The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA
International Atomic Energy Agency

1936-18

Advanced School on Synchrotron and Free Electron Laser Sources and their Multidisciplinary Applications

7 - 25 April 2008

SESAME Project

Françoise Mulhauser
IAEA, Vienna

SESAME Project

Françoise Mulhauser

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International Atomic Energy Agency

- Work presented here is mostly taken from SESAME directors:
  - K. Toukan, Director
  - H. Hoorani, Scientific Director
  - A. Nadji, Technical Director
  - as well as other members of the SESAME beamline coordination meeting
- IAEA is only involved in providing training and expert missions

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Synchrotron light for Experimental Science and Applications in the Middle East

International Center for Research and Advanced Technology

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History

- **1997: H. Winick** of SLAC (USA) and G.-A. Voss of DESY (Germany)
- Germany had decommissioned BESSY 1 and agreed to donate the components to SESAME
- **1999: UNESCO** called a meeting in Paris: delegates from the Middle East and other regions
- Jordan has been selected to host the center, is providing the land as well as funds for the construction of the building
- **2003:** Groundbreaking ceremony and first Council meeting
- The component parts of BESSY 1 have been shipped to Jordan
- President (**H. Schopper** from Germany) was elected.

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Gus Voss (DESY) watching the boat leave Hamburg harbor on its way to Aqaba in Jordan with BESSY I on board; June 7, 2002

Winick - Schopper - Llewellyn Smith – Toukan

SESAME *www.sesame.org.jo*

- ✓ World class synchrotron radiation laboratory of 3rd. generation for the region
- ✓ Interdisciplinary research
- ✓ Providing environment for collaborations as well as individual development
- ✓ Applications
- ✓ Technology
- ✓ An advanced facility for training
- ✓ Bringing nations together

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Location of SESAME

Within easy reach of Jordan, Israel, Palestinian Authority, Egypt.
Samples/equipment/people can in principle be transported by car.

Middle East showing SESAME Members

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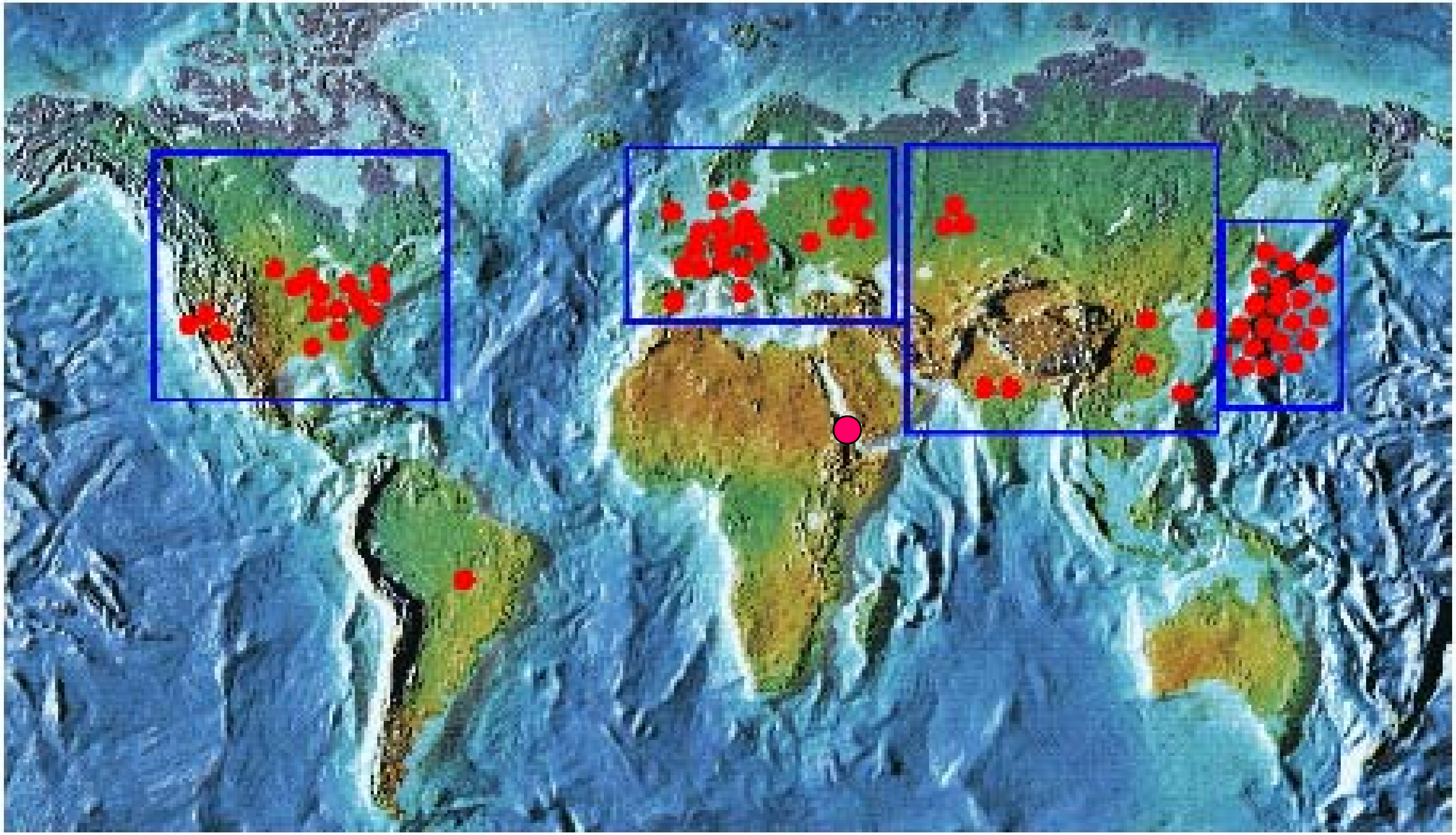
Synchrotron Radiation Around the world



