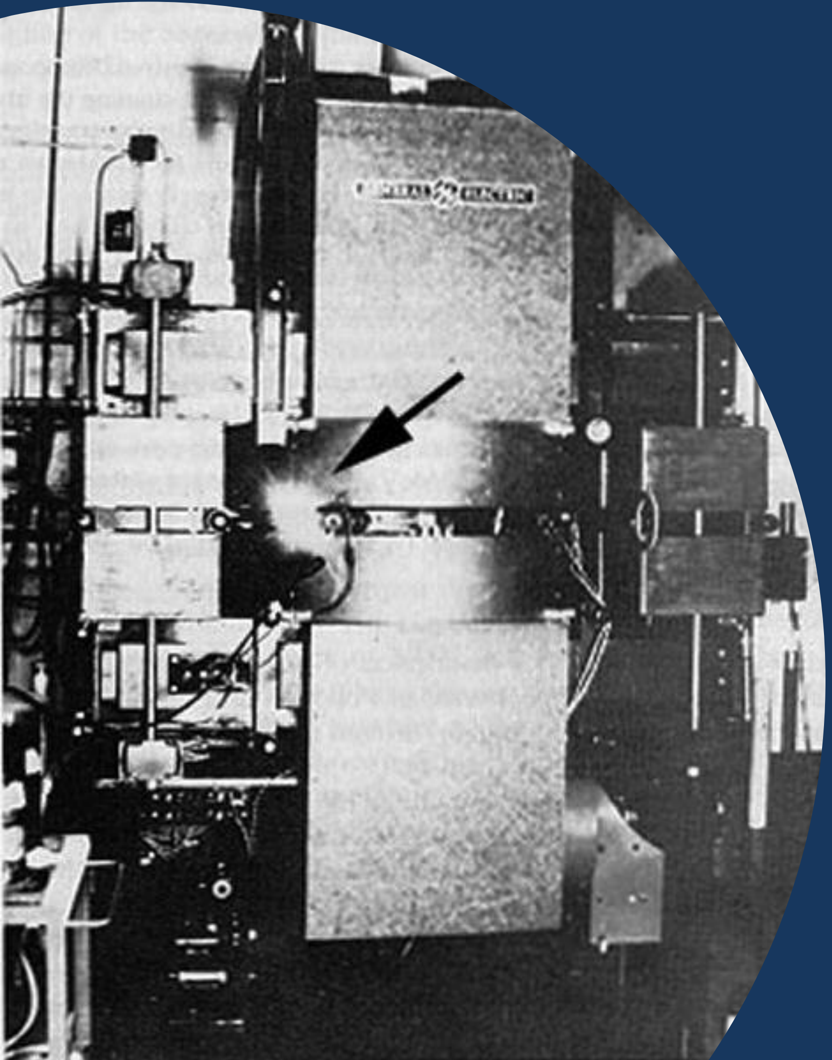
F. R. Elder, A. M. Gurewitsch, R. V. Langmuir, and H. C. Pollock
Research Laboratory, General Electric Company, Schenectady, New York

May 7, 1947

HIGH energy electrons which are subjected to large accelerations normal to their velocity should radiate electromagnetic energy.[1–4] The radiation from electrons in a betatron or synchrotron should be emitted in a narrow cone tangent to the electron orbit, and its spectrum should extend into the visible region. This radiation has now been observed visually in the General Electric 70-Mev synchrotron.[5] This machine has an electron orbit radius of 29.3 cm and a peak magnetic field of 8100 gausses. The radiation ... as a small spot of brilliant white light by an ob... ...oking into the vacuum tube tangent to the orbit ... the approaching electrons. The light is quite ... the x-ray output of the machine at 70 Mev ... per minute at one meter from the target ... rved in daylight at outputs as low as ...

... is obtained by turning off ...

The radiation from electrons in a betatron or synchrotron should be emitted in a narrow cone tangent to the electron orbit, and its spectrum should extend into the visible region. This radiation has now been observed visually



... and then expanded ... radiated light appears to be in... ...y at which the electrons are remove... ...s is to be expected, for in a given mach... proportional to the fourth power of th... ...y. The light radiation is not observed if the ...cted before its energy is about 30 Mev. Wh... beam has been accelerated to the peak ...ic field and then decelerated to low ene... measurement of the phase angle over which th... ...sible gave a value of 90–100 degrees. The lig... through a slotted disk rotating at synch...

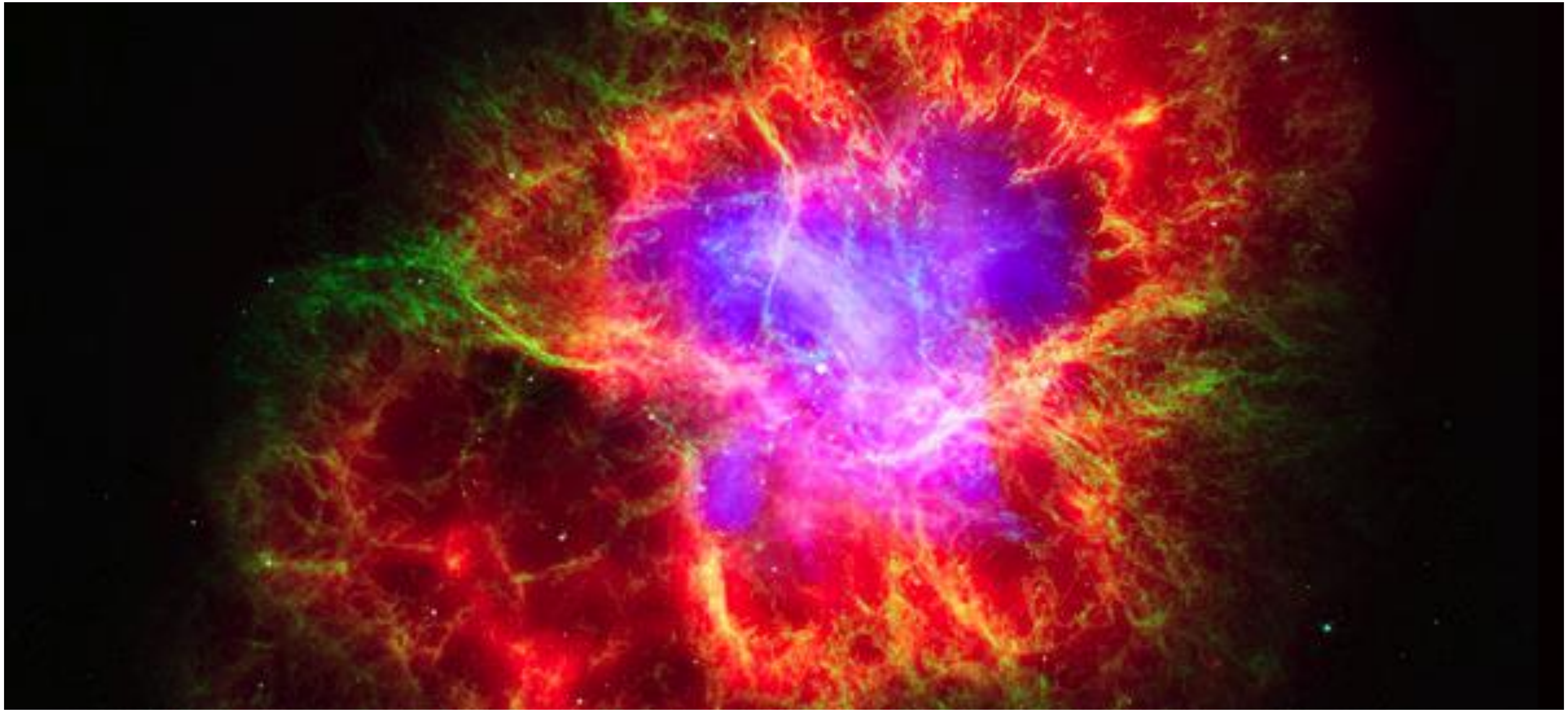
...e r-f resonator is turned off a short time bef... the magnetic field, the electron beam slow... a radius just larger than that of the i...

