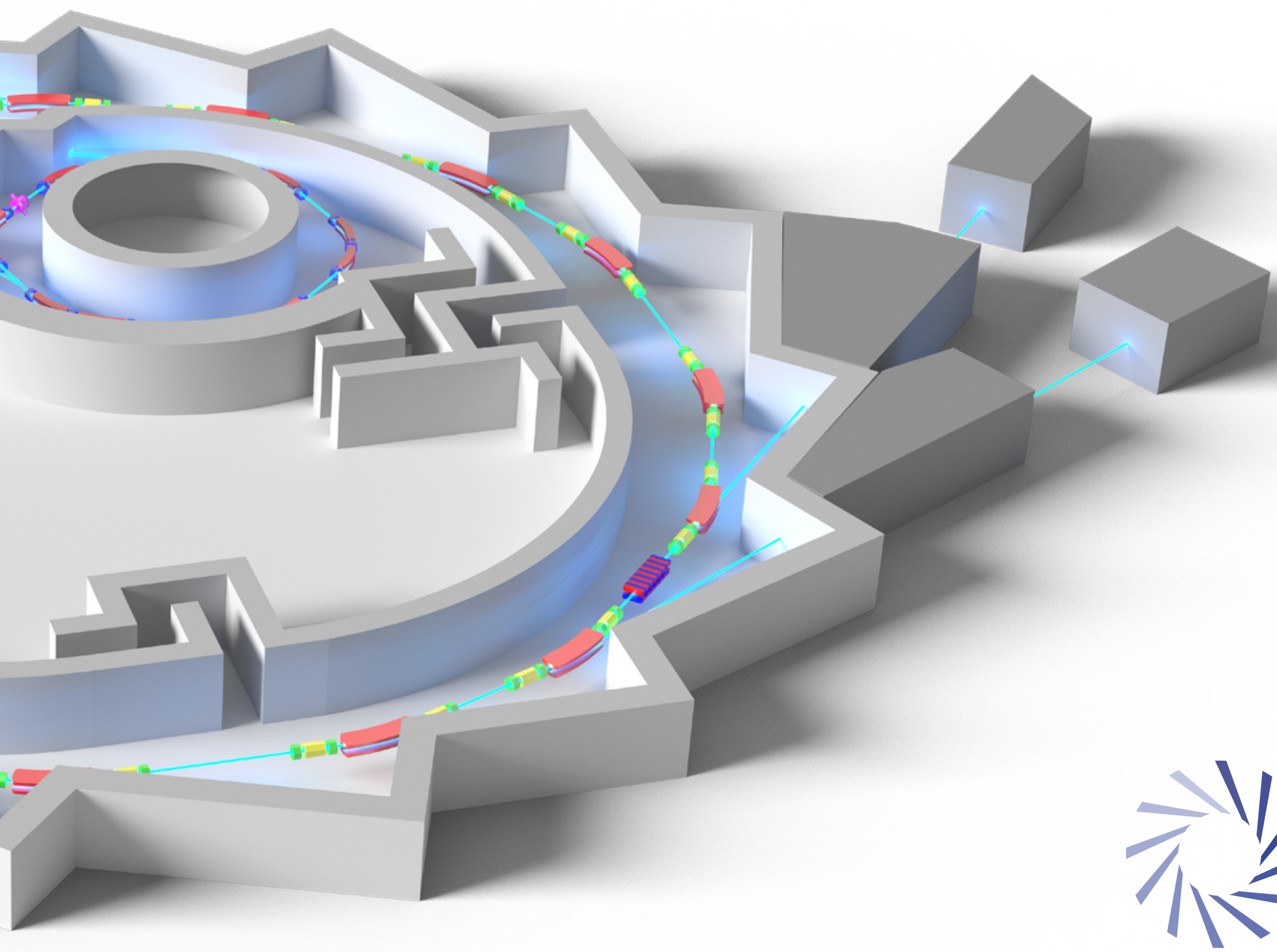
# SESAME

## X-RAYS FOR INDUSTRY

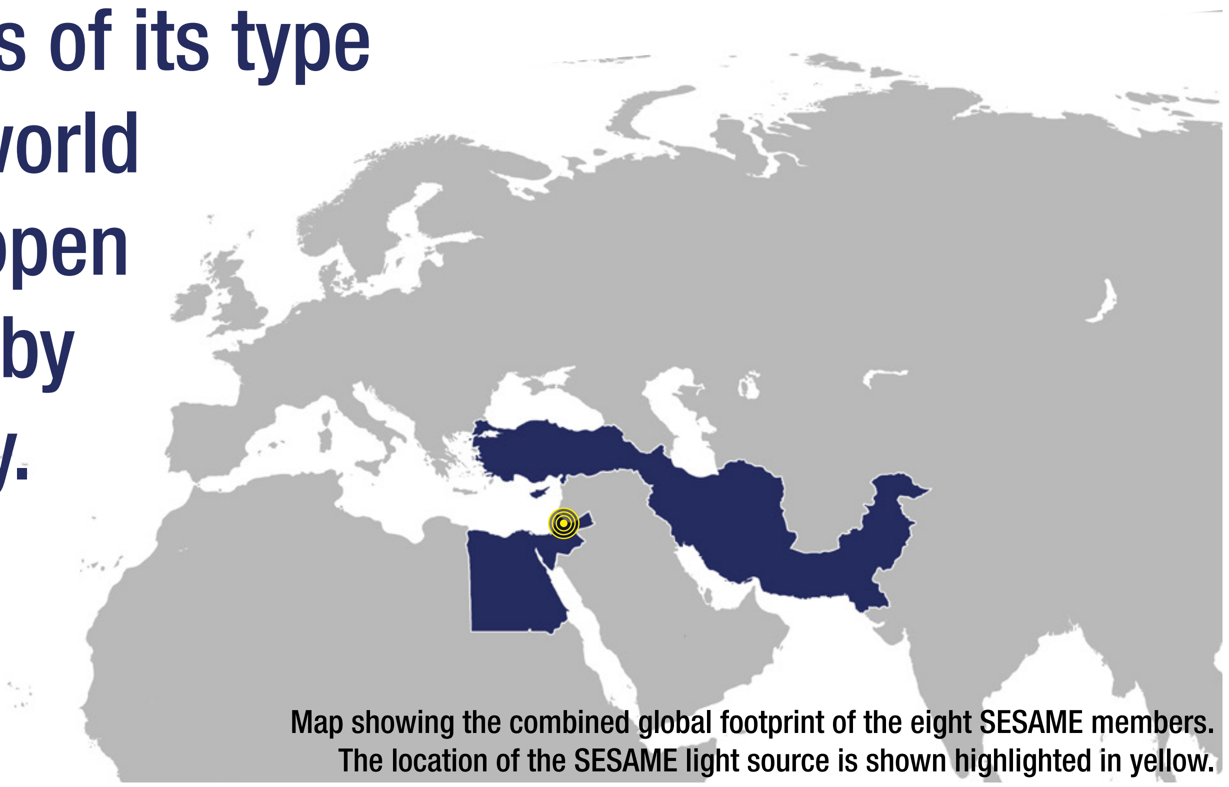
A STATE-OF-THE-ART X-RAY AND INFRARED CHARACTERISATION FACILITY IN THE MIDDLE EAST



SESAME

SESAME is a new, state-of-the-art characterisation facility for the Middle East and neighbouring regions.

It is one of the most advanced facilities of its type in the world and is open for use by industry.



Map showing the combined global footprint of the eight SESAME members. The location of the SESAME light source is shown highlighted in yellow.

## What is SESAME?

SESAME is a 3rd generation synchrotron. Synchrotrons are large-scale science facilities that can generate extremely brilliant X-ray and Infrared beams. SESAME currently operates two characterisation end-stations (called beamlines) to exploit these beams, with two more coming online shortly (SESAME can support up to 26 beamlines in total). Each beamline has a unique range of capabilities and is optimised to gather specific types of sample information.

## Where is SESAME?

The SESAME light source is located in Allan, Jordan. It is an international collaborative venture between (currently) eight Members; Cyprus, Egypt, Israel, Jordan, Pakistan, Palestine and Turkey. More are being sought.

## What can SESAME do for industry?

The beams produced at SESAME are perfect for R&D and for solving product and processing issues. They can be used to look inside working products (non-destructively), determine the chemical composition and structure of materials, develop new drugs and therapies and track chemical reactions. The capabilities of SESAME go far beyond those available in standard characterisation laboratories. SESAME also provides expertise and knowledge ensuring that industry can fully exploit the advanced facilities that are available.

## Who can access SESAME?

SESAME can be accessed by any industrial users. They do not need to come from one of the eight Members.

