Synchrotron Radiation as a Cross-Disciplinary and Versatile Tool & SESAME

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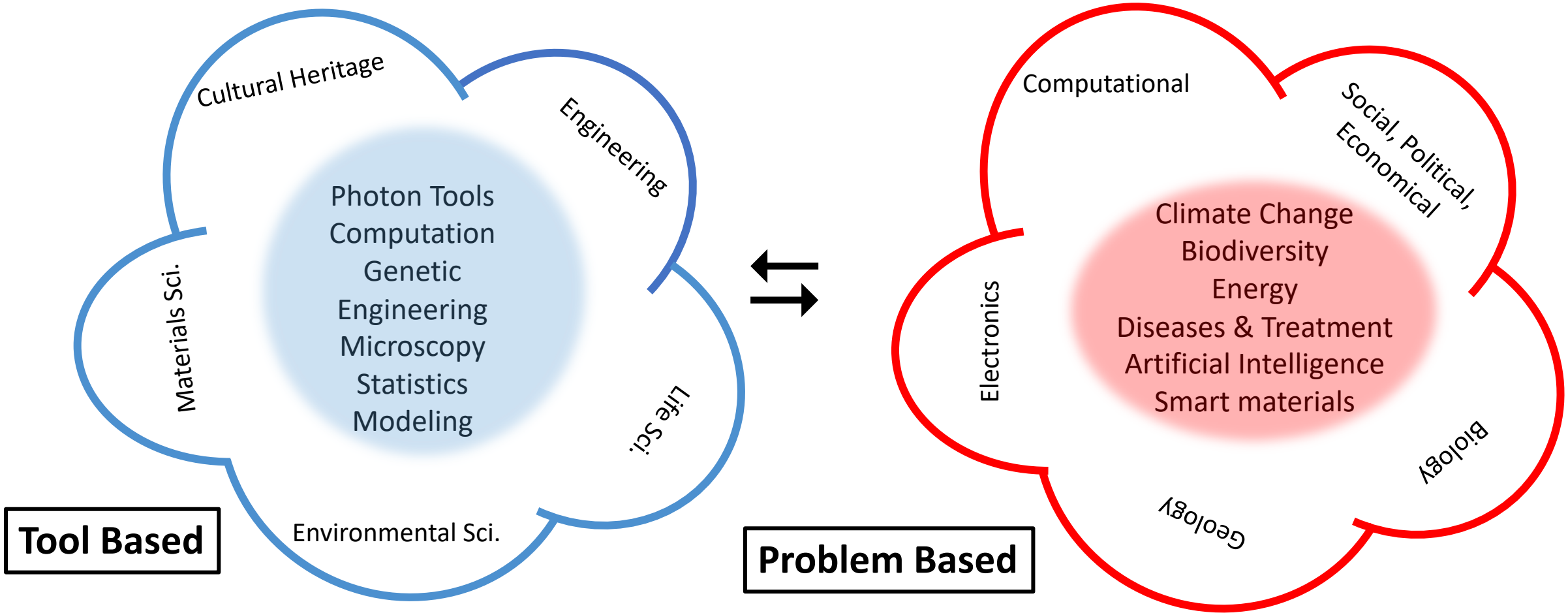
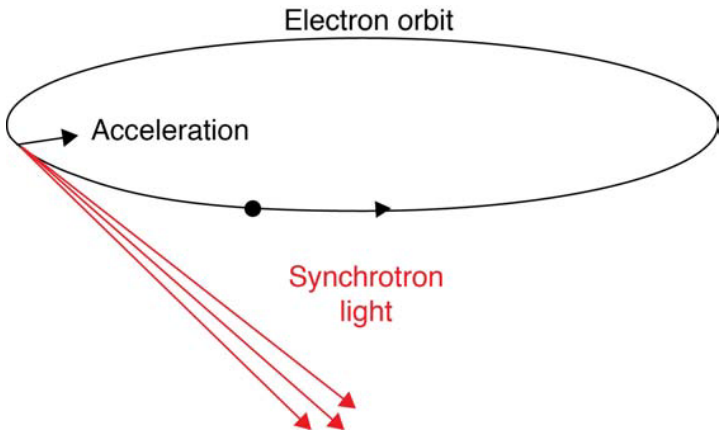
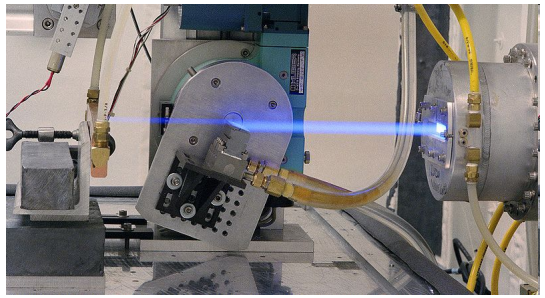
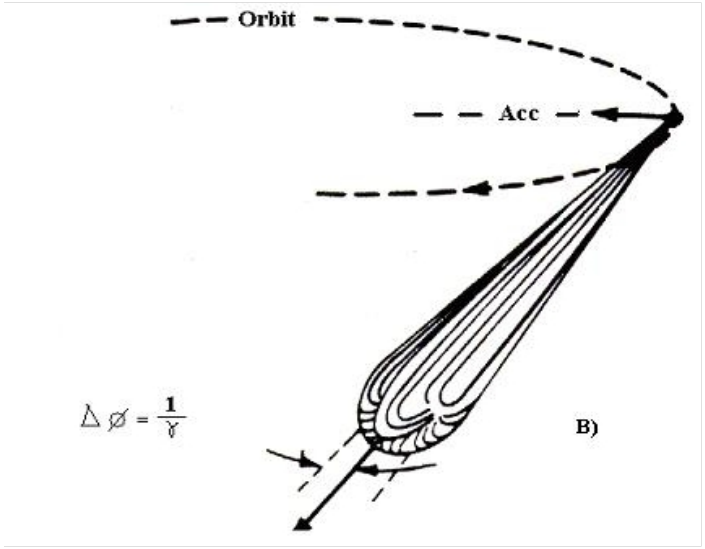
Complex Problems & Cross/Inter Disciplinary Research



Synchrotrons Produce High Intensity Photons







When electrons (or any charged particle) move around a circular orbit with relativisitic speed (close to speed of light) the electric field around the electron is unable to respond instantaneously and is emitted in a cone tangential to the orbit. This is **synchrotron radiation (SR)** (white light).
The broad wavelength offers a wide range of possibilities for structural biology.

As the electron energy increases the cone of radiation narrows and the power of radiation increases.

SR Sources are large circular buildings

ESRF, France
844.4 m, 6 GeV

Spring8, Japan
1.4 km, 8 GeV

Why big strutcures?