F. R. Elder, A. M. Gurewitsch, R. V. Langmuir, and H. C. Pollock

Phys. Rev. 71, 829 – Published 1 June 1947

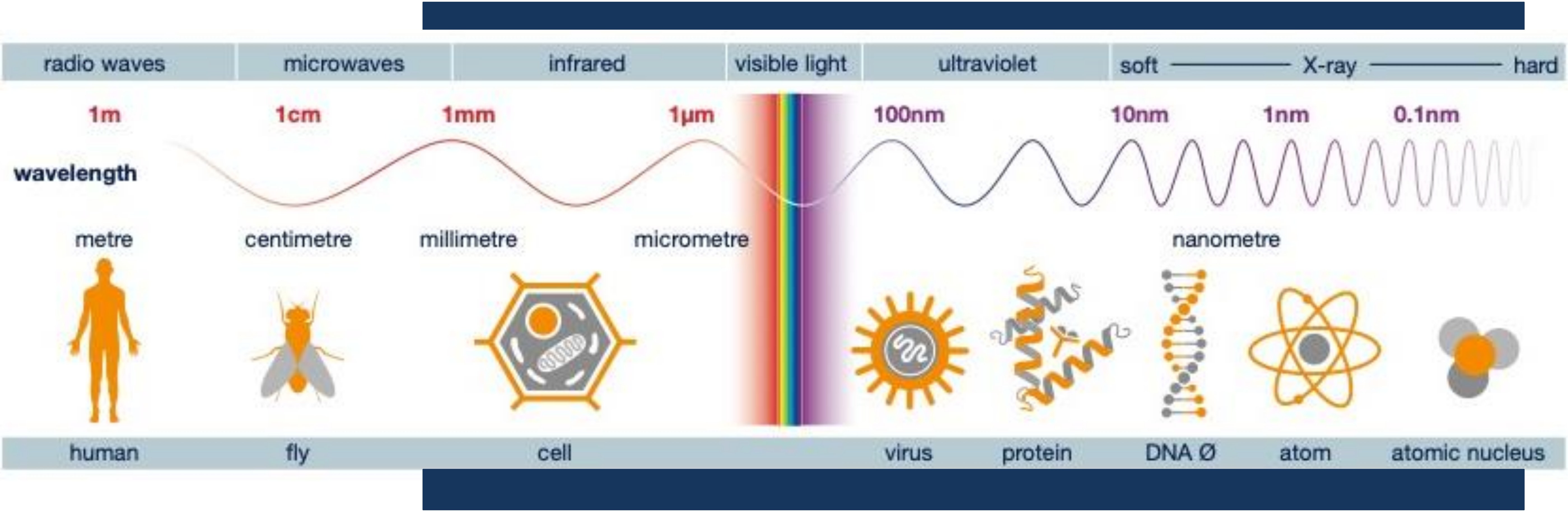
lightsources.org

50,000 users, the largest scientific community in the world



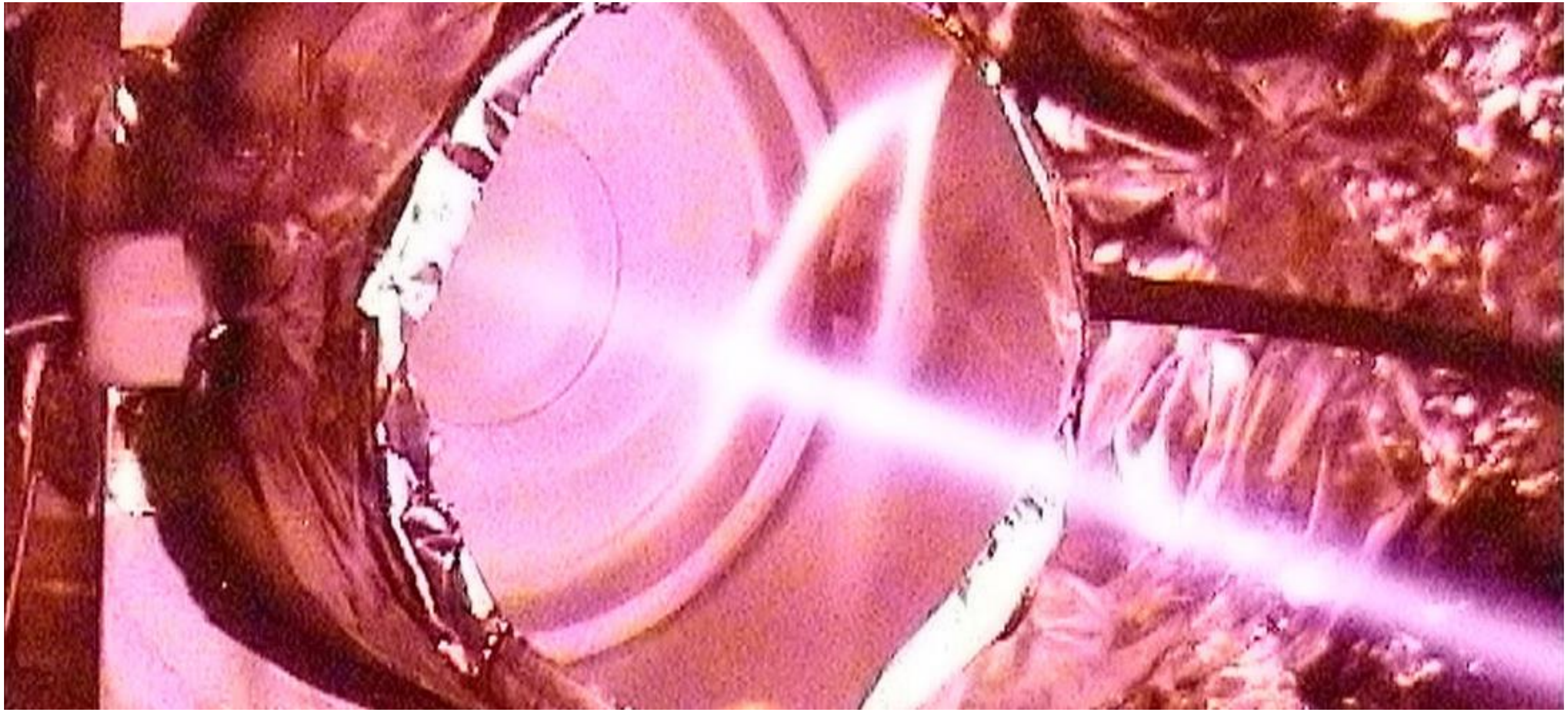
Synchrotron radiation from the Crab Nebula

Composite image of the Crab Nebula obtained merging data from *Chandra* (X-ray, shown in blue), *Hubble* (visible, shown in green), and *Spitzer* (infrared, shown in red).



SR covers a very wide spectrum

Image courtesy xfel.eu



SR is extremely collimated

Image courtesy synchrotron-soleil.fr

Scheme of a SR facility

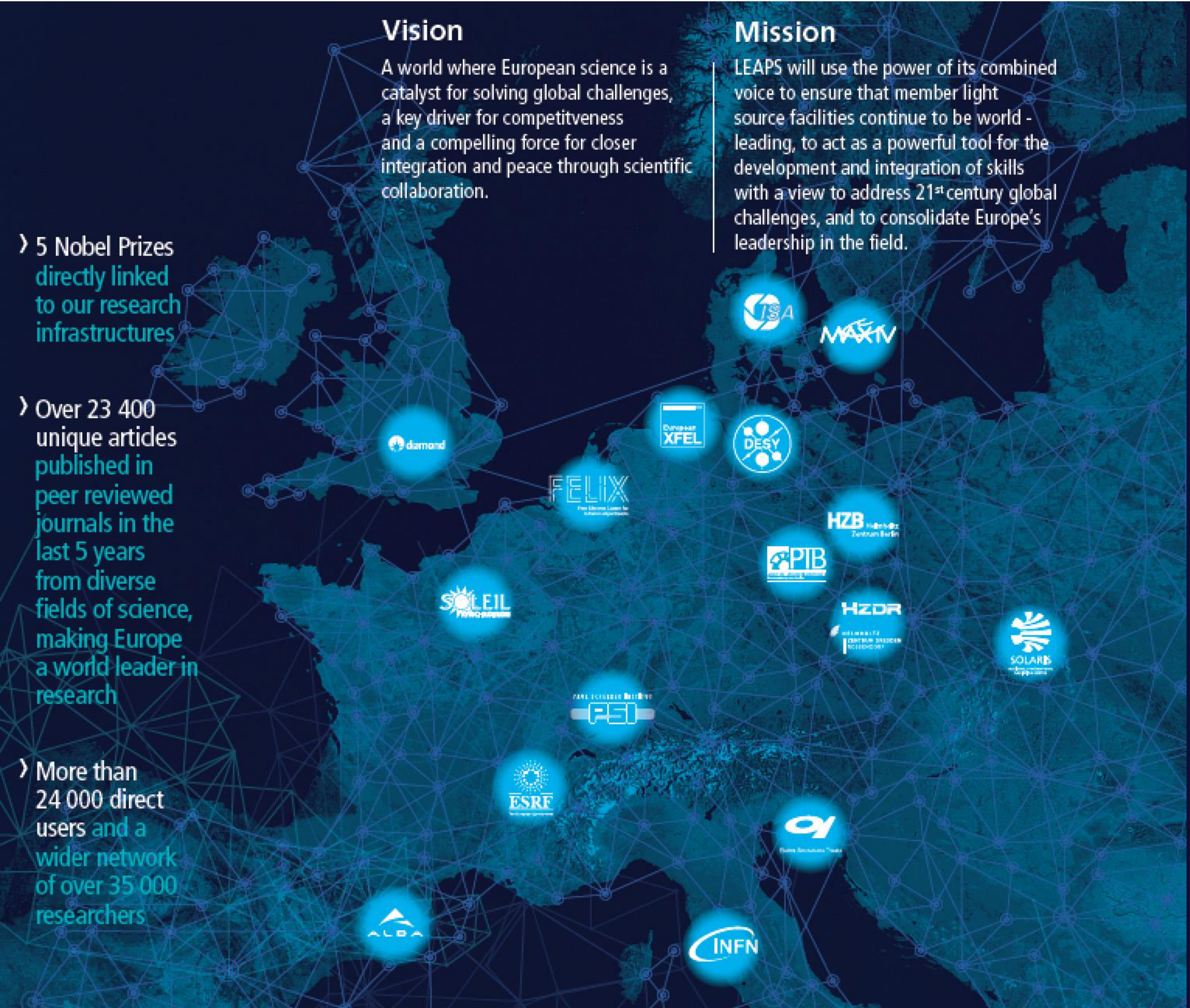
Image courtesy synchrotron-soleil.fr

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 although it has very different scientific aims.

- It was established 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 a User facility open to international academic and industrial communities.



LEAPS:
the League of European Accelerator-based Photon Sources
groups
the major "Photon Factories" in Europe

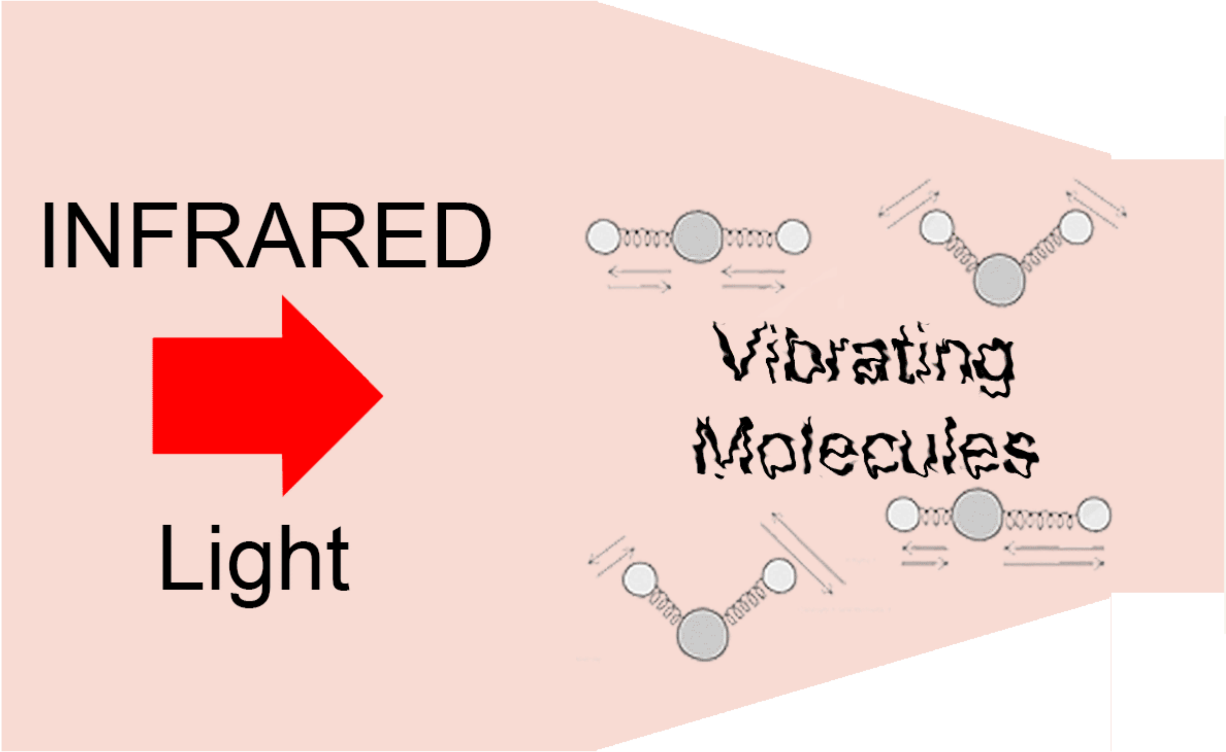
In November 2018, SESAME become the 1st Associate Member of LEAPS