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Five Grand Challenges for Science & Imagination

1. How do we control materials and processes at the level of electrons?
2. How do we design and perfect atom-and energy-efficient synthesis of new forms of matter with tailored properties?
3. How do remarkable properties of matter emerge from complex correlations of atomic and electronic constituents and how can we control these properties?
4. Can we master energy and information on the nano-scale to create new technologies with capabilities rivaling those of living systems?
5. How do we characterize and control matter very far away—from equilibrium?

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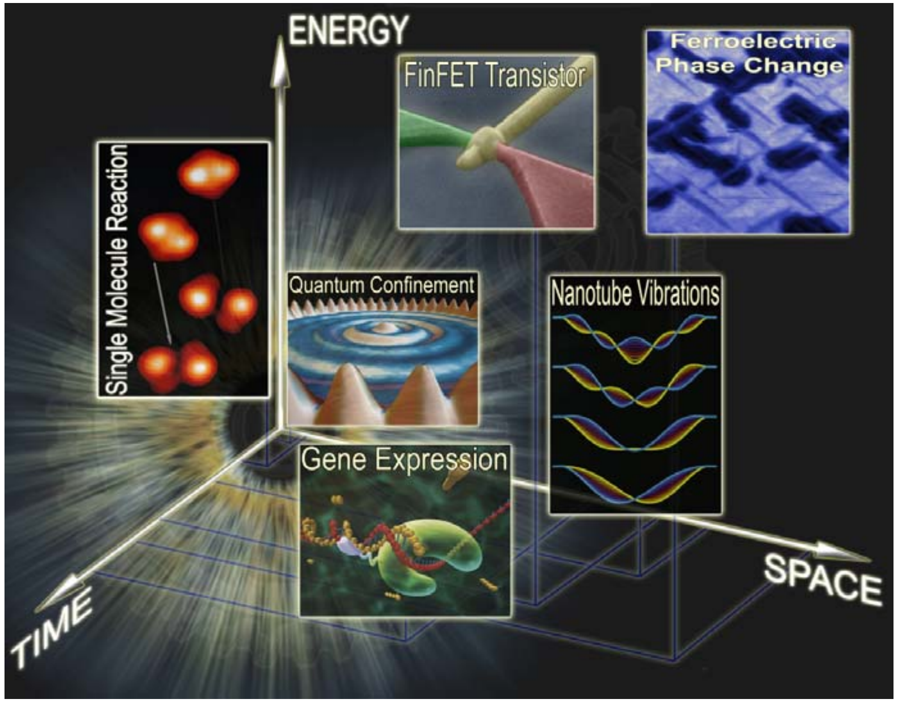
SESAME Overall Challenge: *Making the Leap from Observation Science to Control Science*