# A symbol of cooperation, solidarity and peace

The idea of creating a light source in the Middle East was first proposed by Abdus Salam in the 1980s. Salam, a cowinner of the 1979 Nobel Prize in Physics, recognised that such a facility could promote the cause of science and technology in the region. Today, more than 30 years later, this vision has finally become a reality.

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- **1995** – Dahab meeting (Egypt) organised by the Middle East Scientific Cooperation group to promote Arab-Israeli cooperation
- **1997** – Proposal to use parts from the decommissioned BESSY I machine to create a light source in the Middle East
- **1999** – Official launch of the SESAME project at a meeting organised in Paris by UNESCO
- **2002** – Proposal for the establishment of SESAME under the auspices of UNESCO approved by UNESCO Executive Board
- **2003** – Ground-breaking ceremony at the SESAME site held in the presence of the King of Jordan and the DG of UNESCO
- **2004** – SESAME becomes an independent IGO
- **2006** – Memorandum of Understanding signed between IAEA and SESAME
- **2008** – Official opening of the SESAME building
- **2009** – Endorsement of a strategic path forward by the SESAME Council
- **2012** – Start of funding by Israel, Jordan and Turkey of funds they pledged for capital investment
- **2013** – Start of construction of magnetic system for the storage ring led by CERN with EU funding
- **2014** – First electrons stored in the booster ring. Funding from Italy
- **2017** – First circulation of electrons in the main storage ring. Official inauguration of the laboratory. Construction started on a dedicated solar power plant
- **2018** – First users (July 2018)
- **2019** – SESAME becomes the world's first carbon neutral accelerator laboratory through solar power