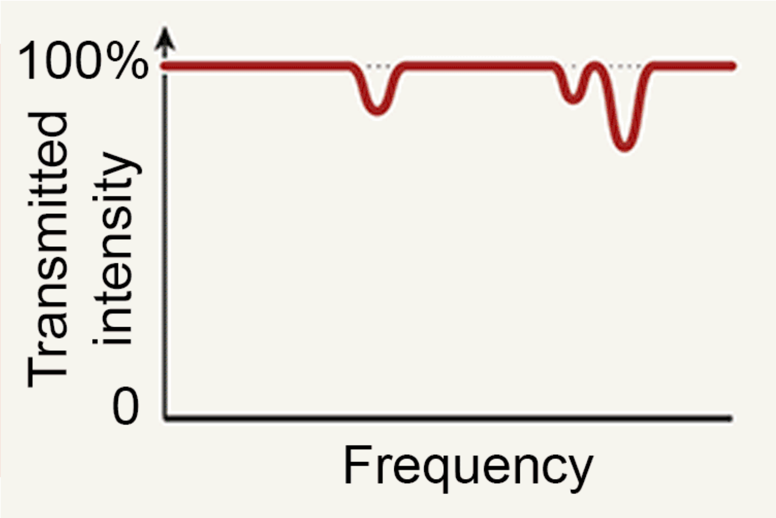
SOLEIL SYNCHROTRON

INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

Gihan Kamel
(Principal
Beamline
Scientist)

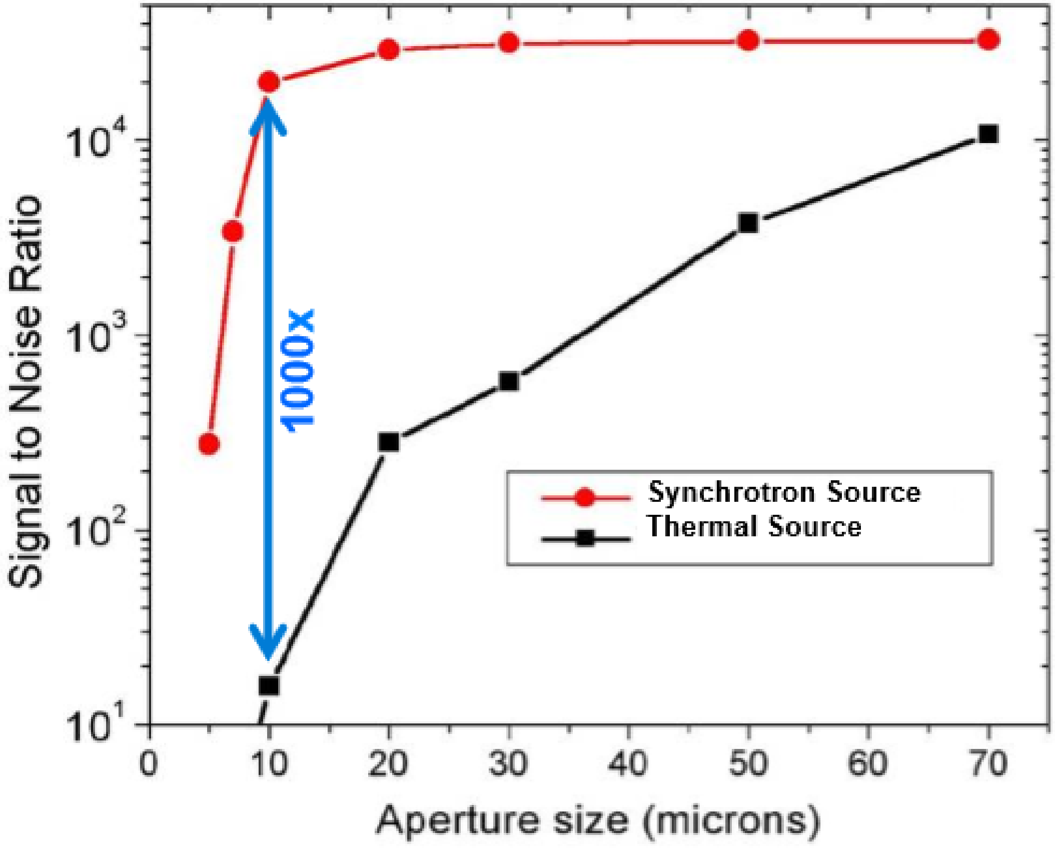
Infrared Spectroscopy





IR: SR Advantages over thermal sources

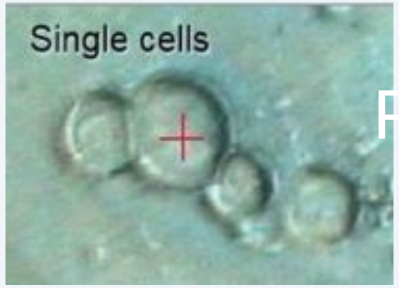
Synchrotron IR is 1000x *brighter* than a conventional blackbody source



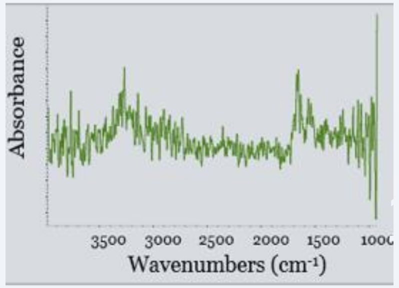
Holman et al., Spectroscopy - An International Journal 17(2-3), 139-159 (2003).

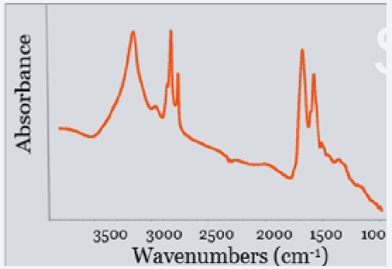
Advantages

- 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



Courtesy Paul Dumas

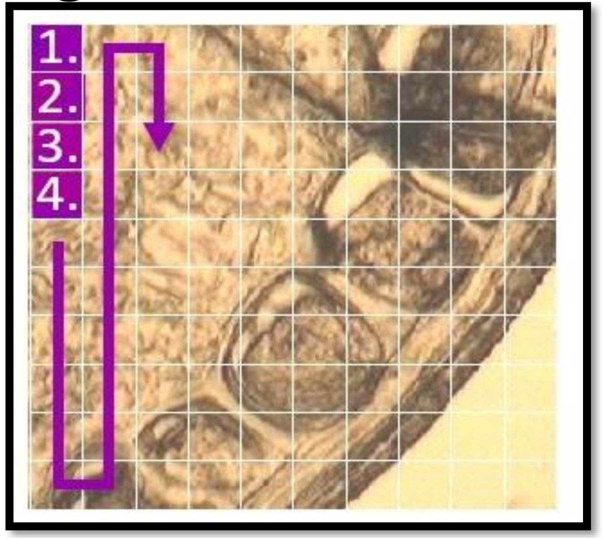




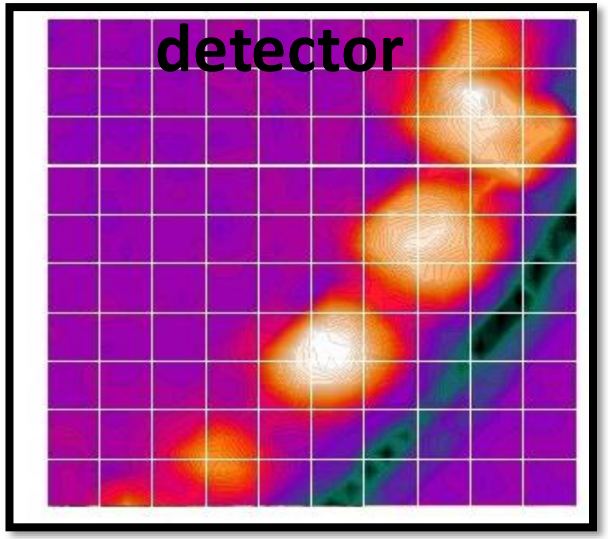
IR: Next Step, Focal Plane Array detector