Electron orbit-Energy-Magnetic field
(R) (E) (B)

R = 3.335 E/ B

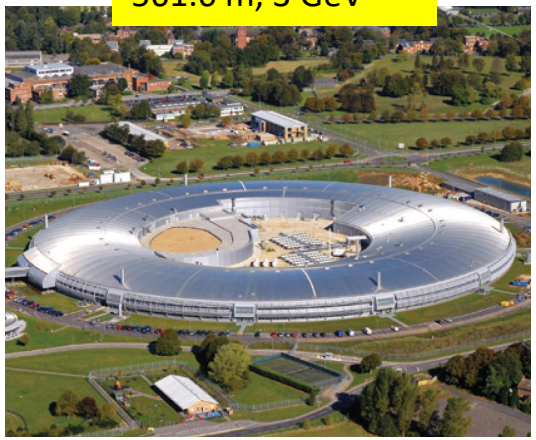
E = 5 GeV, B = 1 T, R = 16.7 m

ALS, USA
198 m, 1.9 GeV

How are synchrotrons compared?

Spectral Brightness (SB)

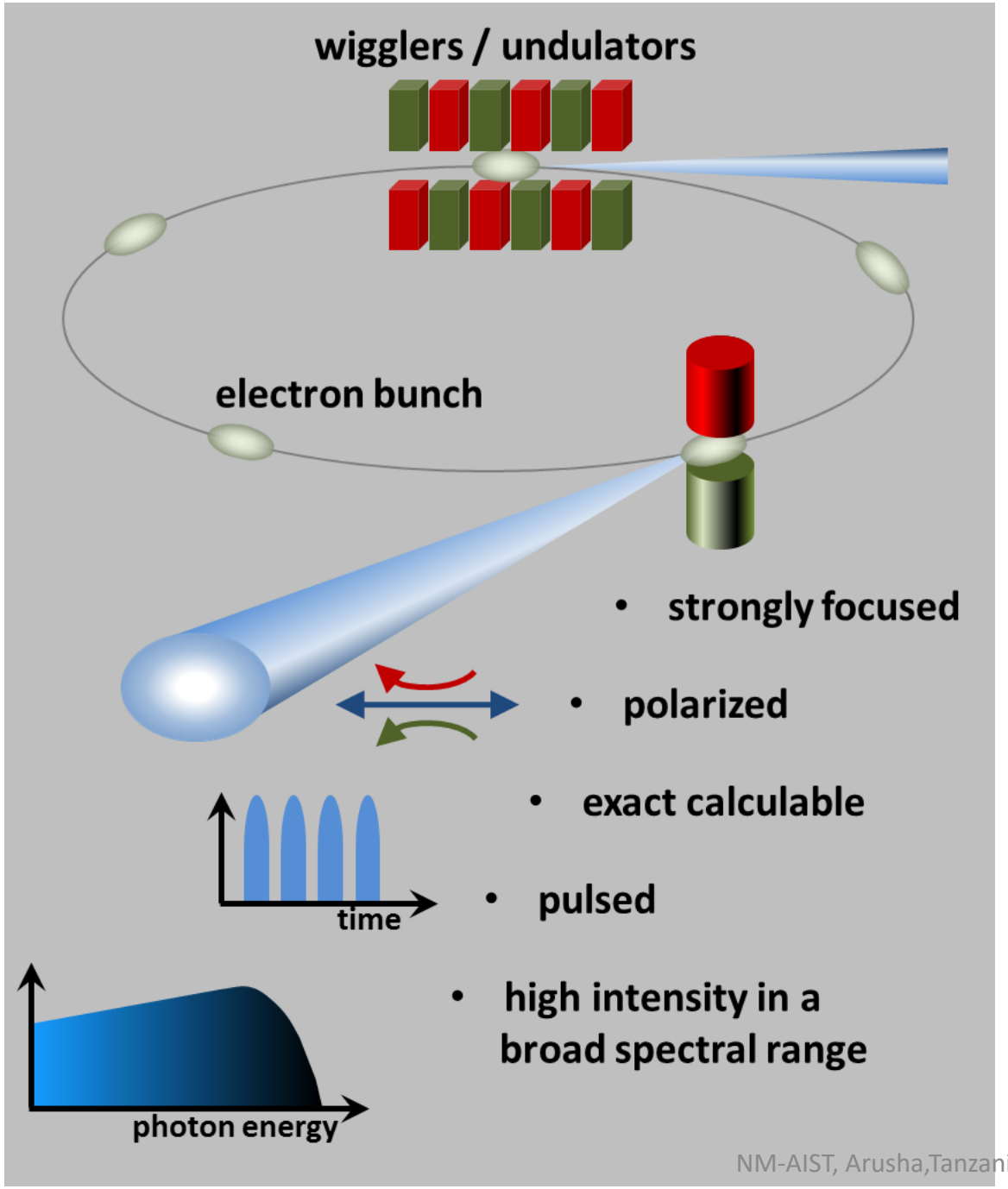
Diamond, England
561.6 m, 3 GeV



Spectral Brightness (SB)= number of photons/(s mm^2 mrad^2 0.1% energy band)

SR facilities around the world

There are more than 60 SR facilities (light sources) around the world.
These are laboratories where you can submit a proposal for experiments necessary for your research.
If your proposal is accepted you are given “beamtime” to go there for measurements. You don’t always have to go there you can also send your sample for measurements.



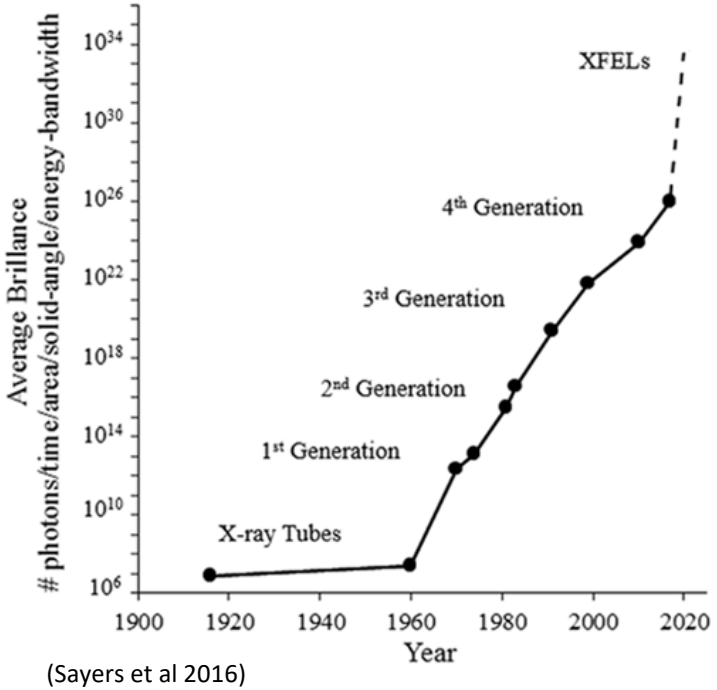
Properties of Synchrotron Radiation

In third generation sources next to bending magnets, wigglers and undulators produce magnetic fields which result in higher intensity, finer focus and tune the energy of the beam.