# Applications in Health, Medical Devices and Pharmaceuticals

- Imaging the biochemical composition of single cells and tissues at sub-cellular resolution and investigating biochemical differences between individual cells
- Developing spectral biomarkers for disease diagnosis (e.g. in cancer research)
- Locating stem cells within tissues
- Following the effects of natural and synthetic chemicals on stem-cell differentiation
- Quantifying drug sensitivity
- Studying time-dependent biological processes
- Probing the chemical composition of human tissues (e.g. hair, skin, bone, brain, etc...)
- Phase identification and quantification of pharmaceuticals
- Rapid single crystal diffraction studies
- Drug development and polymorphism studies of candidate drug materials
- Characterising metalloproteins that are only partially ordered, or for which the oxidation state is in doubt
- Investigating biomolecules in solution
- Studying metal-based therapeutic agents (e.g. anti-cancer, anti-ulcer and anti-arthritic drugs)
- Collecting broadband molecular information with excellent spectral quality
- Proving the impact of changes in the biogeochemical environment on microbial cell surfaces (e.g. the effect of metals on binding characteristics of bacteria)
- Characterising pharmaceutical compounds
- Tumoral cell analysis

# Applications in Geology and Environmental Science

- Identifying inclusions in minerals and chemically-imaging inclusion constituents
- Interfacial studies in geological samples (e.g. grain boundaries between minerals)
- Characterising prototype biofilms (e.g. for bio-corrosion resistance in steel pipes, origin-of-life processes, etc...)
- Identifying toxic metal contamination and speciation in the environment (both solid and liquid contamination)
- Studying sorption/desorption processes on mineral surfaces in the cycling of metals and the structural development of amorphous phases (e.g. Cd, Hg, As, Pb)
- Studying water re-circulation deep in the earth's mantle*
- Tracking chemical changes in minerals under high pressure*
- Studying mineral processing products under non-ambient conditions*
- Studying phases that are stable in the Earth at extreme pressures (up to 100,000 atmospheres or more which requires the use of microscopic samples in heated Diamond Anvil Cells)*
- Digital Rock Analysis to understand and improve the recovery of naturally-occurring oil and gas reserves*
- Studies at high pressures and temperatures to simulate conditions within planets*
- In-situ and ex-vivo biomineralization studies of environmental contaminants in biological systems*

* applications not yet, but soon to be, available at SESAME

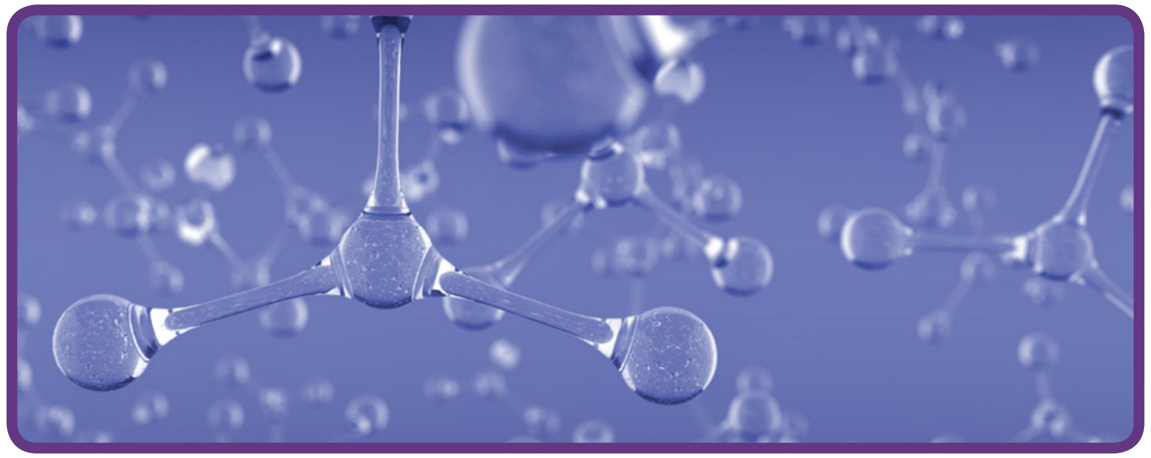
# Applications in Materials Science

- Characterising polymers in terms of their composition, orientation, crystallinity and chain conformation
- Probing interfacial properties in phase-separated copolymers and composites
- Mapping structural variations arising from manufacturing processes
- Microscopic analysis of inclusions in polymers
- Chemical imaging in polymer products
- Investigating structure-property relationships
- Characterising heterogeneous compounds such as compounded plastics, blends, fillers, paints, rubbers, coatings, resins, and adhesives
- Understanding and optimising polymer processing conditions
- Developing novel inorganic pigments
- Characterising metals, oxides, semiconductors and polymers for nano-electronics, optics and catalysis applications
- Structural studies of advanced materials (e.g. quantum dots in inert matrices, metal clusters inside porous structures) to determine their structure
- Depth profiling of multi-layered materials
- Investigating polymer aging (e.g. thermal stability, UV stability) to predict product lifetime
- Studies of polymer interfaces
- Mapping residual strain fields in engineering materials and new alloys, and using the results to improve finite element analysis predictions
- Detecting phases and impurities that degrade material properties
- Mapping texture, grain size and the degree of cold work in metal alloys

# Applications in Chemistry and Catalysis

- Characterising microporous materials such as zeolites for catalysis
- Characterising disordered crystals, amorphous solids, nanoparticles, and liquids
- Determining crystal structures, phase compositions and crystallite sizes
- Optimising the performance of functionalised microporous and mesoporous materials
- Studying catalysts
- Identifying phases and active sites within catalysts and microporous solids
- Studying promoters and poisons in homogeneous and heterogeneous catalysis
- Studying scale inhibitors used in oil production
- Studying electrocatalysts in working fuel cells
- Quantification of very dilute phases
- In-situ characterisation of industrial processes and synthesis*
- Ab initio structure solution*