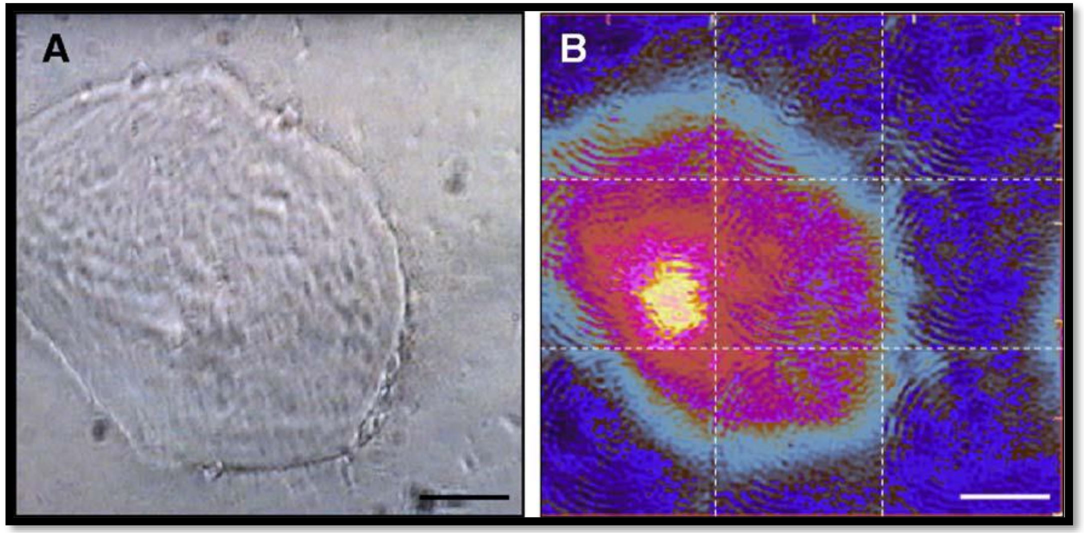
SESAME

Single Point detector



FPA detector





Consecutive

- **Point-by-point detector,**
- **Long data acquisition.**

All at once

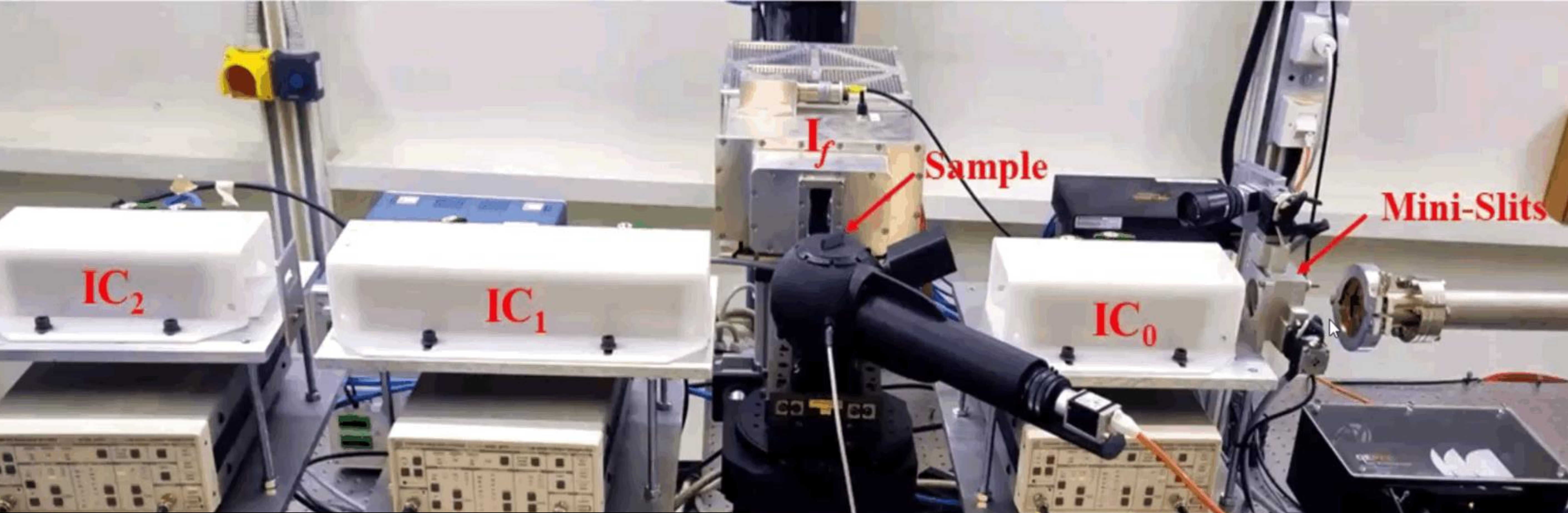
- **State-of-the-art detector** for FTIR imaging,
- **Parallel** acquisition,
- An array of IR detectors arranged in a square (**64 x 64 detectors**),
- **4K spectra captured in a single shot**, almost like a digital camera.

(A) Visible image of a human biological cell. (B) Synchrotron FPA (64x64 pixels) image of the protein (Amide I) absorbance in the cell.

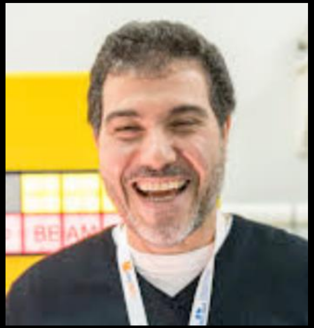
L.M. Miller, P. Dumas / Biochimica et Biophysica Acta 1758 (2006)

BRUKER

INFN
Istituto Nazionale di Fisica Nucleare



BM08 - XAFS/XRF



Messaoud Harfouche
(Principal Beamline Scientist)

Latif Ullah Khan
(Beamline Scientist)

XAFS/XRF: SR Advantages over laboratory sources

Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 51.99	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.6	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At 209.99	86 Rn 222.02
87 Fr 223.02	88 Ra 226.03	89-103	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [269]	109 Mt [278]	110 Ds [281]	111 Rg [280]	112 Cn [285]	113 Nh [286]	114 Fl [289]	115 Mc [289]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 144.91	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.06	71 Lu 174.97
89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244.06	95 Am 243.06	96 Cm 247.07	97 Bk 247.07	98 Cf 251.08	99 Es [254]	100 Fm 257.10	101 Md 258.1	102 No 259.10	103 Lr [262]

XAFS/XRF: High-performance XRF multi-detector

AXPiDe

(Advanced X-ray PIxel DEtector)

64 cells detector, the system can handle more than 10 Mcounts s^{-1} within a linearity of 75%.

Istituto Nazionale di Fisica Nucleare

Elettra Sincrotrone Trieste

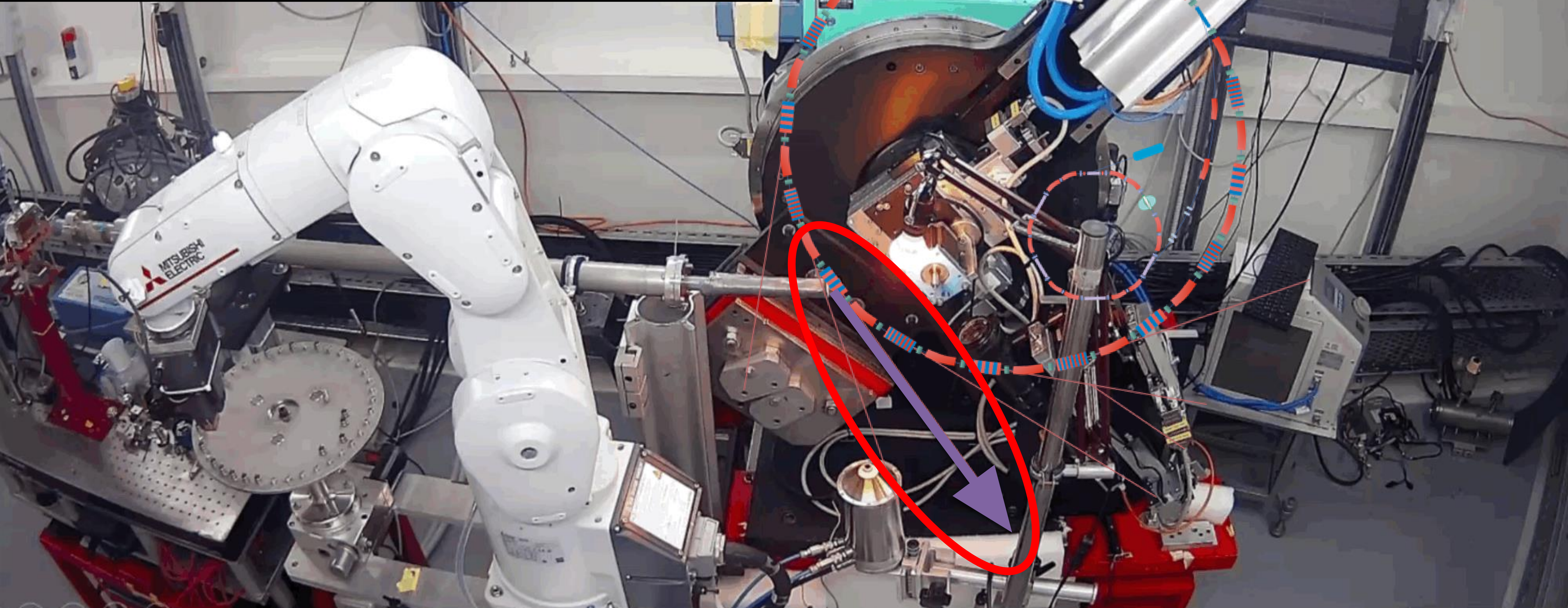
JOURNAL OF SYNCHROTRON RADIATION

Carlomagno *et al.*

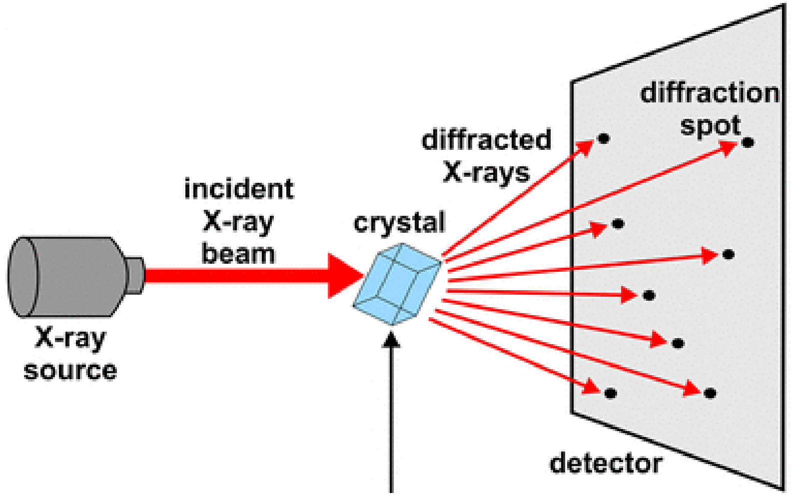
Volume 28 | **Part 6** | Novemeber 2021 | Pages 1811–1819 | 10.1107/S1600577521008857