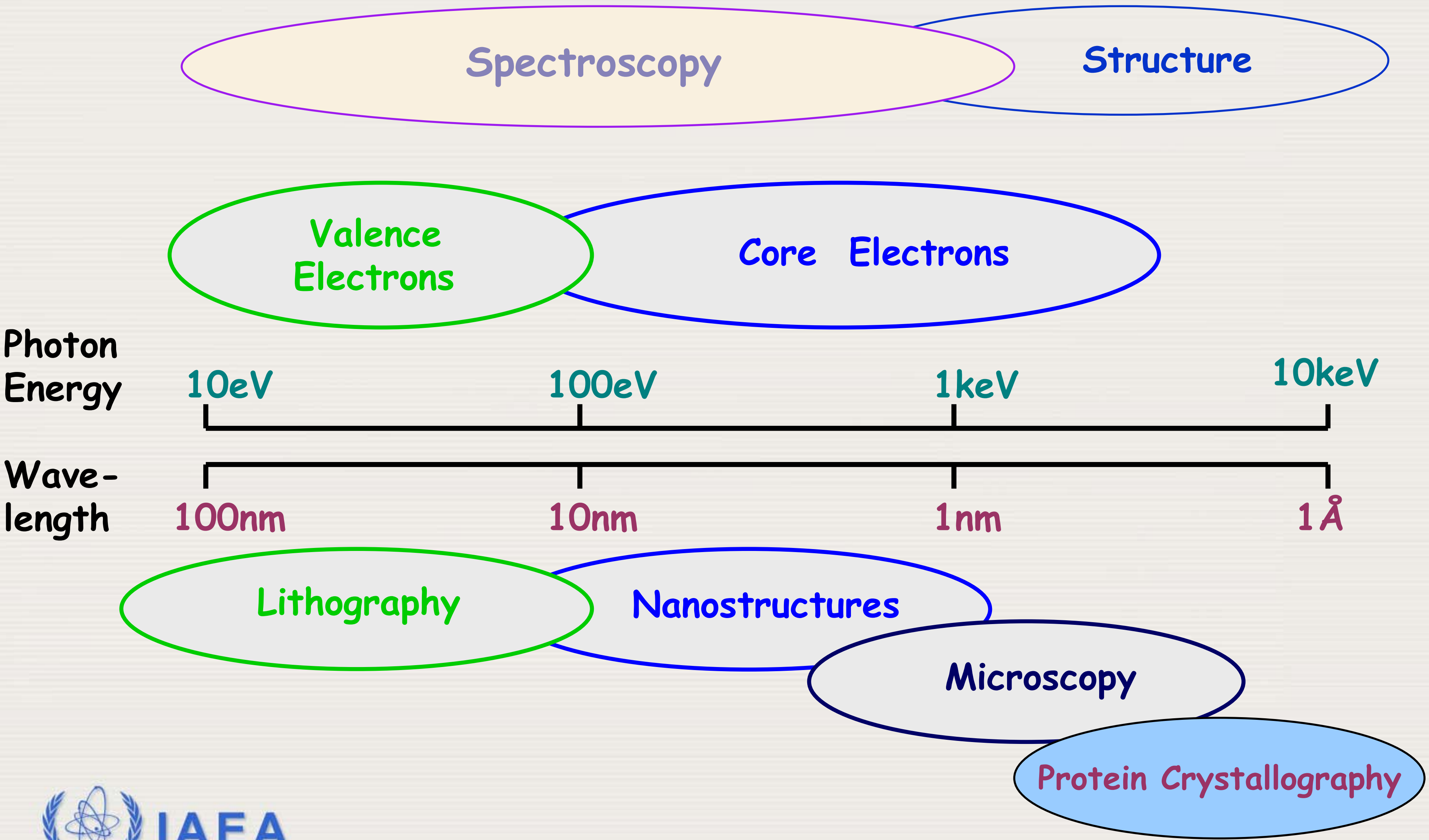
The things we want to do (i.e. designing materials to have the properties we want & directing synthesis to achieve them) require the ability to see functionality at the relevant *time, length & energy scales.*

We will need *to develop & disseminate new tools* capable of viewing the inner workings of matter - transport, fields, reactivity, excitations & motion

This new generation of instruments will naturally lead to devices capable of directing matter at the level of electrons, atoms, or molecules.