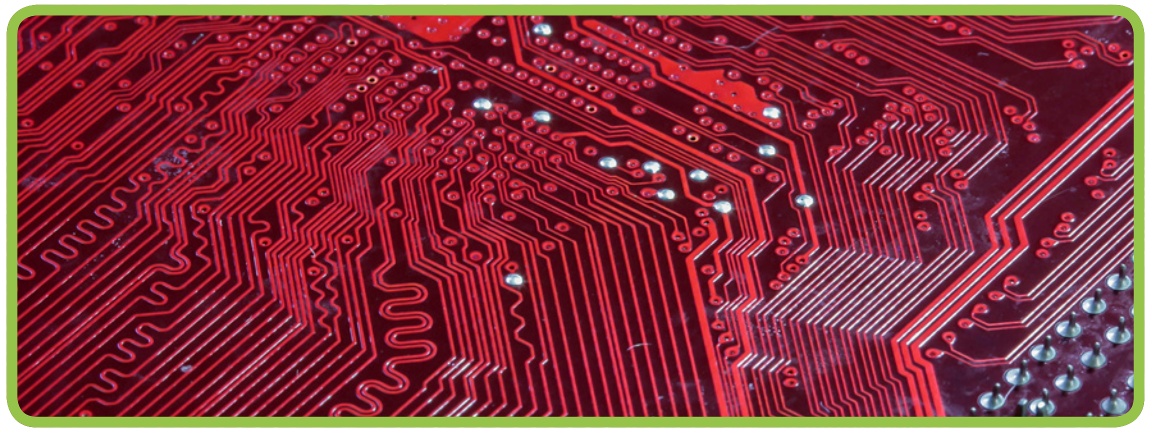
* applications not yet, but soon to be, available at SESAME

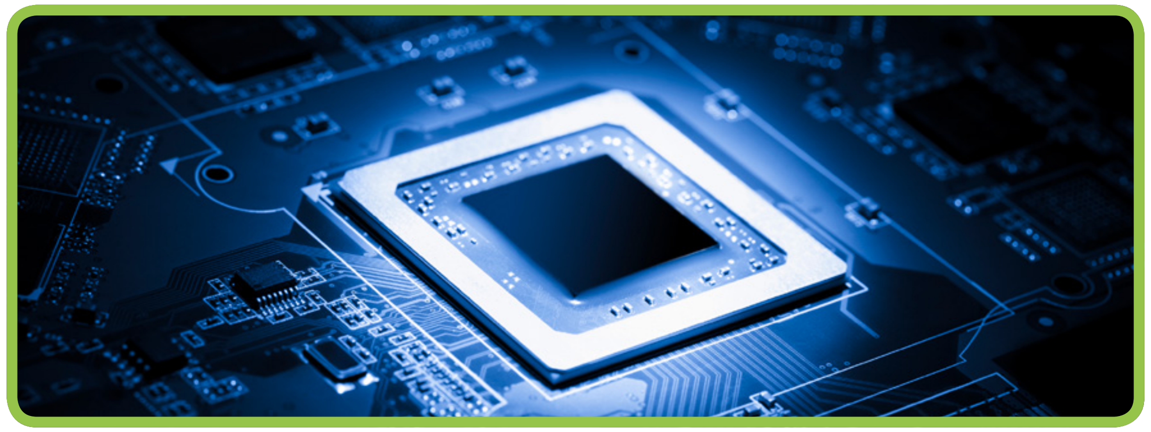


## Applications in Solid State Physics, Energy and Electronics

- Structure/property studies of solid metal oxides for magnetic, conductivity, superconductivity, ferroelectric, catalytic and battery applications
- Characterising dielectrics, ferroelectrics and magneto-resistive materials
- Characterising fuel cells, battery electrodes and photo-catalysts
- Studying structural and geometric changes in semiconductors and the role of dopants
- Characterising ion-conducting oxides and batteries
- Probing surfaces and interfaces in self-assembling and layered materials
- Characterising microelectronics (e.g. investigating voids and delamination)
- Probing reactions within organic crystals (e.g. in-crystal engineering)*
- Studying the kinetics of solid state reactions non-destructively to improve their theoretical modelling*
- Studying ultra-fast electronic responses, from a few picoseconds to nano-seconds (e.g. electron-pair dynamics in high temperature superconductors, fast infrared detectors and emitters, semiconductor optoelectronic devices, etc...)*
- Characterising candidate semiconducting and superconducting devices in-situ*

* applications not yet, but soon to be, available at SESAME





## Applications in Cultural Heritage, Archaeology and Forensics

- Investigating art, antiquities and archaeological finds non-destructively
- Studying how ancient production techniques evolved and identifying the materials used
- Characterisation of mineral microparticles and organic residues in archae-ological sites
- Analysing human remains
- Determining the composition of ancient cosmetics
- Tracking degradation phenomena in historical and ancient artefacts non-destructively
- Evaluating previous restoration work and assessing new conservation techniques for cultural heritage and archaeology
- Analysing organic residues (e.g. skin fragments, drugs, counterfeit prod-ucts, textiles and soils)
- Detecting trace materials from fingerprints and surfaces

# SESAME Supporting Industry

## Access to Knowledge Experts

In addition to providing access to world-class tools, SESAME also provides access to knowledge experts. These can help industrial clients to get the most out of SESAME. This includes planning experiments, assistance with sample preparation, data analysis and interpreting results.