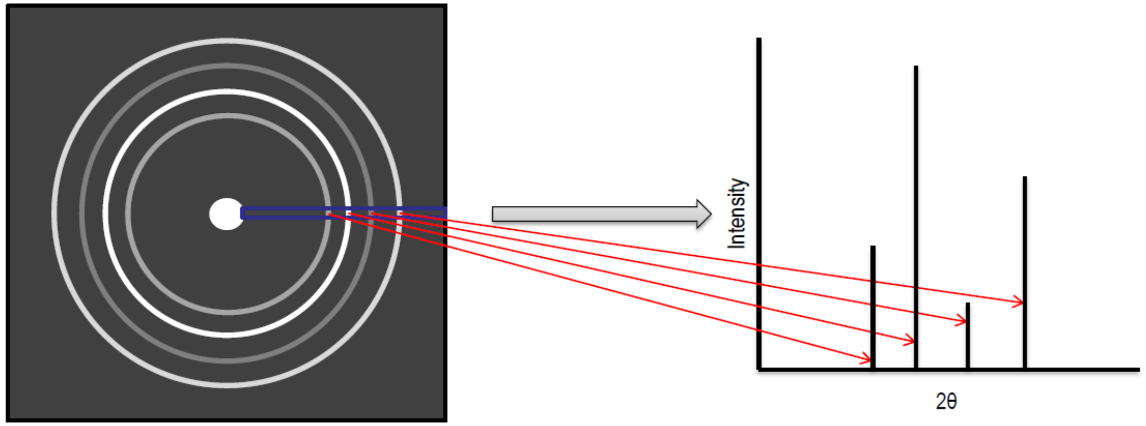
ID09 – MS/XPD

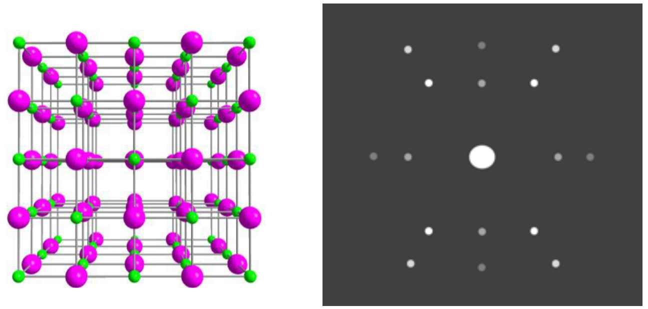
Mahmoud Abdellatief
(Principal Beamline Scientist)

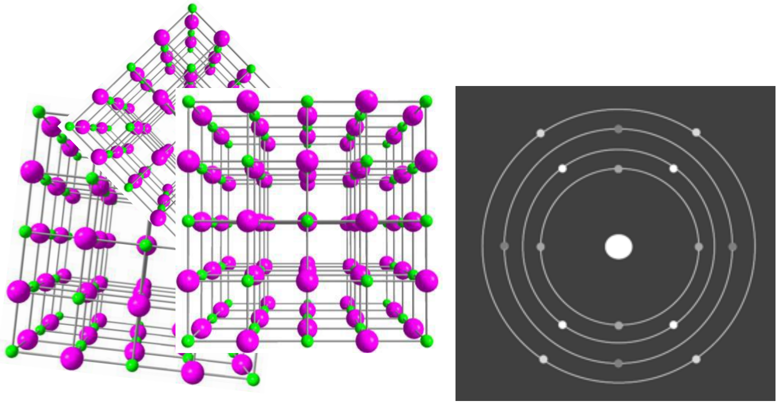


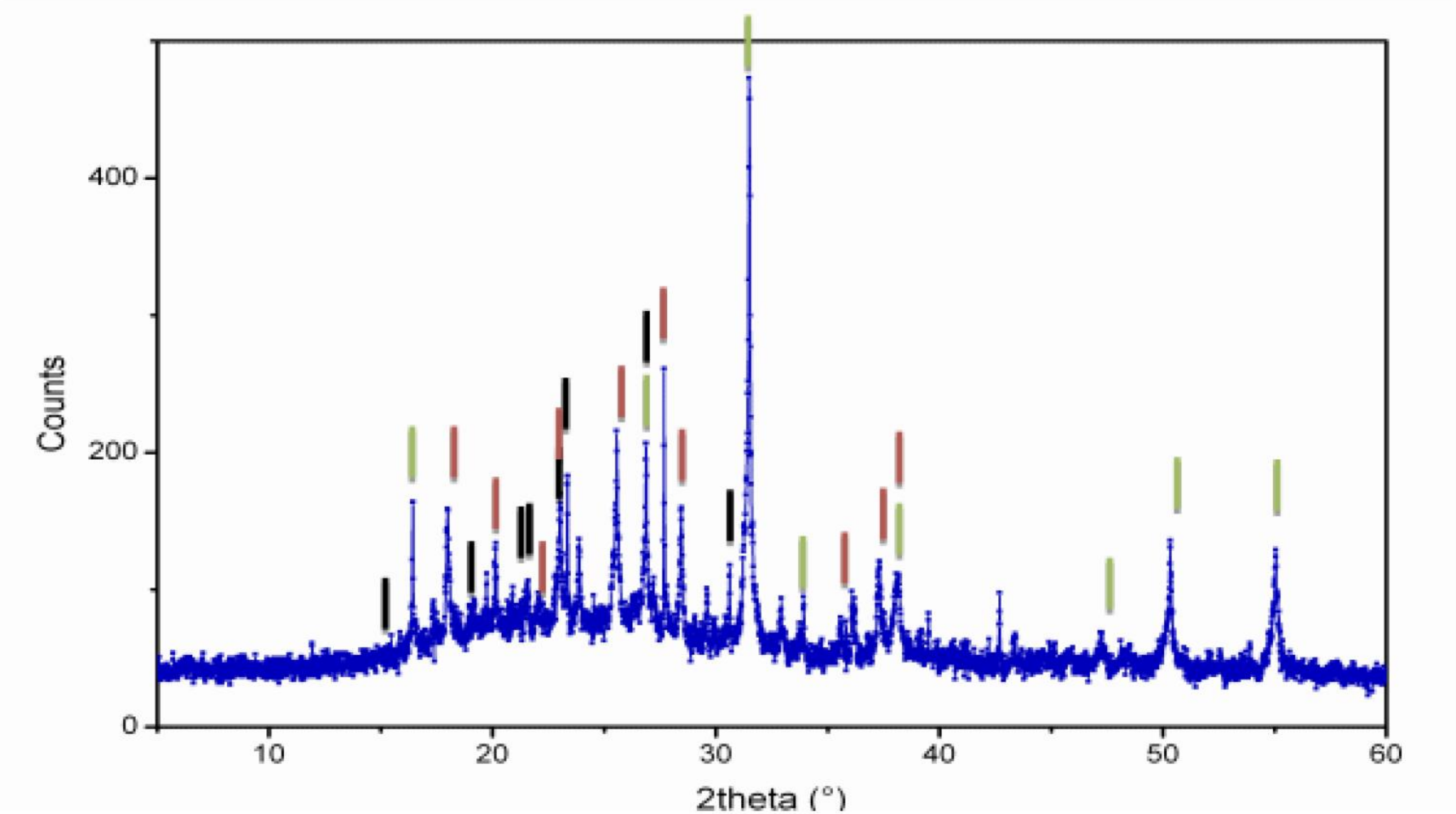
MS/XPD: SR Advantages over laboratory sources