Synchrotron Radiation

- Strongly focused-
- High intensity-
- Broad spectral range-
- Polarized-
- Pulsed-

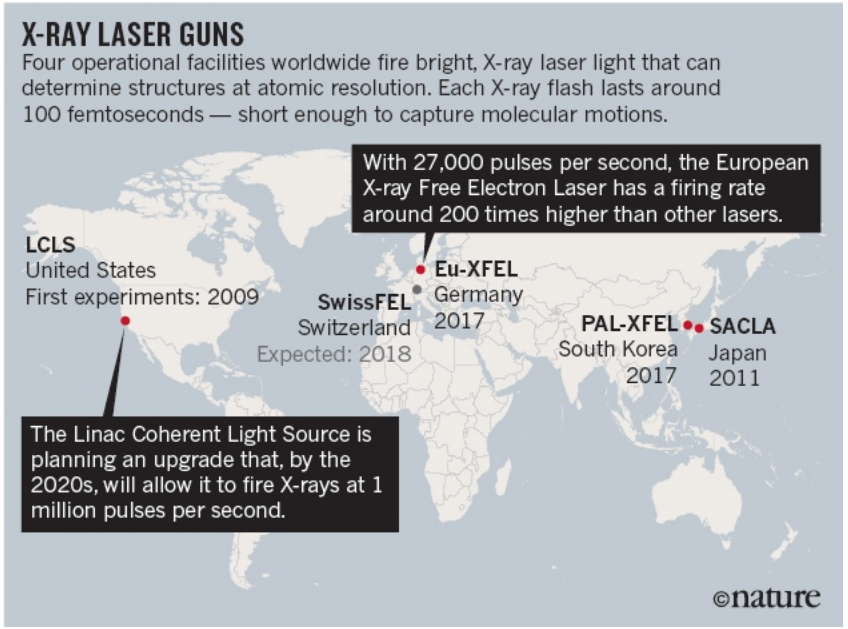
Cross Disciplinary Tools: Photon Sources



(Sayers et al 2016)

Evolution of photon sources
(more than 40 around the world)

X-ray Free Electron Lasers



Experiments in Life and Material Sciences .

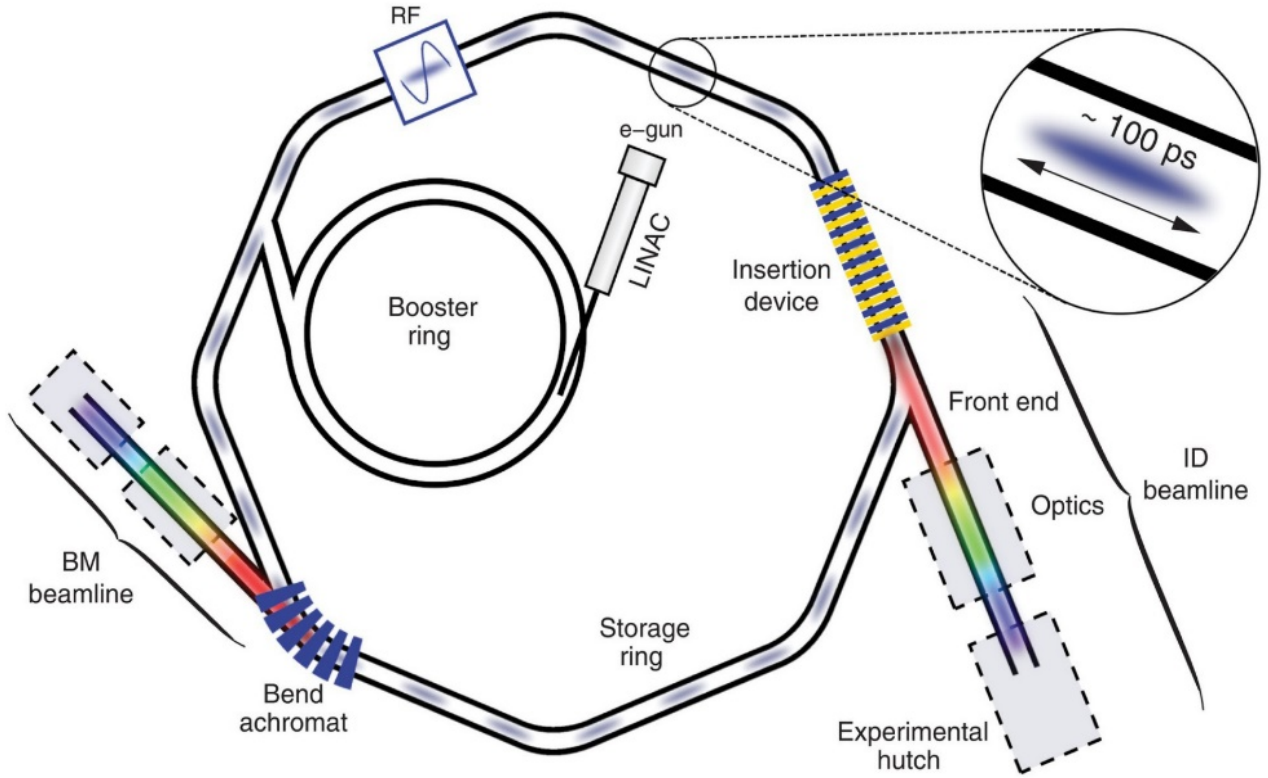
Serial Femtosecond Crystallography.

Single Particle Imaging.

Solution Scattering (Fast/Mixing).

Single Particle Analyses (P/T).

What is in the big round building?