## Knowledge and Technology Transfer

SESAME is an international centre of excellence in the Middle East that will share knowledge and promote the use of newly-developed technologies by industrial partners.

## Supporting Agile Innovation

With dedicated beamtime set aside for industrial users and quick access, SESAME is the perfect partner to support agile innovation and enable fast learning cycles.

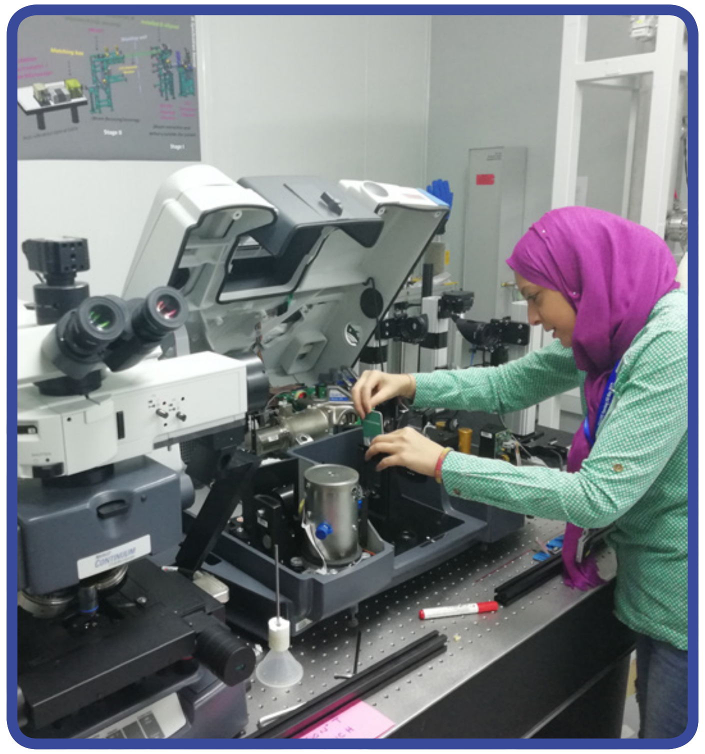
## Synchrotrons are used by many of the world's leading companies.

Synchrotrons can provide unique sample information that is inaccessible to other characterisation techniques. Consequently they are used by many of the world's foremost product leadership, innovation and manufacturing companies. This includes Exxon Mobil, Chevron, General Electric, Ford Motor, HP, GM, IBM, Boeing, Johnson & Johnson, Pfizer, Novartis, Intel, 3M, L'Oreal, Procter and Gamble, VW, Airbus, Continental (tyres), Toyota, Jaguar Land Rover, Rolls Royce, Dupont and Unilever.

Each beamline at SESAME has unique capabilities. Together these can be leveraged to give unique insights across all parts of the product life-cycle:

- product R&D
- feasibility studies
- resolving processing issues
- optimising the processing window
- characterising production samples for due diligence
- non-destructive quality control
- evaluating competitive products
- answering sustainability questions
- failure analysis
- aging (physical, chemical, UV, temperature cycling, etc...)






Insertion device at SESAME

# The Machine

## Brilliant X-ray and Infrared Beams

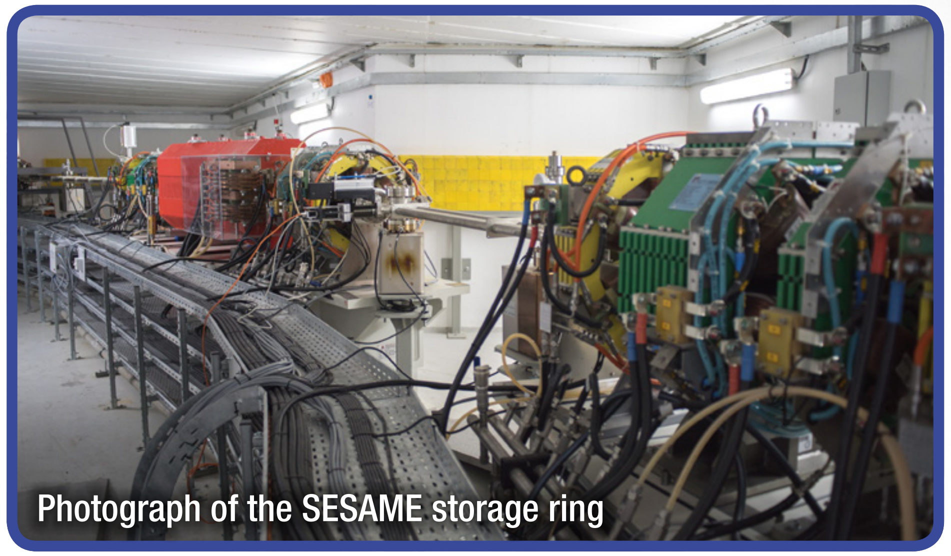
Synchrotrons generate extremely brilliant X-ray and Infrared beams. The X-rays produced at SESAME are roughly a billion times brighter than those produced by a hospital X-ray source and, unlike a standard X-ray generator, they are fully tunable. Meanwhile the infrared beams can be up to a thousand times brighter than a conventional laboratory infrared spectrometer.