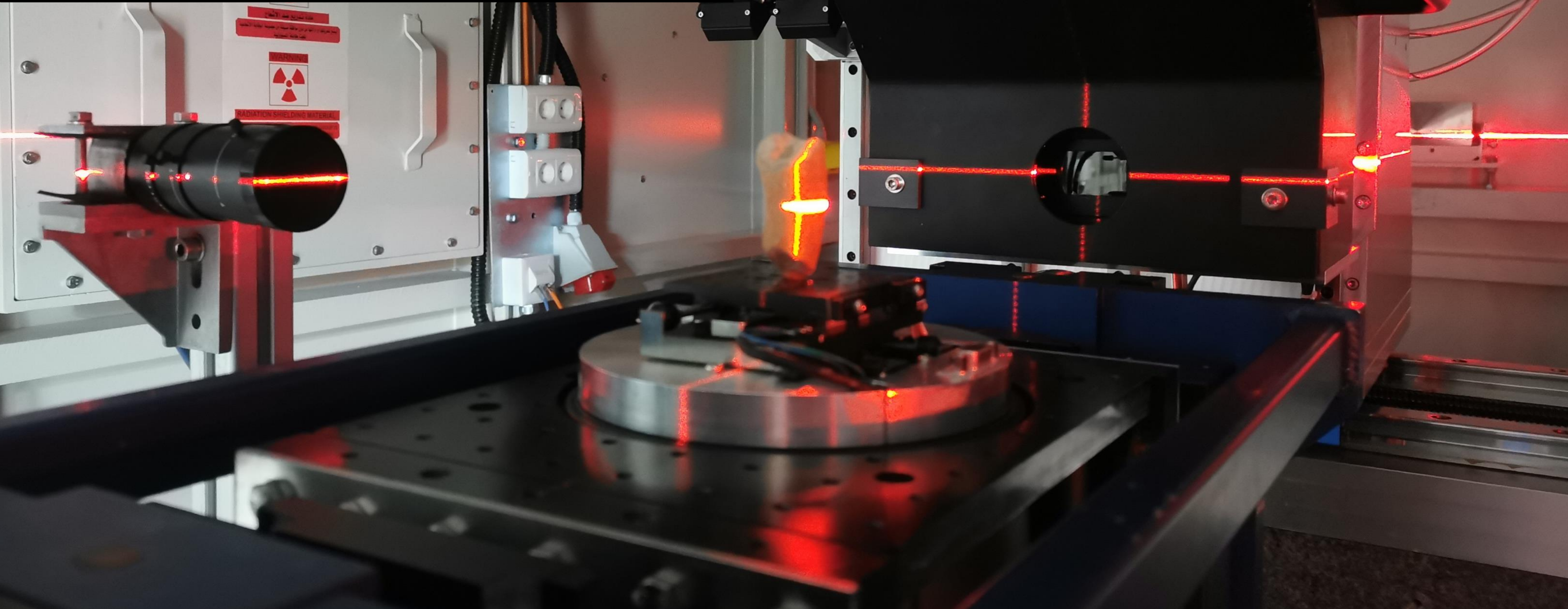




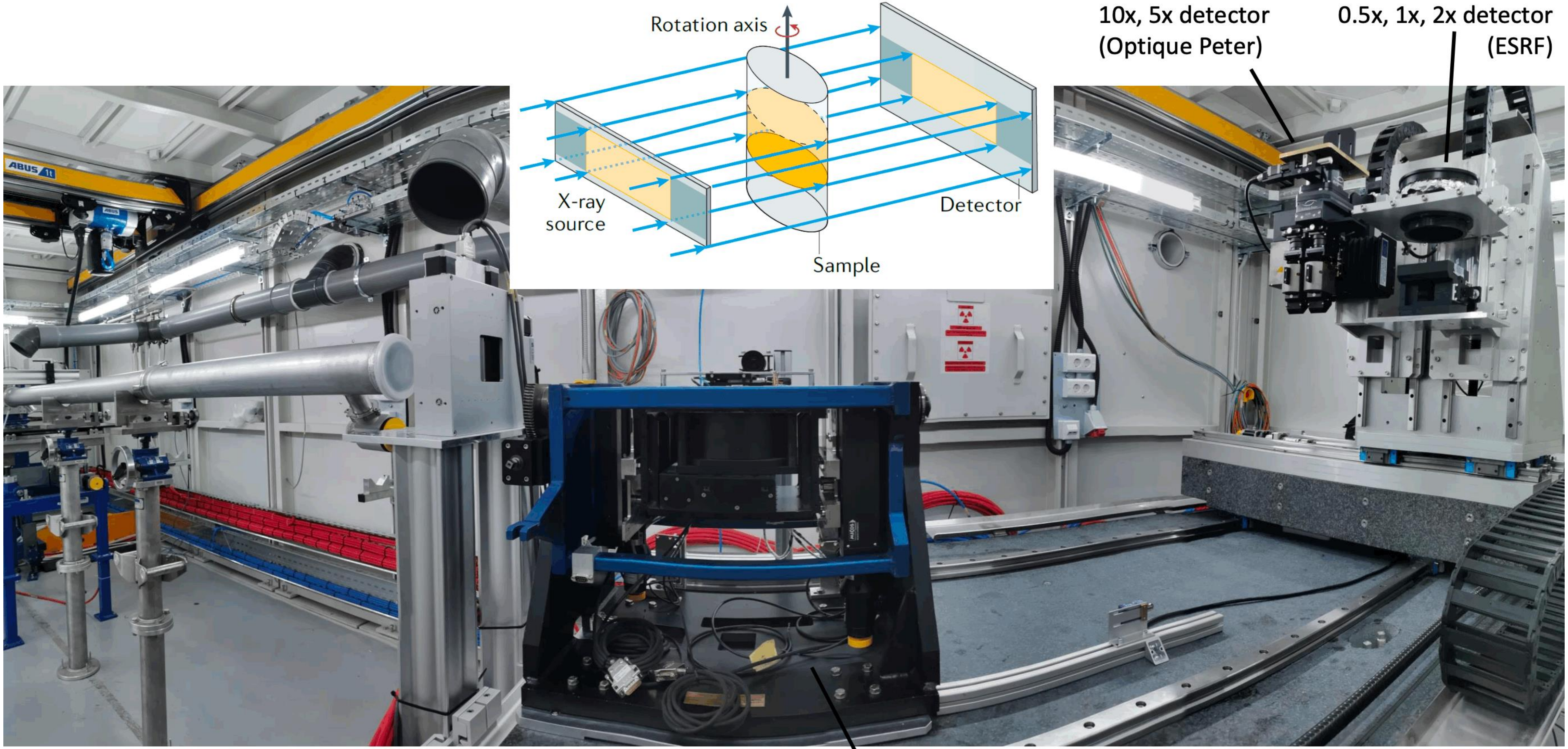


ID10 – BEATS

Fareeha Hameed
(Principal Beamline Scientist)

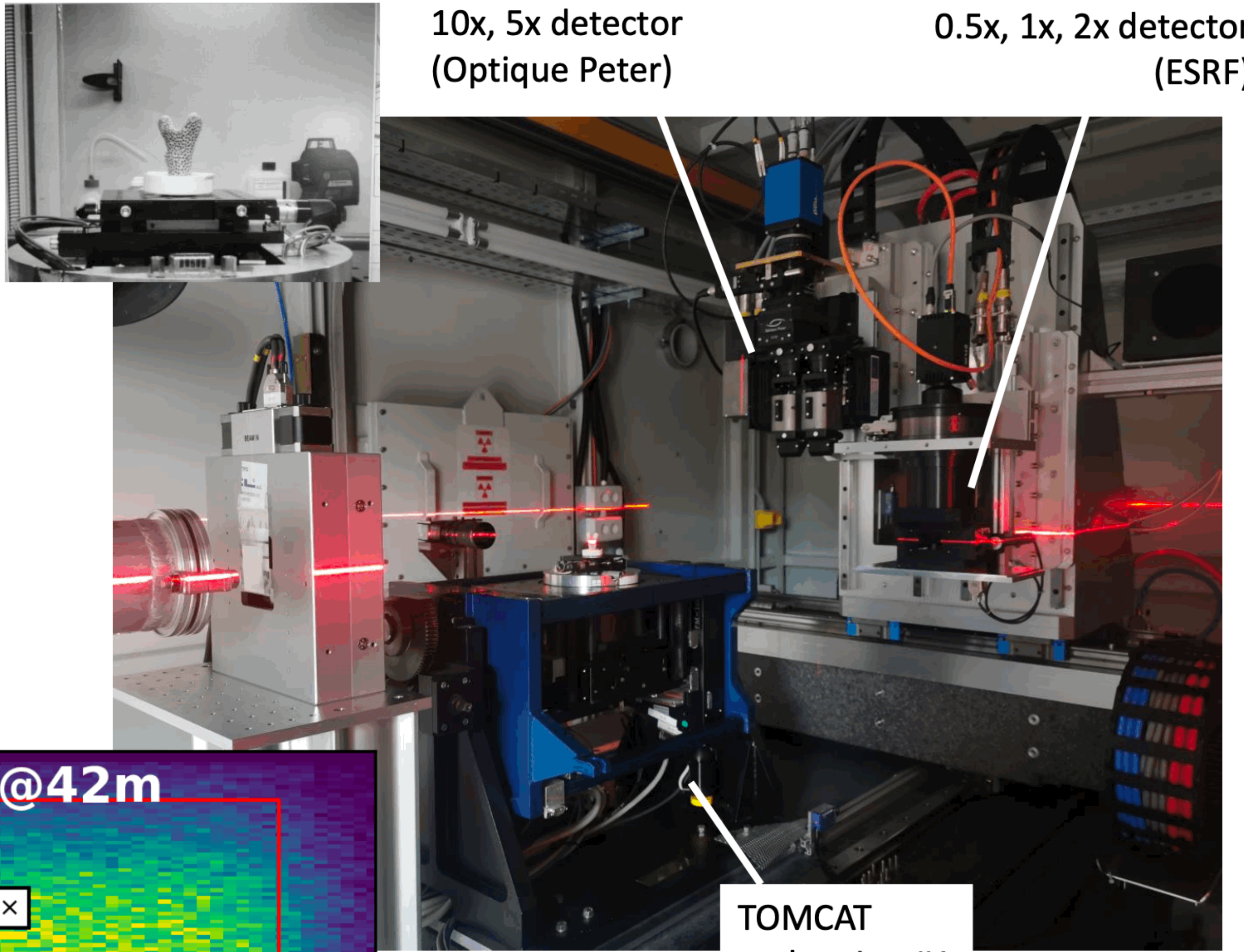


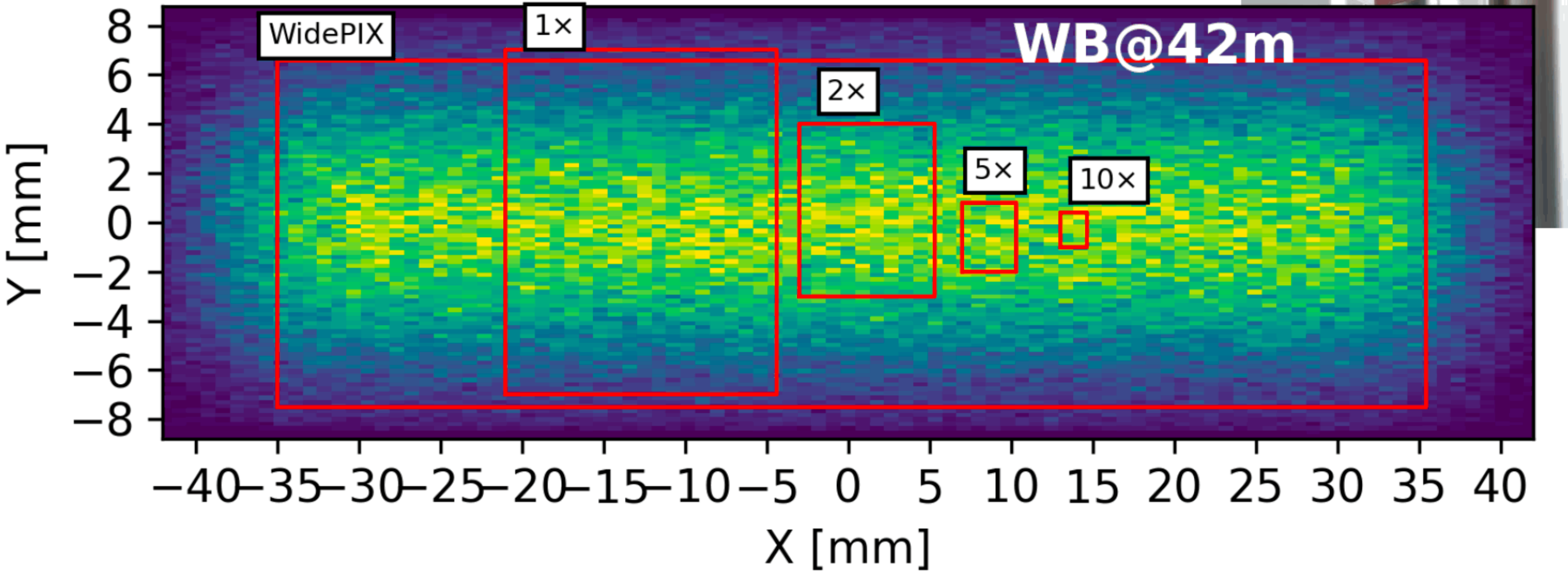
SR XCT experimental setup



BEATS: Experimental Station

Magnif.	Field of view	Pixel size
0.5×	33.2 × 28.0 mm^2	13.0 µm
1×	16.6 × 14.0 mm^2	6.5 µm
2×	8.3 × 7.0 mm^2	3.25 µm
5×	3.4 × 2.8 mm^2	1.3 µm
10×	1.7 × 1.4 mm^2	0.65 µm