Science with Light Sources



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Techniques of Light Sources

SPECTROSCOPY	SCATTERING	IMAGING	DYNAMICS
Energy = E	Momentum p=v/m	Position	Time

SPECTROSCOPY

1. Low-Energy
2. Soft X-ray
3. Hard X-ray
4. Optics
5. Calibration
6. Metrology

SCATTERING

1. Hard X-ray Diffraction
2. Macromolecular Crystallography
3. Hard X-ray
4. Soft X-ray

IMAGING

1. Hard X-ray
2. Soft X-ray
3. Infrared
4. Lithography

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Techniques of Spectroscopy

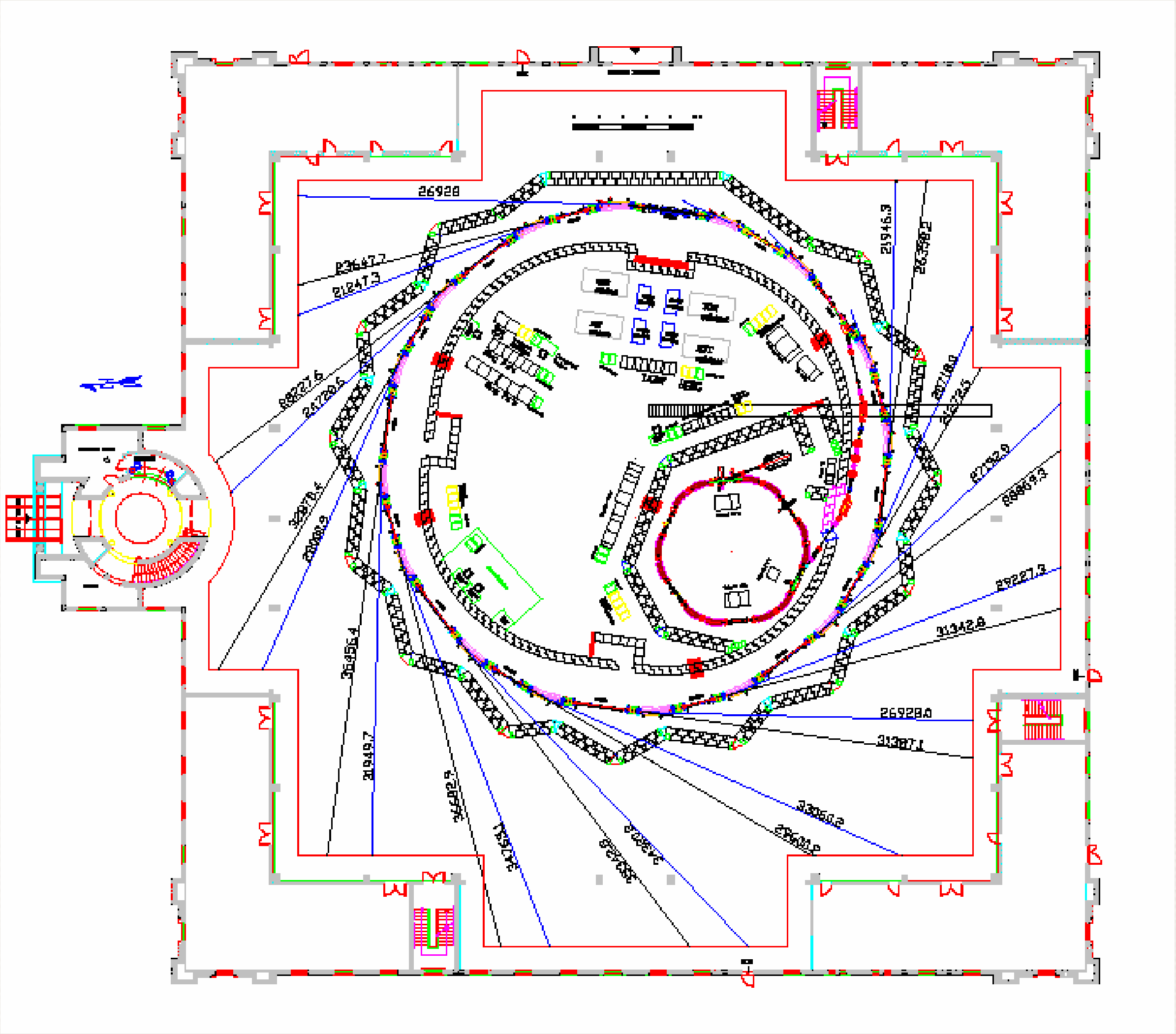
Acronym	Technique
VUV	Vacuum Ultra-Violet
PES	Photo-Electron Spectroscopy
ARPES	Angle-Resolved Photo-Electron Spectroscopy
IR	Infra-Red Spectroscopy
XRF	X-Ray Fluorescence
UPS	Ultraviolet Photoemission Spectroscopy
COLTRIMS	Cold-Target Recoil-Ion Momentum Spectroscopy
XAS	X-ray Absorption Spectroscopy
EXAFS	Extended X-ray Absorption Fine Structure
SXES	Soft X-ray Emission Spectroscopy
RIXS	Resonant Inelastic X-ray Scattering
XMCD	X-ray Magnetic Circular Dichroism
XPS	X-ray Photoemission Spectroscopy

Techniques of Scattering

Acronym	Technique
XRD	X-Ray Diffraction
XSW	X-ray Standing Wave
PX	Protein Crystallography
SAXS	Small-Angle X-ray Scattering
WAXS	Wide-Angle X-ray Scattering
IXS	Inelastic X-ray Scattering
RIXS	Resonant Inelastic X-ray Scattering
NRS	Nuclear Resonant Scattering
XPCS	X-ray Photon Correlation Scattering

Techniques of Imaging

Acronym	Technique
PEEM	Photo-Electron Emission Microscopy
STXM	Scanning Transmission X-ray Microscopy
CAT	Computer-Aided Tomography
XDI	X-ray Diffraction Imaging
IRI	Infra-Red Imaging
	Microspectroscopy
	Infrared Microprobe
	Soft X-ray Imaging
DEI	Diffraction Enhanced Imaging
	X-ray Tomography
	Full-Field Microscopy
EUV	Extreme Ultraviolet Lithography
LIGA	Lithography, Electroplating and Molding