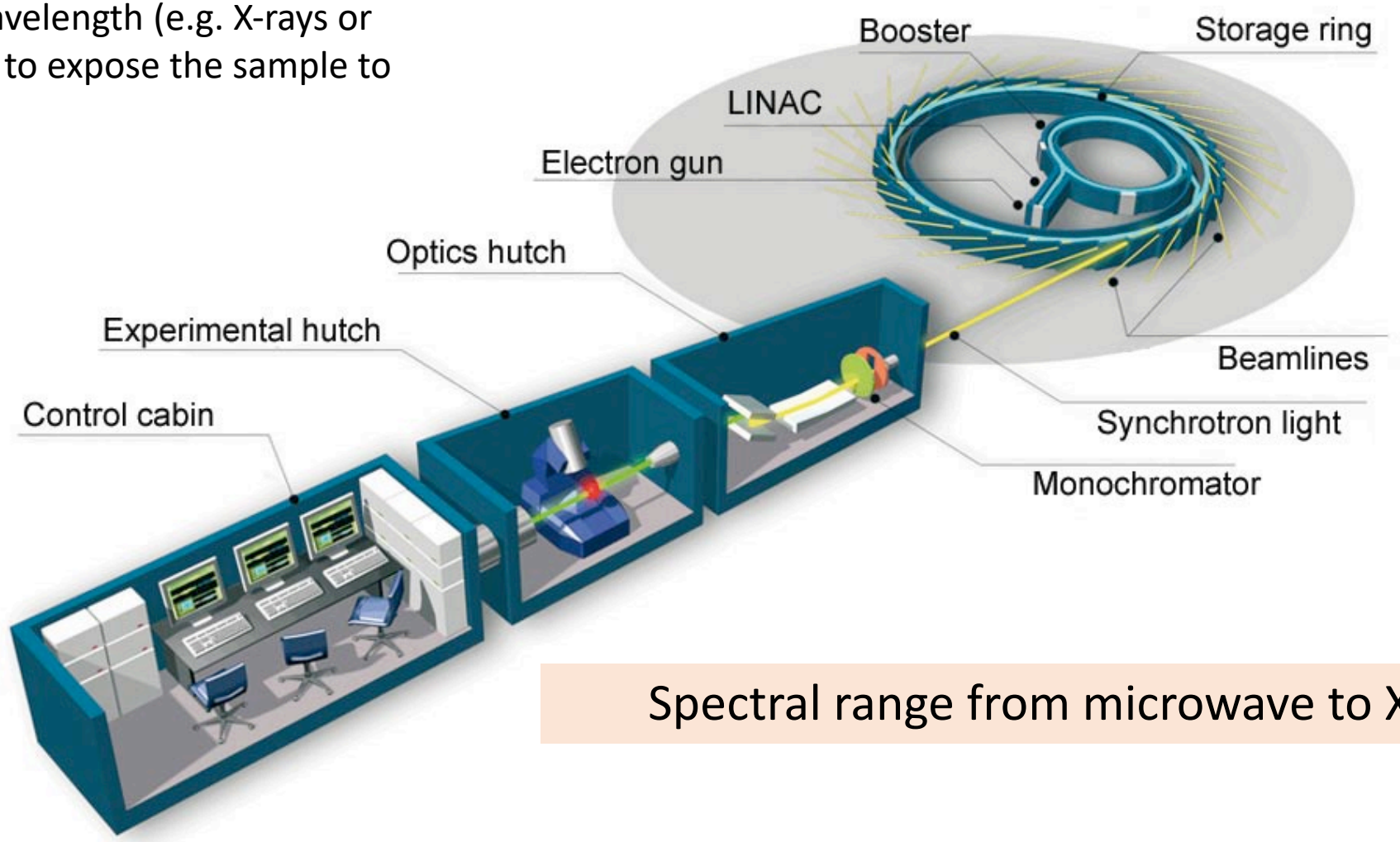


Willmott, P. (2019) Wiley

- Electron gun
- Linac
- Booster ring
- Storage ring
- Insertion device beamline
- Bending magnet beamline
- Front end
- Optics
- Experimental hutch

Data are collected at bemlines at SR facilities

SR is collected at **beamlines** to select the correct wavelength (e.g. X-rays or IR or UV) and to expose the sample to radiation



Spectral range from microwave to X-rays

http://www.synchrotron-soleil.fr

Why X-rays?

Nobel prizes

Physics

1901 W. Röntgen
1914 M. von Laue
1915 W. H. & W. L. Bragg
1917 C. Barkla
1924 K. Siegbahm
1927 A. Compton
1981 K. Siegbahn

Chemistry

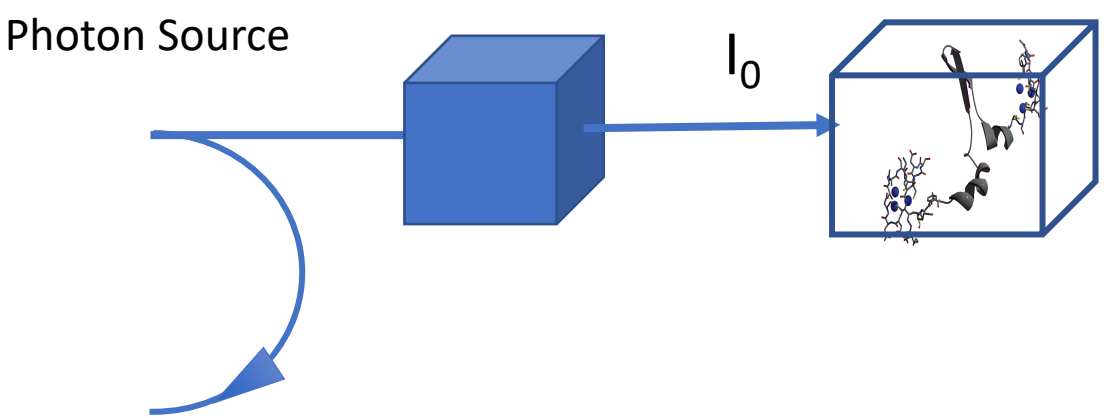
1936 P. Debye
1962 M. Perutz & J. Kendrew
1976 W. Lipscombe
1985 H. Hauptman & J. Karle
1988 J. Deisenhofer, R. Huber & H. Michel
1997 P. D. Boyer & J. E. Walker (SR)
2003 P. Agre & R. Mackinnon (SR)
2006 R. Kornberg
2009 A. Yonath, T. Steitz & V. Ramakkrishnan (SR)
2012 R. J. Lefkowitz & B. K. Kobilka (SR)
2018 F. H. Arnold

Medicine

1946 H. Müller
1962 F. Crick, J. Watson & M. Wilkins
1979 A. Cormack & G. Hounsfield

X-rays are powerful tools because they can penetrate into materials and give information about the structure of materials

Photons as Versatile Tools of Molecular Structure

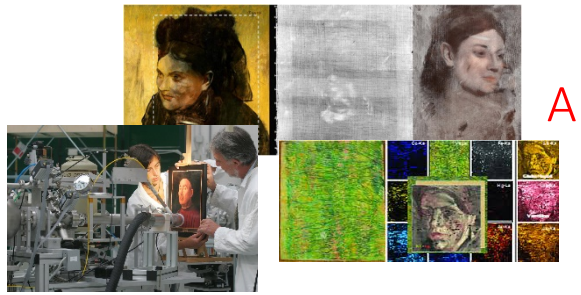


Scattering
Macromolecular Crystallography
Diffraction
Small angle scattering SAXS/WAXS)
Soft X-ray scattering

Spectroscopy
Hard X-ray spectroscopy
Soft X-ray spectroscopy
Low energy spectroscopy

Imaging
Hard X-ray imaging
Infrared imaging
Soft X-ray imaging
Infrared imaging

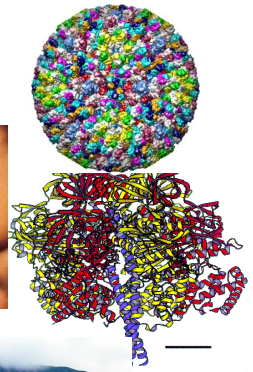
Where do we use SR?