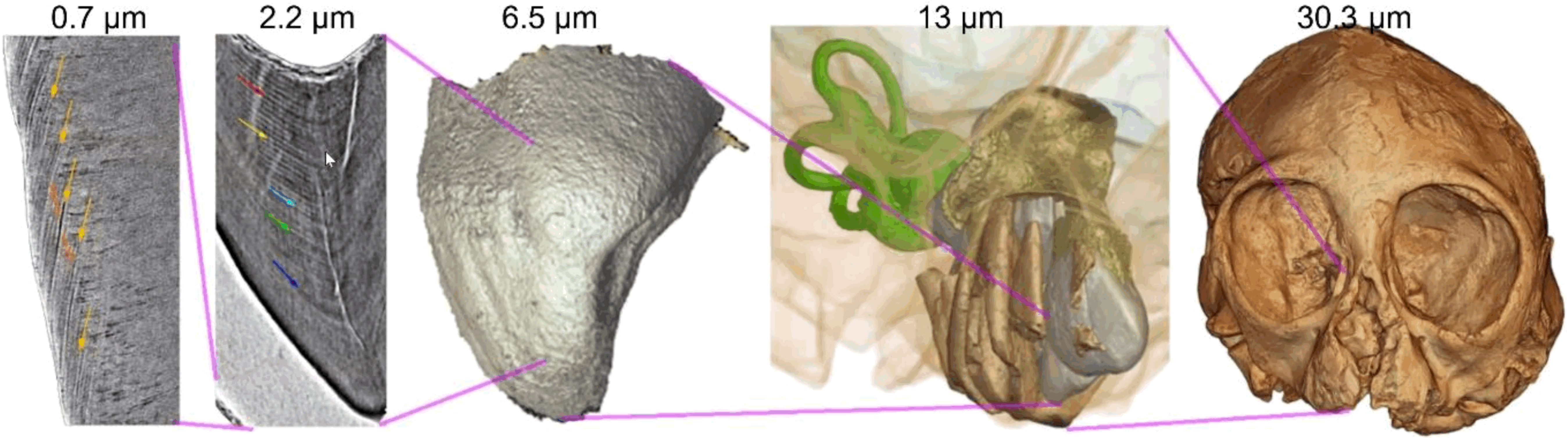




BEATS: Multiresolution

***Nyanzapithecus alesi*, fossil skull of an infant ape from Kenya aged of 13 My**

Nengo I., Tafforeau P., Gilbert C. C., Fleagle J. G., Miller E. M., Feibel C., Fox D. L., Feinberg J., Pugh K. D., Berruyer C., Mana S., Engle Z. & Spoor F. (2017). New infant cranium from the African Miocene sheds light on ape evolution. **Nature**, 548:169-174.

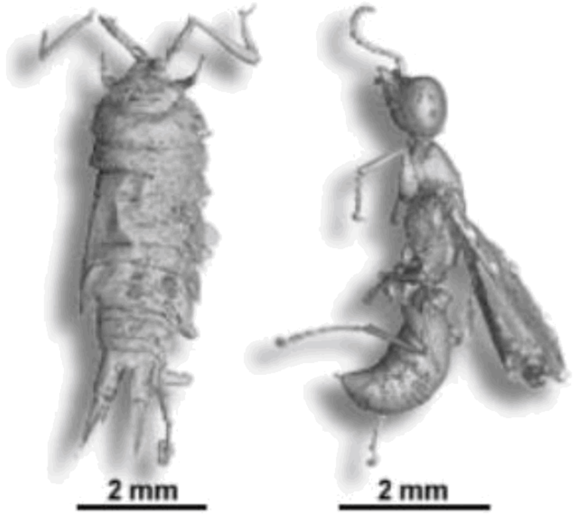


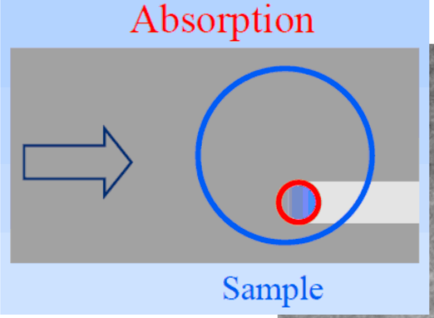
[Courtesy P. Tafforeau, ESRF]

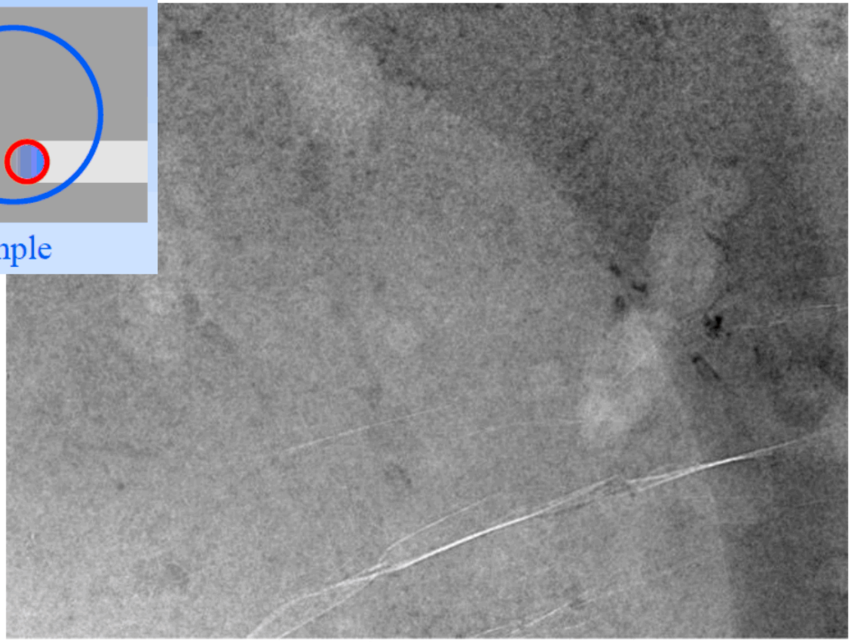
BEATS: Phase Contrast Imaging

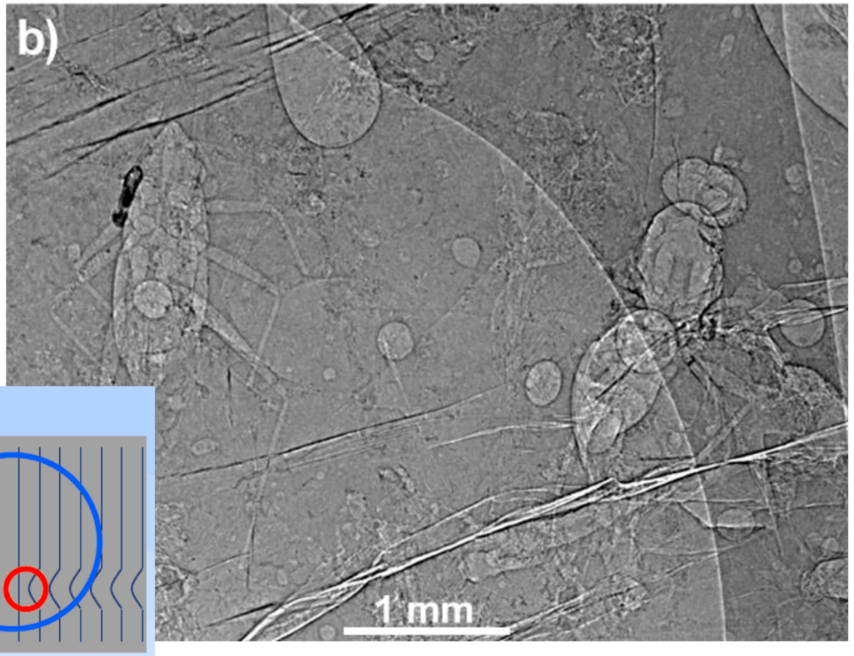
Propagation-based phase contrast XCT

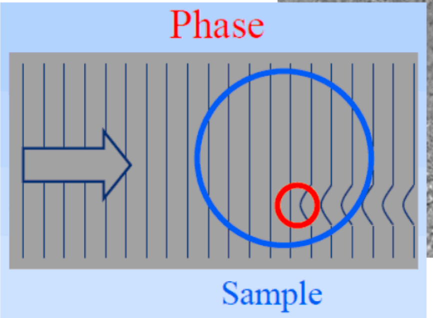
- Phase-contrast XCT make it possible for paleontologists to study opaque amber, previously inaccessible using classical microscopy techniques









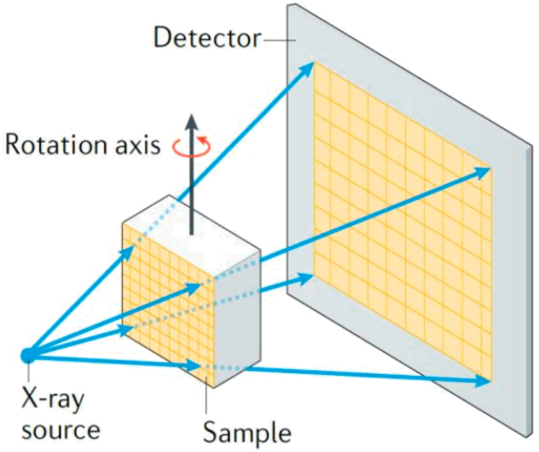


[Credits: M. Lak, P. Tafforeau, D. Néraudeau (ESRF Grenoble and UMR CNRS 6118 Rennes)]