SESAME Design Parameters

• Energy	2.5 GeV
• Circumference	133.12 m
• Bending Dipole Field	1.45 T
• Bending Radius	5.73 m
• RF Frequency	499.56 MHz
• Current (200 bunches)	400 mA
• Long Straight Section	4.44 m
• Short Section	2.38 m

SESAME Beamlines

- SESAME has the capacity for ~28 beamlines:

  Straight Sections = 16 (8 long 4.44 m, 8 short 2.38 m):
  Beamline Length 21 - 36.7 m

  Photon energies from IR to soft x-rays to hard x-rays
- Mission for beamline development is to ensure appropriate capabilities to:
  - meet needs of very diverse user community (novice to experienced in many different areas of science),
  - develop state-of-the-art user-friendly capabilities,
  - provide user support for carrying out outstanding science,
  - has clear and transparent policy that provide equal opportunities for access of beam times

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Phase I Beamlines

No.	Beamline	Energy Range	Source Type	Research Area
1.	**Mad Protein Crystallography**	4 - 14 keV	In-vacuum Undulator	Biology
2.	**Soft X-ray - VUV**	0.05 - 2 keV	Elliptically Polarizing	Atomic Molecular
3.	**SAXS/WAXS**	8 - 12 keV	Undulator	Material Science
4.	**XAFS/XRF**	3 - 30 keV	2.0 Tesla MPW	Material, Arch.
5.	**Powder Diffraction**	3 - 25 keV	2.1 Tesla MPW	Material, Arch., Env.
6.	**IR Spectro-microscopy**	0.01 - 1 eV	Bending Magnet	Material, Arch., Env.
7.	**VuV Spectroscopy**	5 - 250 eV	Bending Magnet	Atomic Molecular

Phase I Beamlines at SESAME & Other

<u>SESAME: Phase I</u>
1) PX (und)
2) Soft x-ray (EPU)
3) SAXS/WAXS
4) EXAFS/XRF (Wiggler)
5) Powder Diff (Wiggler)
6) IR (BM)
7) AMO (und)

<u>NSLS-II</u>
1) Inelastic
2) Nanoprobe
3) Soft Coherent
4) Hard Coherent
5) EXAFS
6) Powder

<u>A(ustralian)SP</u>
1) IR
2) PX (BM)
3) Soft (undulator)
4) EXAFS (wiggler)
5) Powder (BM)

<u>C(anadian)LS</u>
1) far-IR
2) UV (PEEM+XAS)
3) Soft (STXM)
4) Soft (PEEM+XAS)
5) EXAFS

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Phases I & II Beamlines at SESAME & Other Facilities

SESAME: Phase I

1) PX (und)
2) Soft x-ray (EPU)
3) SAXS/WAXS
4) EXAFS/XRF (Wiggler)
5) Powder Diff (Wiggler)
6) IR (BM)
7) AMO (und)

NSLS-II

1) Inelastic
2) Nanoprobe
3) Soft Coherent
4) Hard Coherent
5) EXAFS
6) Powder

A(ustralian)SP

1) IR
2) PX (BM)
3) Soft (undulator)
4) EXAFS (wiggler)
5) Powder (BM)