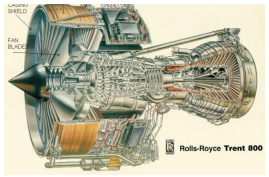
Arts

Archaeology

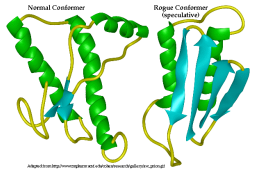
Medicin



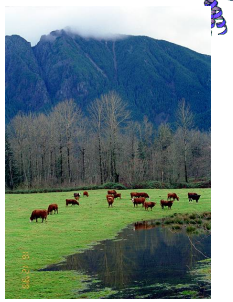
Engineering



SR: wide community

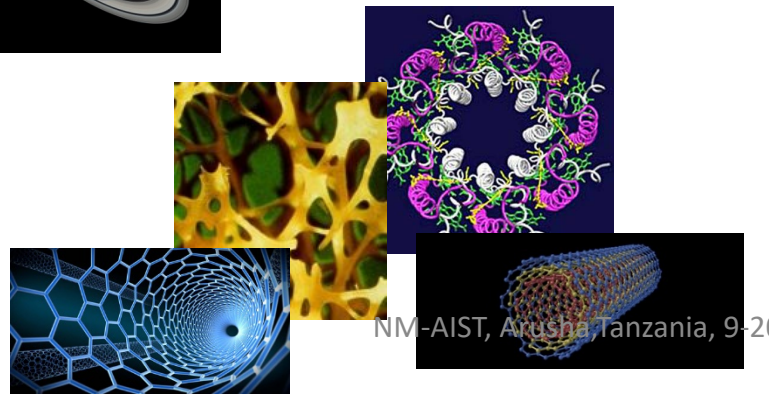


Energy

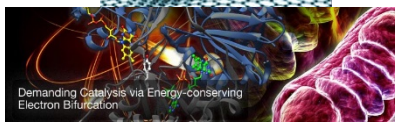


Physics

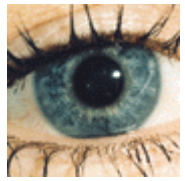
Chemistry&Materials



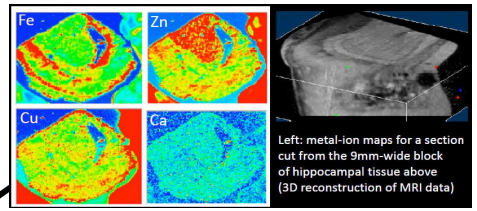
Environment



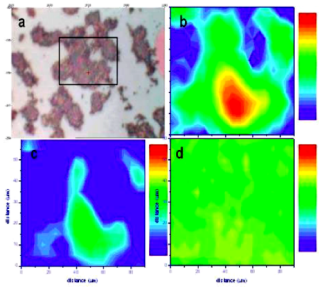
Using SR in Life Sciences



Biological processes

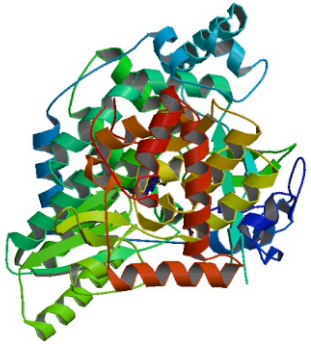


Biofilms

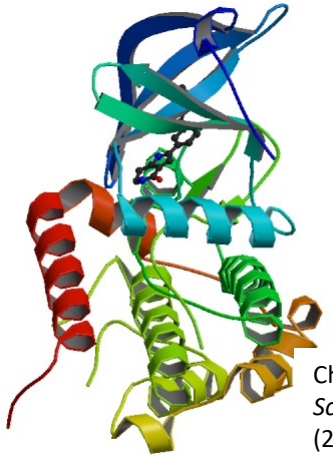


SR: complementary techniques

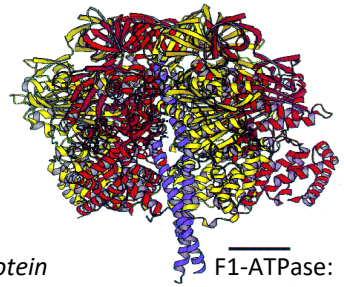
Wang et al, *Bioorg. Med. Chem. Lett.*, **19**, 4480-4483, (2009)



Protein structure

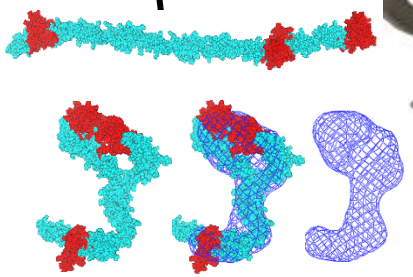


Cheng et al, *Protein Science*, **19**, 168-173, (2010)



F1-ATPase: Energy generation

Medical coatings



Protein shape

Possibility of remote Access: FedEx Users

The SESAME Project

Synchrotron-light for **E**xperimental **S**cience and **A**pplications in the **M**iddle **E**ast
(www.sesame.org.jo)

SESAME

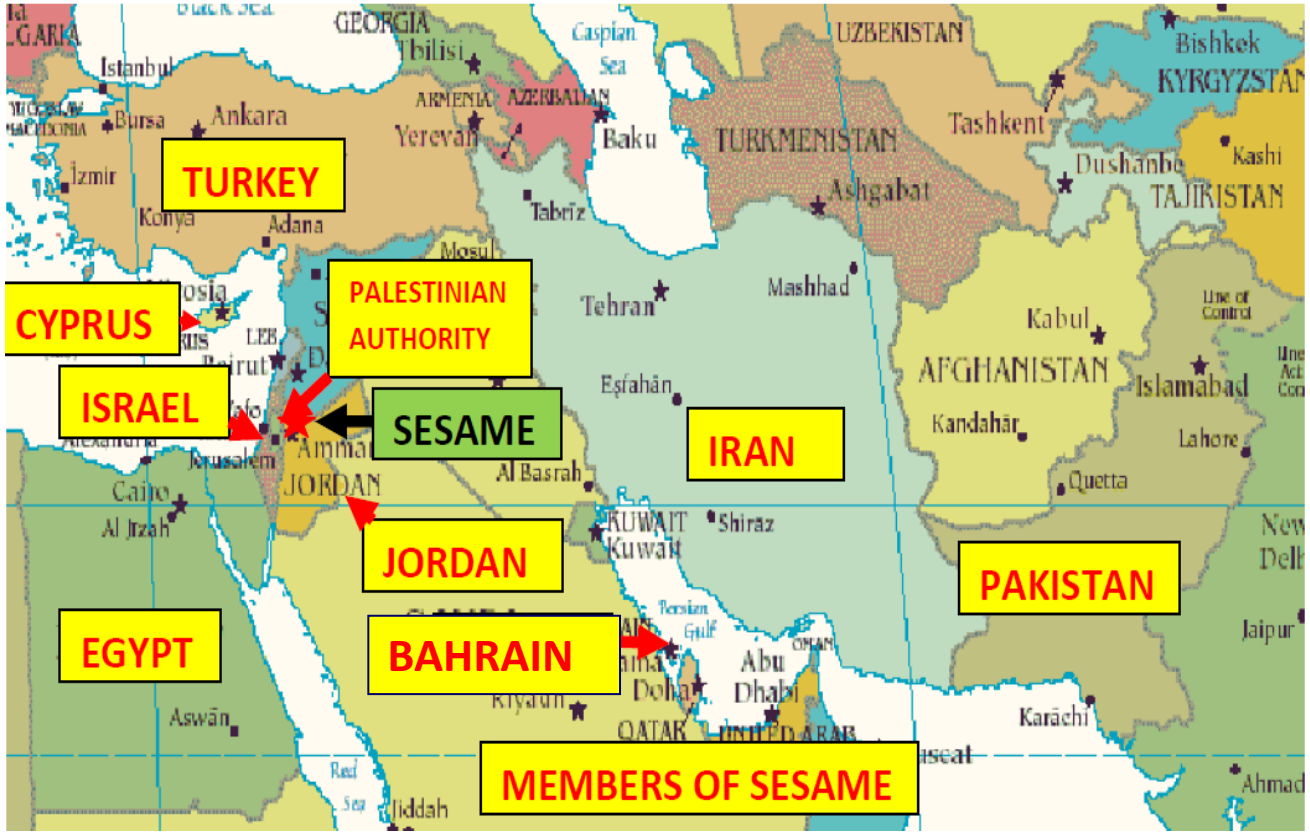
A 3rd generation SR source in the Middle East.