## Creating Synchrotron Light

Synchrotrons work by circulating electrons in a storage ring at close to the speed of light. The storage ring is actually a polygon with 'steering' magnets at each corner (called bending magnets). At SESAME each bending magnet bends the electron beam by exactly 22.5 degrees. Thus the SESAME storage ring has 16 bending magnets (to make a 360 degree circuit).

Whenever the electrons in the storage ring change direction (via the bending magnets) they lose energy, emitting light. This is synchrotron light, and it is 10 billion times brighter than the sun.

Third generation synchrotrons like SESAME also use special magnets placed on the straight sections of the storage ring. These are called insertion devices, and they 'undulate' the electrons. These special magnets can create synchrotron light that is even brighter than the synchrotron light generated by the bending magnets.



Photograph of the SESAME storage ring

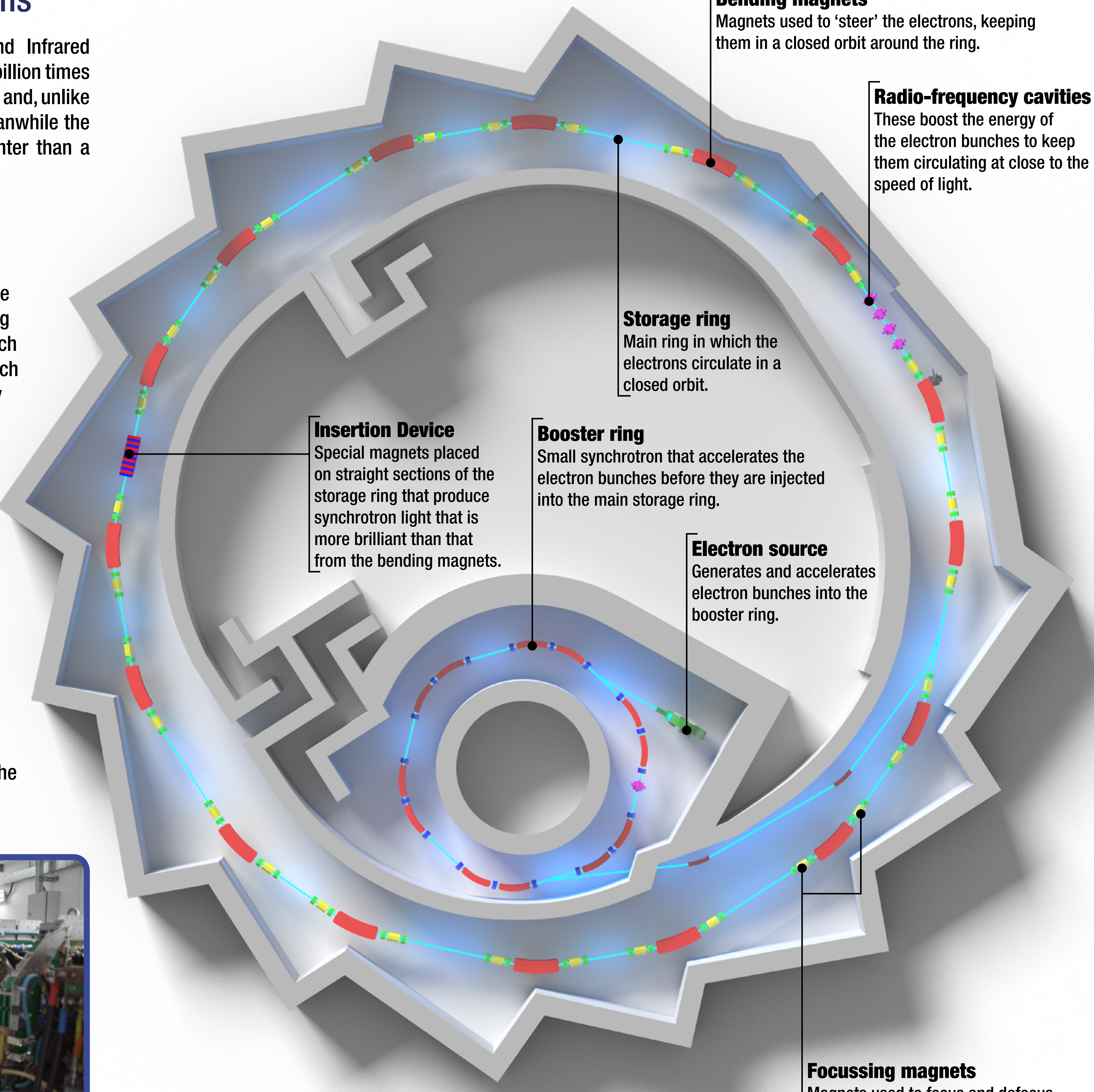
## KEY MACHINE FACTS

Energy
2.5 GeV

Current
200 mA

Circumference
133.2 m

Emittance
26 nmrad



# The Beamlines

## The First Four SESAME Beamlines

There are currently four beamlines at SESAME that are either already operational or will be coming online soon. Each beamline is a unique characterisation facility in its own right, with some offering more than one type of experimental technique. The first four beamlines and the techniques that they offer are shown below:

**IR Beamline**
Infrared Microspectroscopy (IR)

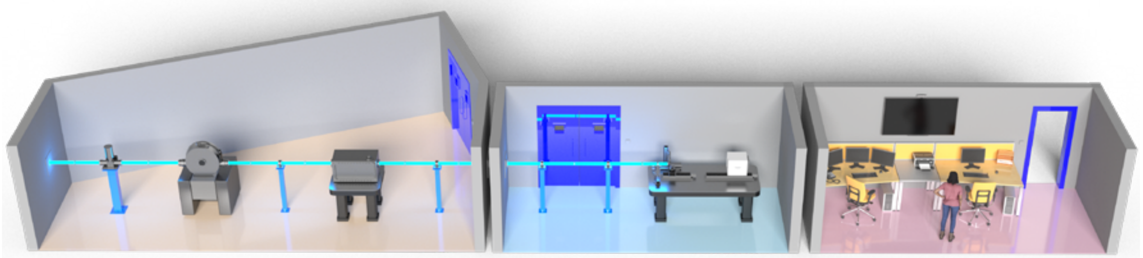
**XAFS/XRF Beamline**
X-ray Absorption Fine Structure (XAFS)
and X-ray Fluorescence (XRF)

**MS Beamline**
X-ray Diffraction (XRD)

**BEATS Beamline**
X-ray Computed Tomographic Imaging (CT)

## Anatomy of a Synchrotron Beamline

Most beamlines consist of an optics hutch, an experimental hutch and a control cabin. The optics hutch houses all of the instrumentation needed to condition the beam, such as focusing optics, a monochromator and slits. The experimental hutch is where the samples are mounted and characterised. This usually has detectors, sample environments and motorised stages for positioning and scanning. The control cabin is used to manage data collection and remotely control all aspects of the beamline.




### XAFS/XRF Beamline

Provides key information relating to a sample's **structure, atomic geometry** and **chemical state.**

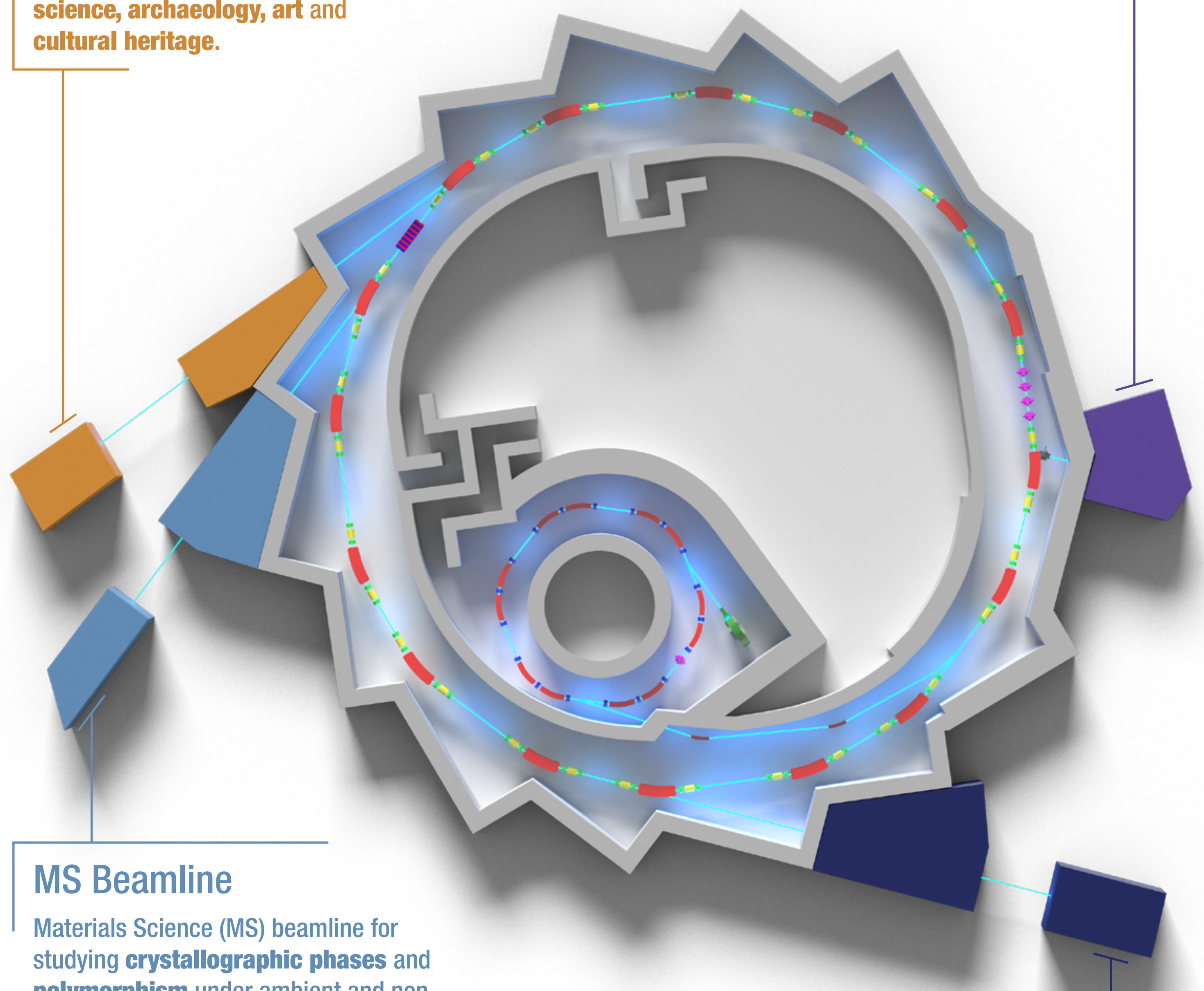
Offers techniques that are widely applicable across many industrial sectors including **materials science, environmental science, life science, archaeology, art** and **cultural heritage.**

### IR Beamline

Provides information about the **chemical composition** of almost any sample in practically any state, and can do so completely **non-destructively.**

Combines the **spatial resolution** of an IR-visible microscope with the **high chemical sensitivity** of a FTIR spectrometer.