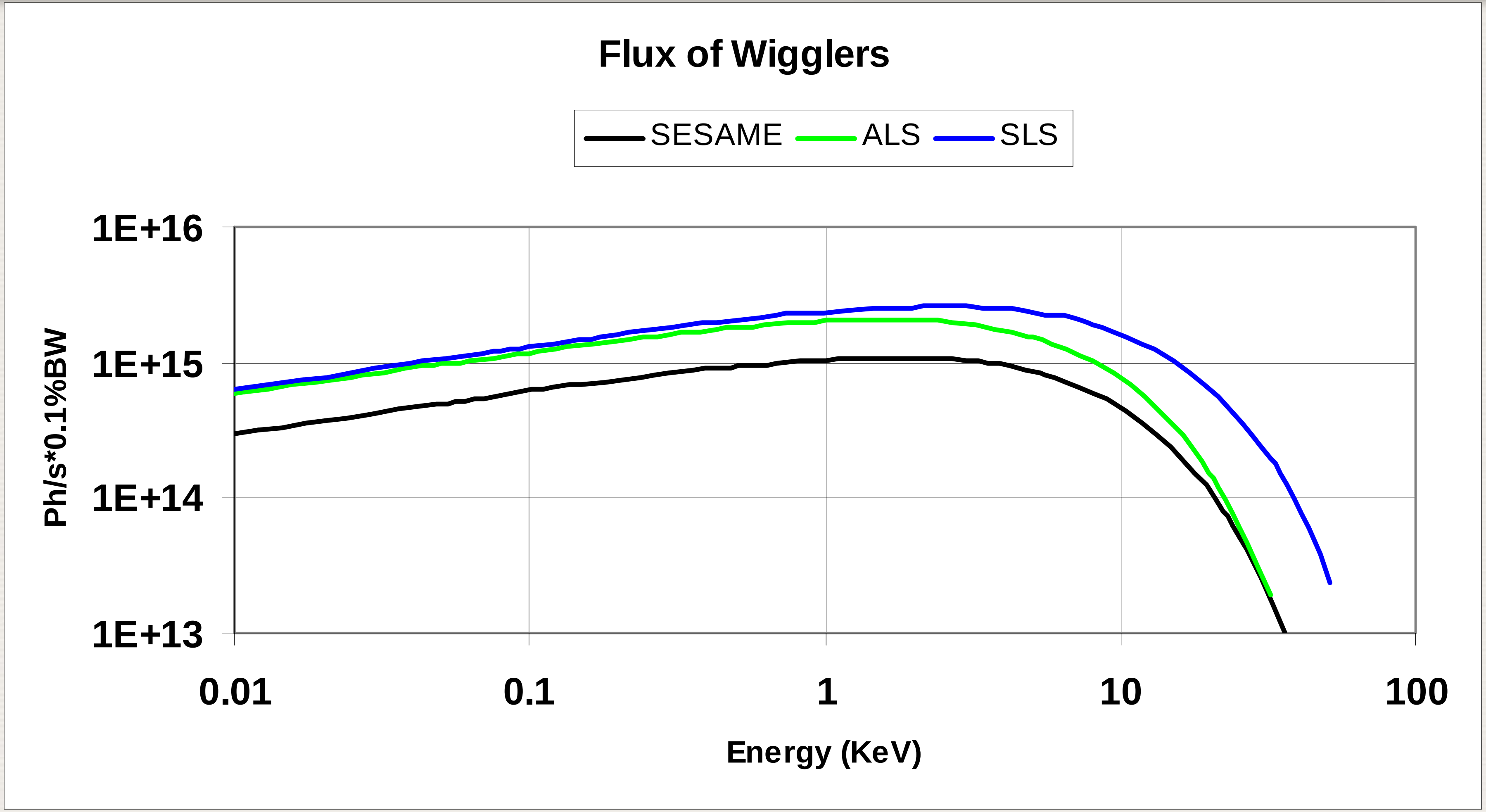
C(anadian)LS

1) far-IR
2) UV (PEEM+XAS)
3) Soft (STXM)
4) Soft (PEEM+XAS)
5) EXAFS

Possible Phase II Beamlines

8) Photon in/photon out spectroscopy (energy/water problem)
9) Soft and/or hard Microscopy (nanoscience)
10) Coherent Scattering/Imaging (biology, correlated system)
11) MCD/PEEM (magnetism)
12) PX (BM)
13) MicroProbe/diffraction (materials, archeology)
14) High Pressure (materials)