SESAME's mission

Conduct world class science and technology in the Middle East and neighbouring countries (from biology and medical sciences through materials science, chemistry, and physics to archaeology),
Contribute to reverse brain drain in the region,
Participate in developing high technology infrastructure development in the region,

Establish cooperation across cultural and political divides.

SESAME members, observers and structure



Observers: Brazil, China, EU, France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russian Federation, Spain, Sweden, Switzerland, UK, USA

Council:
Delegates from member countries and observers.

Directorate: Director, Technical, Scientific and Administrative Directors.

Advisory Committees: Machine and Science.
Proposal evaluation committee.

Total staff 40-50 people.

SESAME User Office.

Budget ~5.2 M USD

Why a SR source in the Middle East?

There are no SR facilities in the region.

Broad programmes make synchrotron-light sources ideal facilities for building scientific capacity.

Platform for interdisciplinary research.

International collaboration is the obvious way for countries with relatively small scientific communities and/or limited science budgets to build a synchrotron-light source.

SESAME will be a user facility: scientists will typically go to SESAME two or three times a year for a few days to carry out experiments, in collaboration with scientists from other institutions/countries.

A very brief history of SESAME

Convergence of two ideas – build a light source in the Middle East (Abdus Salam – early 1980s) + foster projects that cross divides

Original proposal (1997) - rebuild old 0.8 GeV Berlin Synchrotron (BESSY 1) in the Middle East, as basis for a new international organisation, modelled on CERN

1999 - (Interim) Council established: followed by international advisory committees

2002 - decision to build a <u>new 2.5 GeV ring</u> (still using BESSY booster)

competitive 3rd generation facility

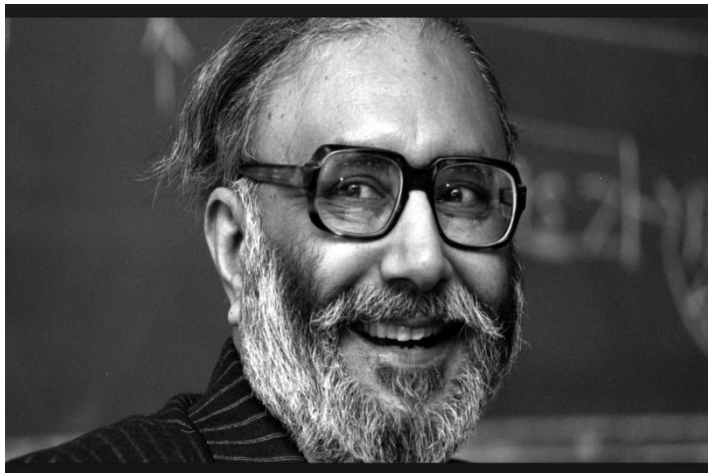
Ground breaking (2003); **completion of building (2008)**

Commissioning – start November 2016. Opening by HM King Abullah II in May.

User operation start – February 2017 (friendly users).

Abdus Salam

A true visionary and great scientist Founder of the International Centre for Theoretical Physics in Trieste.
The 1st Muslim to win a Nobel Prize

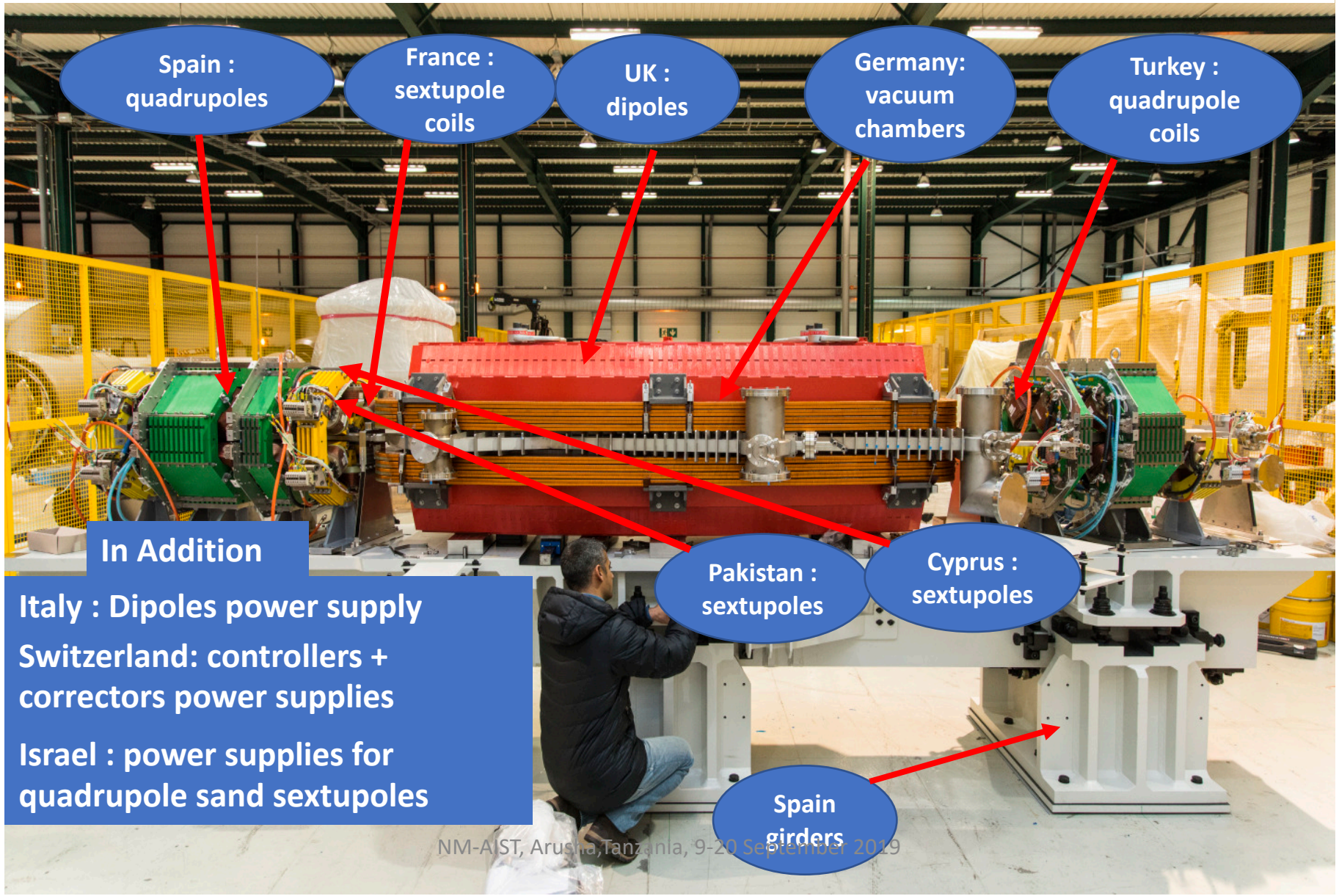


1995 meeting in Dahab (Egypt)