BEATS: SR Advantages over laboratory sources

Laboratory XCT

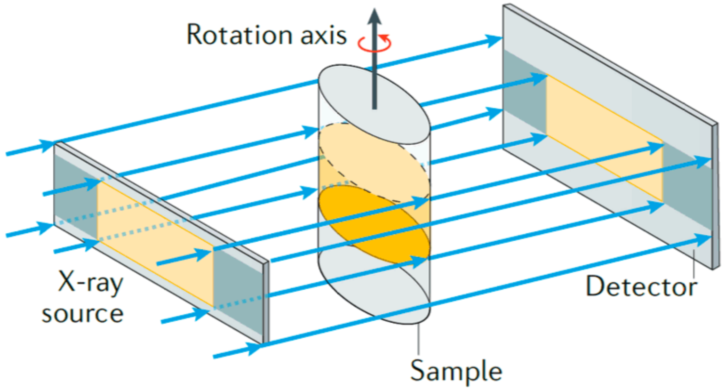
- Wide spectrum of (**polychromatic**) X-ray energies, with bright peaks characteristic of the source target material
- **Cone-beam** geometry



- Can illuminate **large objects** and exploit physical magnification
- **Typical scan times: hours to minutes**

Synchrotron XCT

- **Higher flux** by several orders of magnitude
- **Monochromatic X-ray beam** possible: improved sensitivity and limited artefacts
- **Parallel-beam geometry**



- (Generally) **higher resolution**
- (But) smaller field of view
- **Typical scan times: minutes to <seconds**
- **Time-resolved (4D) CT**
- High spatial coherence enables **phase contrast**

ID11 left – HESEB

Mustafa Fatih Genişel
(Principal Beamline Scientist)

Photo © Ivan Lim

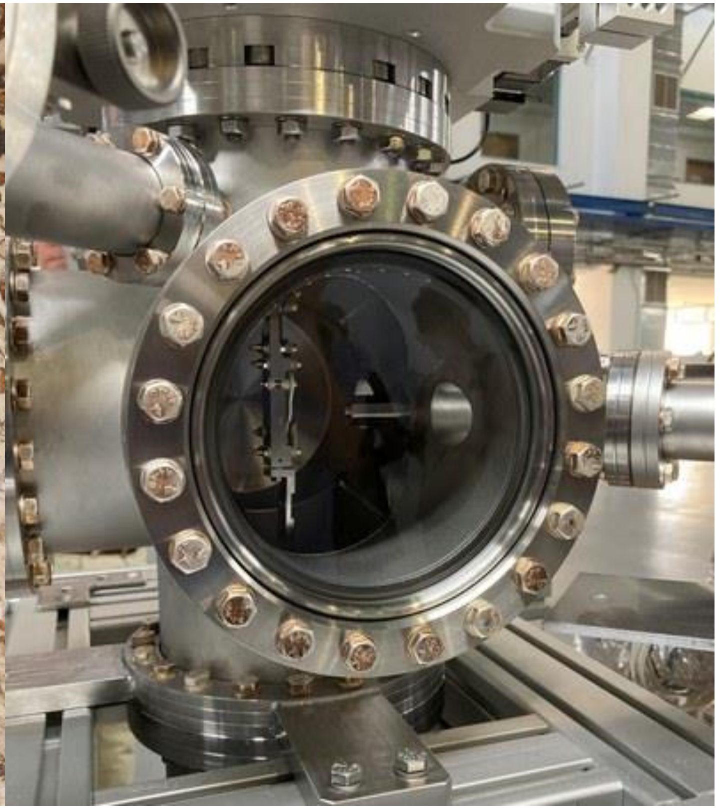
HESEB: SR Advantages over laboratory sources

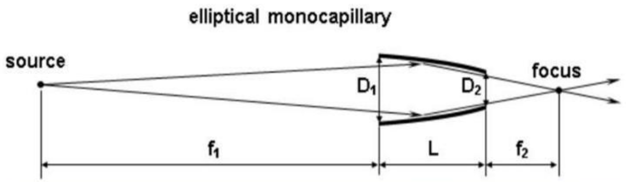
Periodic Table of the Elements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.01																	2 He 4.00
3 Li 6.94	4 Be 9.01											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 51.99	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.63	33 As 74.92	34 Se 78.97	35 Br 79.90	36 Kr 83.80
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.95	43 Tc 98.91	44 Ru 101.07	45 Rh 102.91	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.6	53 I 126.90	54 Xe 131.29
55 Cs 132.91	56 Ba 137.33	57-71	72 Hf 178.49	73 Ta 180.95	74 W 183.84	75 Re 186.21	76 Os 190.23	77 Ir 192.22	78 Pt 195.09	79 Au 196.97	80 Hg 200.59	81 Tl 204.38	82 Pb 207.2	83 Bi 208.98	84 Po [208.98]	85 At 209.99	86 Rn 222.02
87 Fr 223.02	88 Ra 226.03	89-103	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [269]	109 Mt [278]	110 Ds [281]	111 Rg [280]	112 Cn [285]	113 Nh [286]	114 Fl [289]	115 Mc [289]	116 Lv [293]	117 Ts [294]	118 Og [294]

57 La 138.91	58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm 144.91	62 Sm 150.36	63 Eu 151.96	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.93	68 Er 167.26	69 Tm 168.93	70 Yb 173.06	71 Lu 174.97
89 Ac 227.03	90 Th 232.04	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu 244.06	95 Am 243.06	96 Cm 247.07	97 Bk 247.07	98 Cf 251.08	99 Es [254]	100 Fm 257.10	101 Md 258.1	102 No 259.10	103 Lr [262]

HESEB: soft X-ray spectroscopy beyond UHV

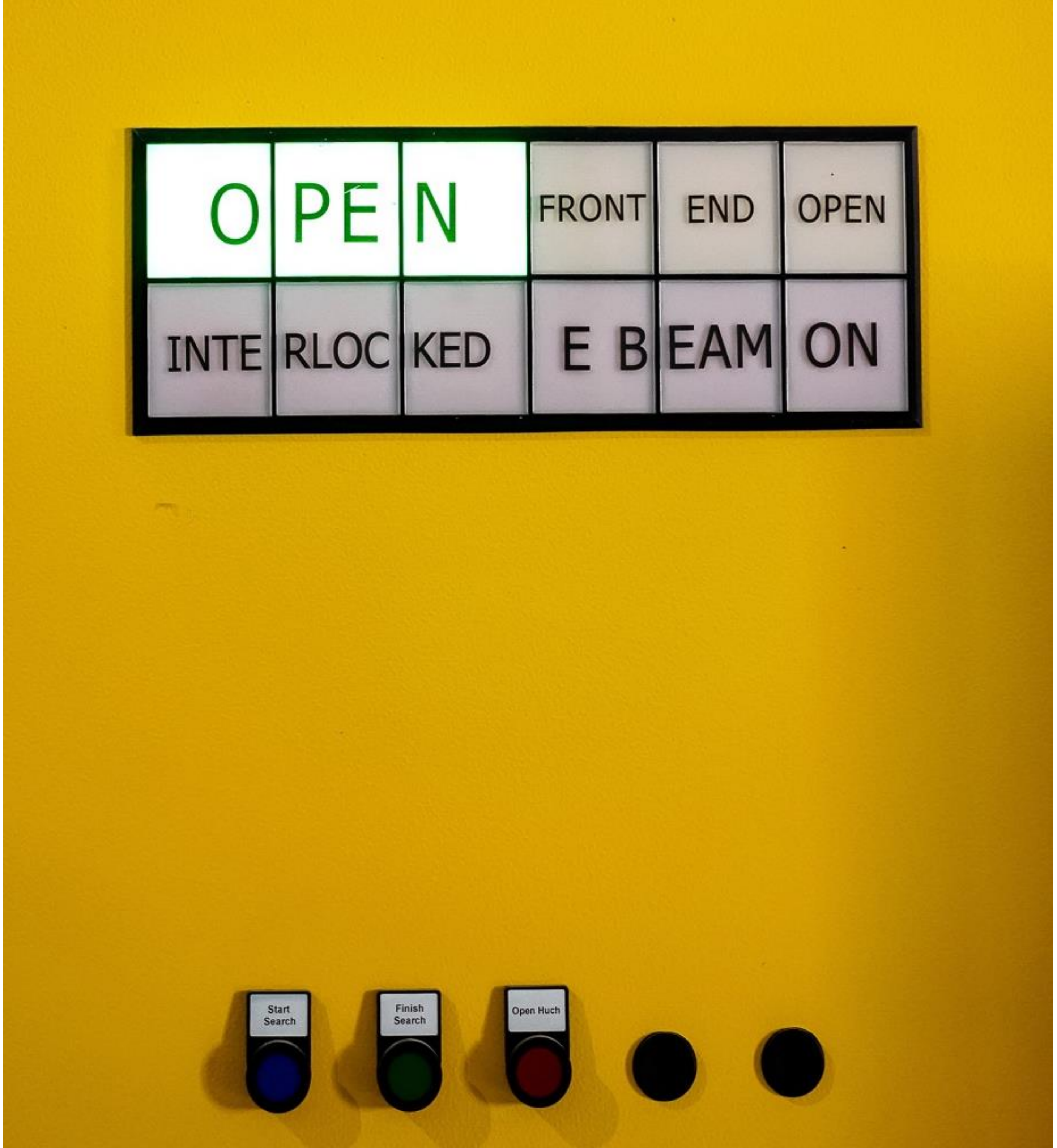




Variable pressure experiment chamber: a unique distinguishing feature of HESEB.

The sample manipulator allows for spatially resolved energy dependent x-ray absorption spectroscopy for obtaining the elemental and chemical composition of surfaces.

Combined with an elliptical focussing capillary that creates a focus of about 20 µm diameter and acts as a differential pumping stage, HESEB allows studies of archeological samples at atmospheric pressure.



SESAME Today

SESAME is an internationally well-connected facility producing world-class science

SESAME continues to increase its beamlines' portfolio and research opportunities

andrea.lausi@sesame.org.jo
https://www.sesame.org.jo/