Ideal for **spatially-resolved** and **time-resolved** studies.



### MS Beamline

Materials Science (MS) beamline for studying **crystallographic phases** and **polymorphism** under ambient and non-ambient conditions.

Ideal for studying **dynamic phenomena**, combining an extremely brilliant X-ray beam with an ultra-fast detector (7 ms readout time).

Applications in the fields of **catalysis, chemistry, renewable energy, energy storage, metallurgy,** and **aerospace,** as well as in the **pharmaceutical** and **automotive industries.**

### BEATS Beamline

**BEA**mline for **T**omography at **S**ESAME (**BEATS**)

**Non-destructive 3D imaging** using hard X-rays (10 to 30 keV).

Combines a **high spatial resolution** (imaging structures down to one micrometre) with the ability to scan **large samples** (centimetres).

Ideal for seeing inside **working devices** (e.g. running fuel cells).

Online data processing gives **immediate access to 3D images.**

# SESAME is open for industry.
# For further information about industrial applications at the SESAME light source please contact us.

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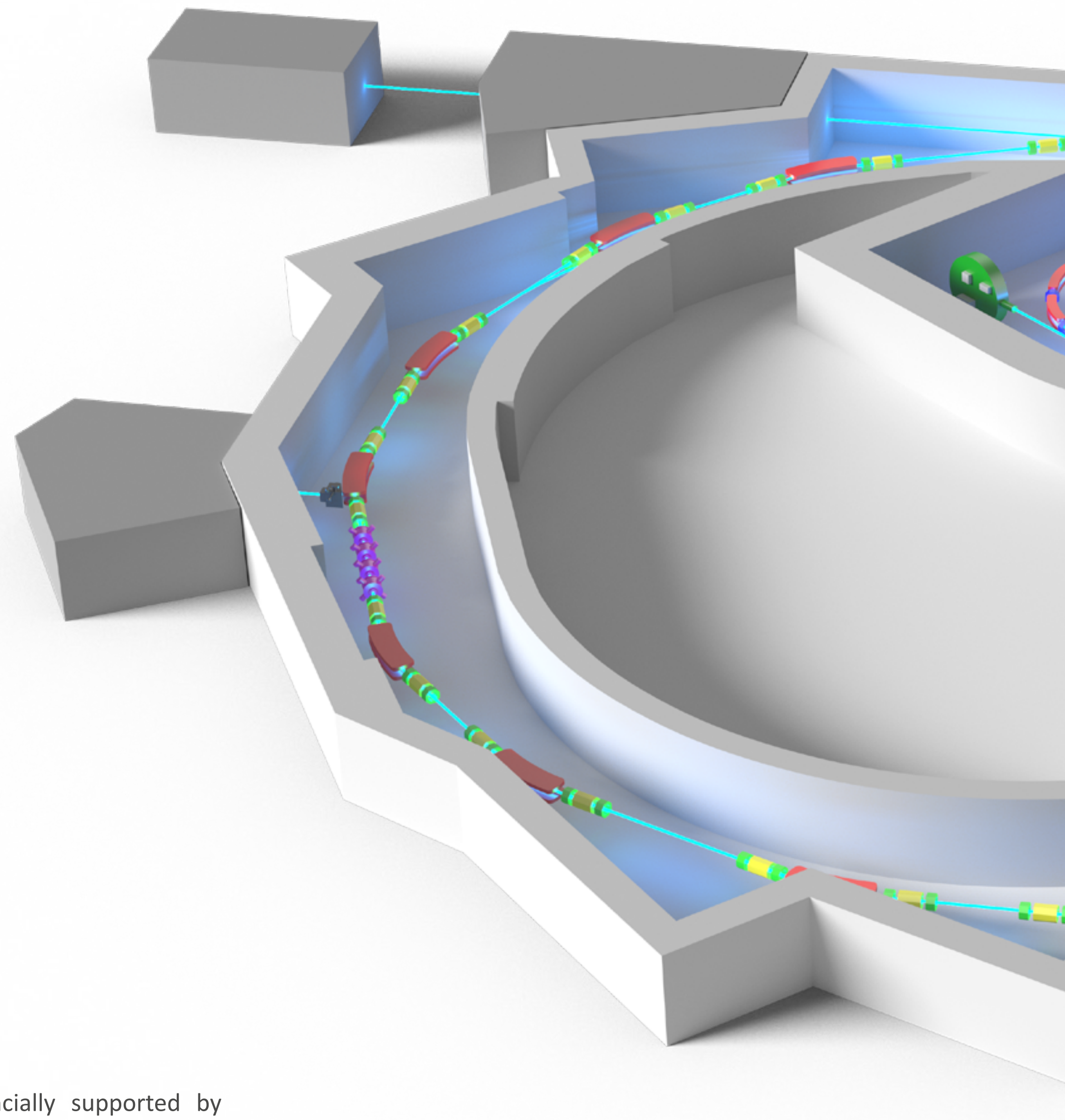

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