- during which Venice Gouda (Egyptian Minister of Education) and Eliezer Rabinovici took an official stand in favour of Arab-Israeli Cooperation

The new storage ring

Collaboration between CERN, SESAME Members and Observers – funded by EU

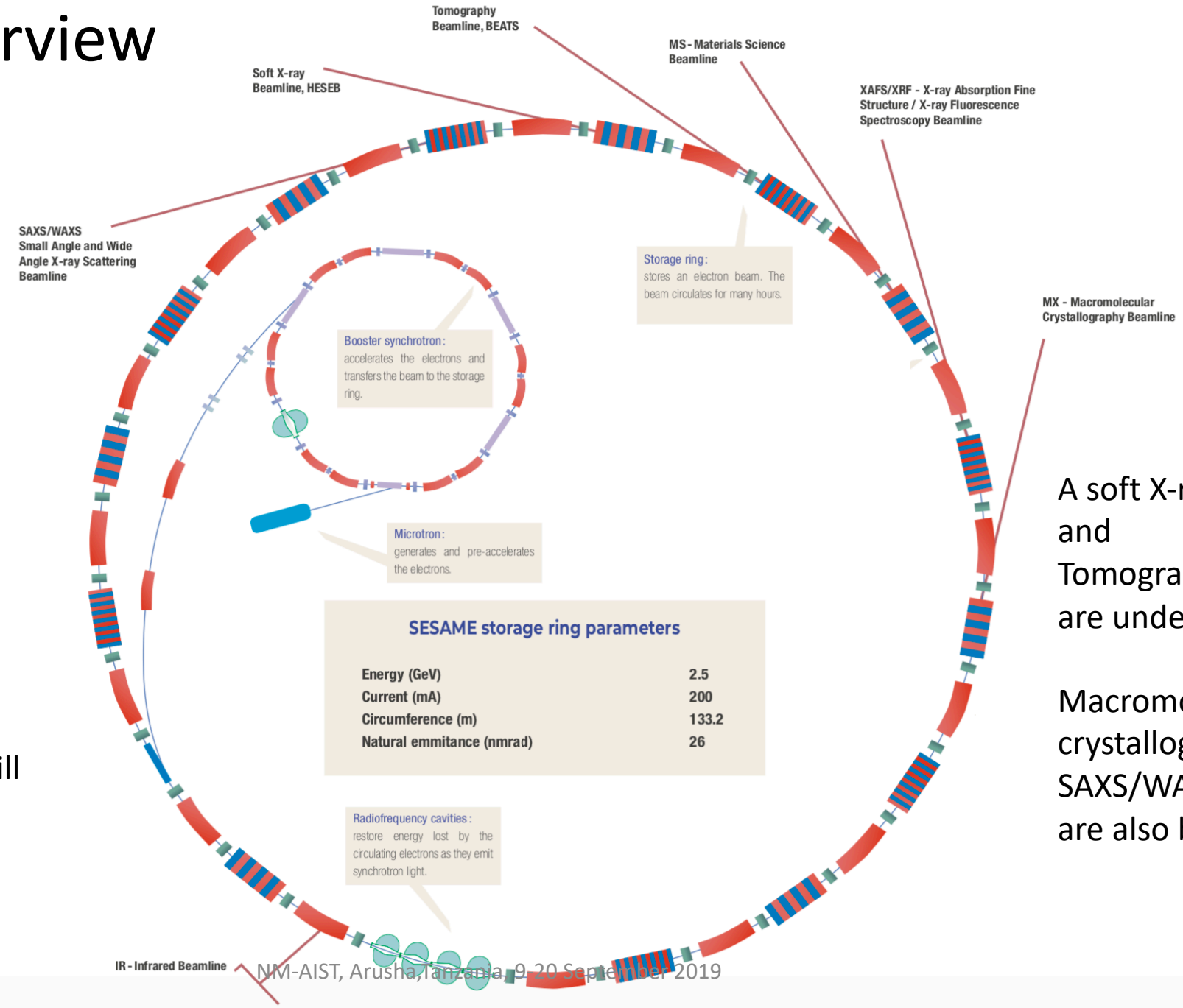


Schematic overview of SESAME

Possibility of having more than 25 beamlines.

Currently two operational beamlines:
(1) X-ray absorption spectroscopy
(2) Infrared spectroscopy

Material science beamline will be operational at the end of 2019.



A soft X-ray beamlines and
Tomography beamline are under construction.

Macromolecular crystallography and SAXS/WAXS beamlines are also being planned.

SESAME Training programmes

Training has always had high priority. Starting form year 2002 there have been yearly Users Meetings as well as specialized workshops.

Training Programs have been made possible by support from IAEA, EU, UNESCO, ICTP, National Agencies…

Programmes are open to staff, users capacity building in the region. More than 175 people have attended seminars and workshops.

Training has also been conducted in cooperation with other light sources including ALS, CELLS-ALBA, DESY, ESRF, Elettra, FSZ, HZB, INFN, KEK, MAXIV, SLS, SOLEIL…..

SESAME Users

So far 2 calls for beamtime proposals on the 2 operational beamlines took place.

First call:
Beam time allocated for 28 of the 55 proposals.
Distribution of users:
Colombia (1), Cyprus (3), Egypt (4), France (1), Iran (1), Italy (1), Jordan (2), Pakistan (4) and Turkey (11).
The first users arrived at SESAME on 17 July 2018.

Second call:
Beam time allocated 57 of 102 proposals.
Distribution of users:
(Cyprus (4), Egypt (12), Germany (1), Iran (5), Israel (3), Italy (2), Jordan (6), Mexico (1), Pakistan (13) and Turkey (10).

Tayel EL-HASAN

"SESAME's XRF beamline was used in an applied environmental study related to the toxic elements speciation and mobility within solidified mixtures composed of oil shale ash and various natural materials. We measured the leachability and the nature of hosting matrix for these elements. Moreover, the effect of ageing on oxidation states was recoded, particularly the reduction of Cr^{+6} to Cr^{+3}."