Comparison of SR from wigglers of SESAME, ALS and SLS



Thus at 10keV there is little difference between ALS and SESAME

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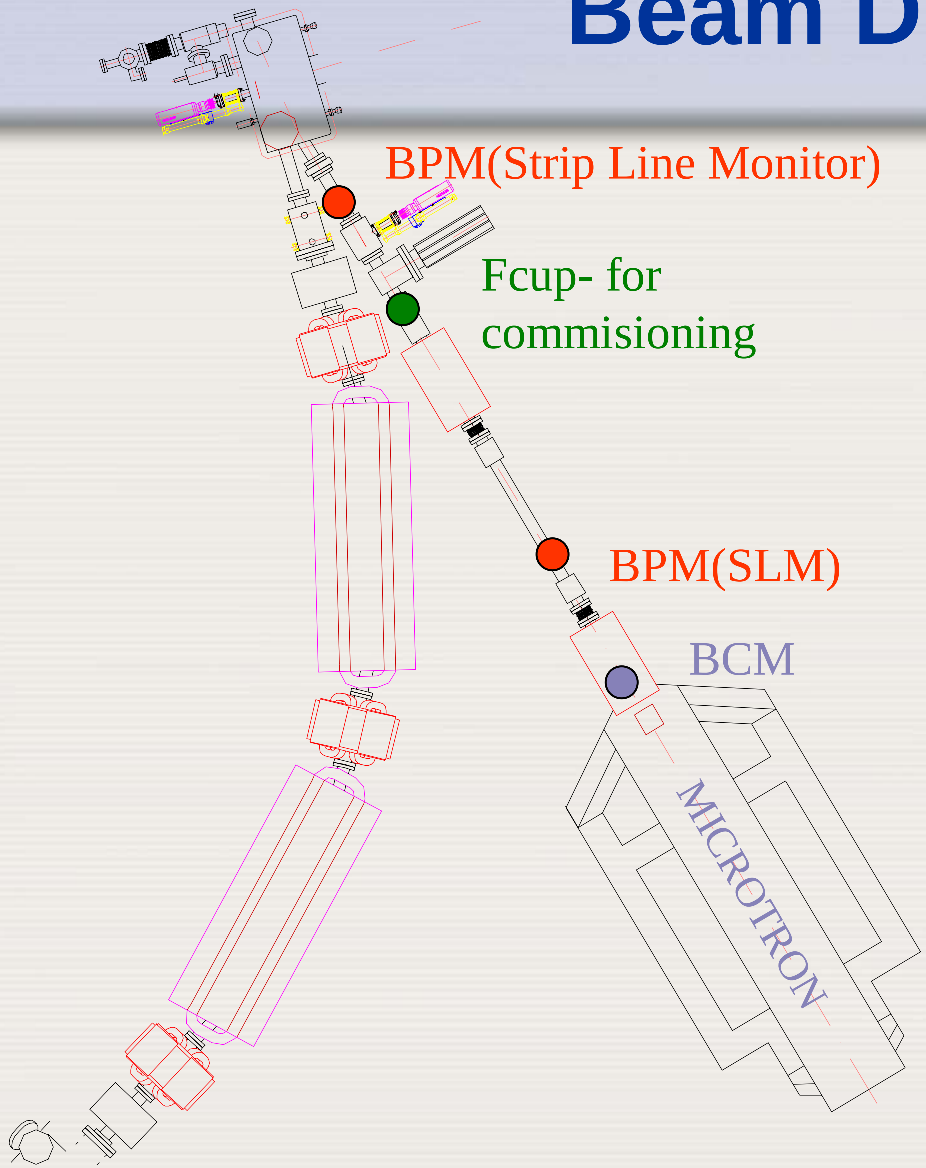
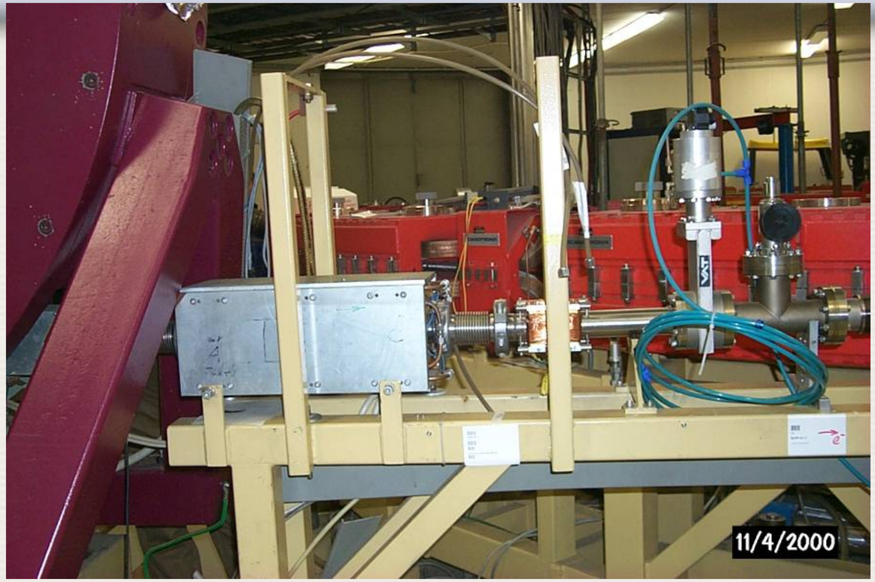
Microtron during shipment

Beam Diagnostics





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Collaboration or “Parentage”

- SESAME will be assisted by international laboratories who have built 3rd generation synchrotron radiation sources

- Signing of agreement with **SOLEIL**: Since 2007
  Pulsed Magnets, Power Supplies, Building Infrastructure, Alignment, …
- Approval by **ESRF** Directorate for
  Calculation of the Shielding, Radiation Monitors Distribution, PSS
- Collaboration with **ALBA** is being arranged
  Bending Magnet Measurement, IOTs and LLE-RF, Personnel Exchange
- Collaboration with **SLS** is in progress
  Vacuum and Control Systems