Department of Chemistry, Faculty of Science, Mutah University (Jordan)

Gehan AHMED

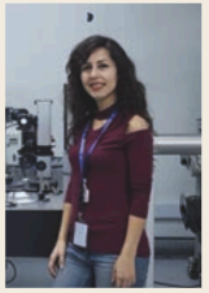
"Dramatic changes in the brain's biochemical composition are associated with Alzheimer's disease (AD) which gradually leads to memory loss and brain damage. In our research, we induced Alzheimer's disease in a rat model and monitored the effect of a specific medicinal plant water extract in treating the brain tissues. The measurement was done using the synchrotron FTIR microscopy provided by SESAME which was able to detect, with high accuracy, detailed structural information from very small biological materials with much higher resolution than a conventional FTIR."

National Research Center (Egypt)

Mehmet YESILTAS

"We study molecular content of meteorites, rocks that are pieces and fragments of larger rocks such as asteroids and planets, to understand the origin of our solar system and history of planetary objects. Molecular content of meteorites contain signatures of previous chemical reactions and events. Infrared spectroscopy allows identification of minerals and organics in our samples and help us unravel such signatures. SESAME's IR beamline helps us better detect what is in our meteorite samples."

Kirklareli University (Turkey)



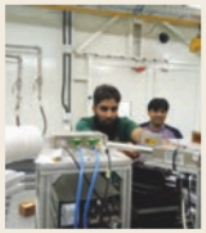
Maedeh Darzi

"Manuscripts in ancient cultures employed inks from natural resources (e.g. earth minerals, plants, insects and animals), and their chemical composition sheds light on the prevailing culture and trade routes. Our joint study with Soleil Synchrotron aims at identifying the chemical composition of the inks on a Quranic paper-manuscript from the Qajar dynasty, Iran (ca. 18-20 AD.). The FTIR at SESAME's IR beam-line served to identify the chemical composition of the coloured inks (black, blue, red and golden) on the paper. FTIR is a versatile technique enabling minimally-invasive investigation of the wide range of materials present in the manuscript (e.g. mineral, proteins, polysaccharides)."

Department of Chemistry, Isfahan University Of Technology (Iran)

Muhammad YOUNAS

"Understanding of fundamental physics of colossal dielectric constant (CDC) materials (permittivity $\varepsilon' > 10^3$) is important from an application viewpoint. Transparent ZnO thin film based CDC materials have special applications in transparent displays, super capacitors and radar absorbing materials. Knowledge of the local structure of CDC materials is mandatory for device fabrication. The XAFS data collected by Pakistani scientists at SESAME's XAFS/XRF beamline was of great help in solving scientific problem for transparent ZnO thin film systems having CDC."



Electronic and Magnetic Materials Group, NPD, PINSTECH (Pakistan)

Ahmed BASSALAT

"Palestine is very fortunate to have SESAME on its doorstep. It is a window to international collaboration in science of a very high level and I have used the facility for the training of a number of the students in my laboratory. We are actively preparing our community to use the beamlines available at SESAME, which is why in April this year I organized the 2nd International Workshop on Synchrotron Radiation and Applications: SESAME in Palestine at An-Najah National University in Nablus."

An-Najah National University (Palestine)

Brian A. ROSEN

"Fuel cells are devices which can convert chemical energy into electrical energy with the aid of electrodes made from catalytic materials. Degradation of these materials negatively impacts the performance of the cell and limits its lifetime. The Rosen group is developing new catalytic materials for fuel cells based on transition metal carbides with enhanced stability and activity. X-ray adsorption techniques at SESAME assist us to learning the electronic configuration of these materials to reveal the origin of their improved performance."

Department of Materials Science and Engineering, Tel Aviv University (Israel)

Kirsi Lorentz

"Archaeological remains of humans who lived in the Middle East, the cradle of civilization as we know it, are being studied at SESAME. Ancient bone, dental tissues, and hair are being analysed by teams I am leading at The Cyprus Institute. Our research employs synchrotron radiation to throw light on key questions for the archaeology of the region, including exploring evidence for human heavy metal exposure using SR-XRF, XANES, and EXAFS, as well as preservation status of bone, dental tissues and hair at micrometer scales using SR-FTIR. (We look forward to using the tomography beamline being constructed at SESAME for further data collection on these unique human remains)."

The Cyprus Institute (Cyprus)

A selection of events

SESAME 1st Industry and Applied Science Workshop, Allan (Jordan), 28-29 October 2019

HERCULES School at SESAME, Allan (Jordan), 26 October - 7 November 2019

Joint OPEN SESAME and Instruct Macromolecular Crystallography Thematic School, Oxfordshire (UK), 30 September - 4 October 2019

Workshop on Scientific Case for BEATS, Nicosia (Cyprus), 27-28 June 2019

OPEN SESAME Environmental Science Thematic School, Allan (Jordan), 23-27 June 2019

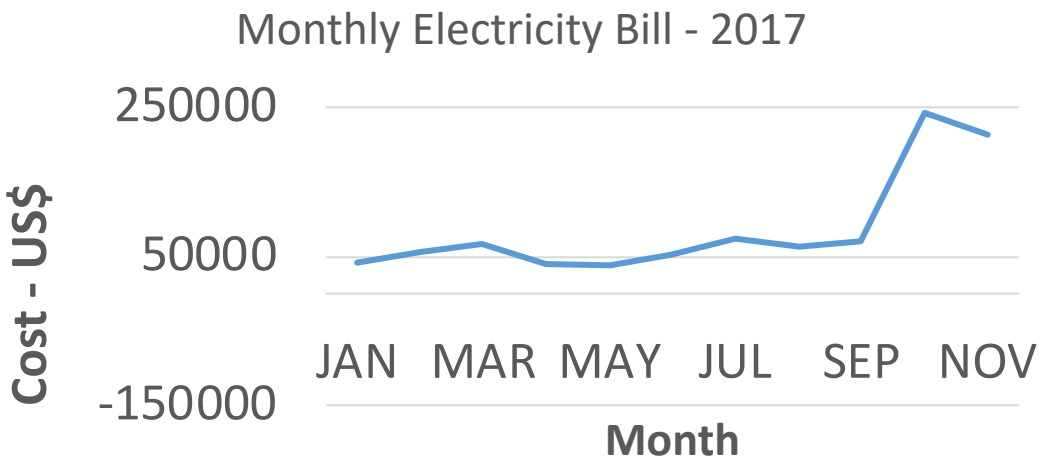
16th SESAME Users' Meeting, Allan (Jordan), 15-16 December 2018

Training Course on Synchrotron Techniques for Cultural Heritage, Allan (Jordan), 11-15 March 2018

15th SESAME Users' Meeting, Amman (Jordan), 18-19 December 2017

14th SESAME Users' Meeting, Amman (Jordan), 3-4 December 2016

SESAME is the first accelerator in the World powered by renewable energy



Completion of essentials

SESAME guest house has been completed in August 2019.

Buildings can be used for high-quality Middle East Scientific meetings

Thank You