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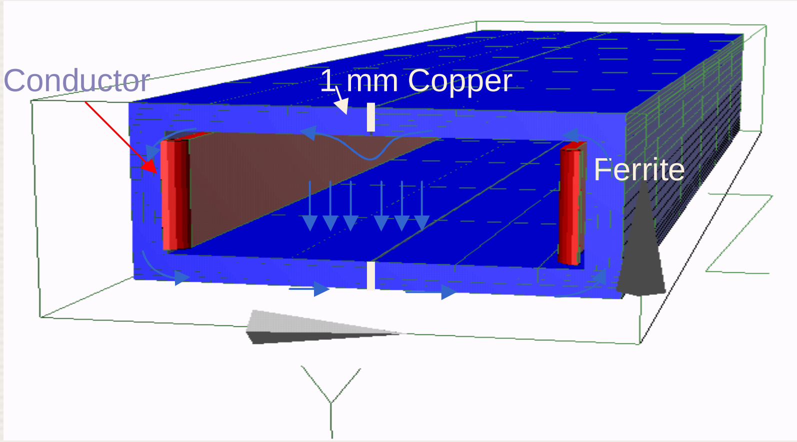
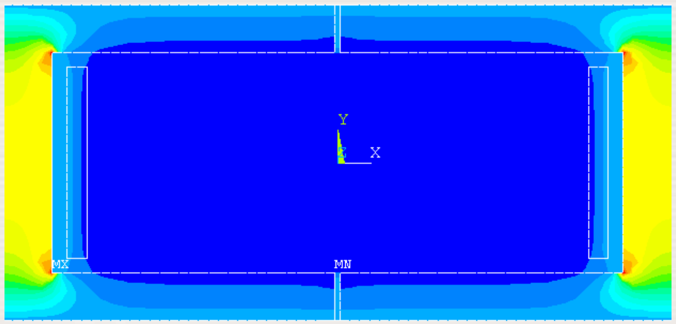
Storage Ring Devices

- Injection Septum Magnets and Kickers:
- detailed specification (SESAME), drawings (SOLEIL)
- Bending Magnet:
- Conceptual design is completed (2D & 3D magnetic calculations): SESAME results confirmed by SOLEIL
- Technical discussion and collaboration with Industries and ALBA for magnets and magnetic measurements

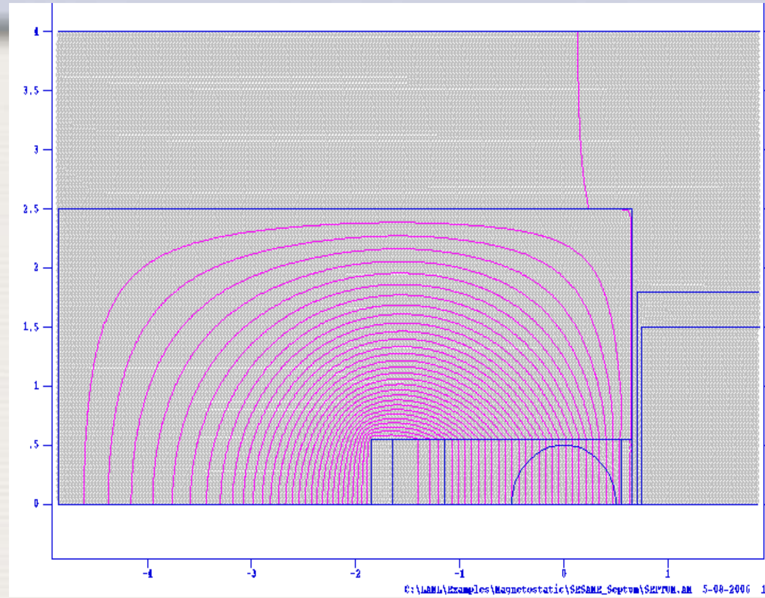
Kicker magnet design



Kicker vertical field distribution

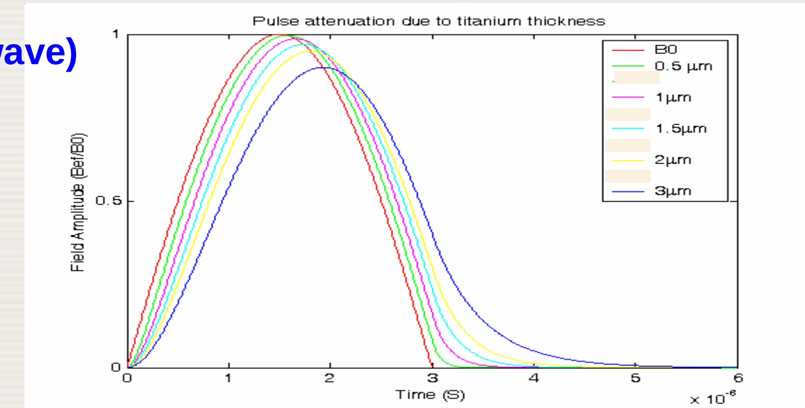


Septum downstream general cross section

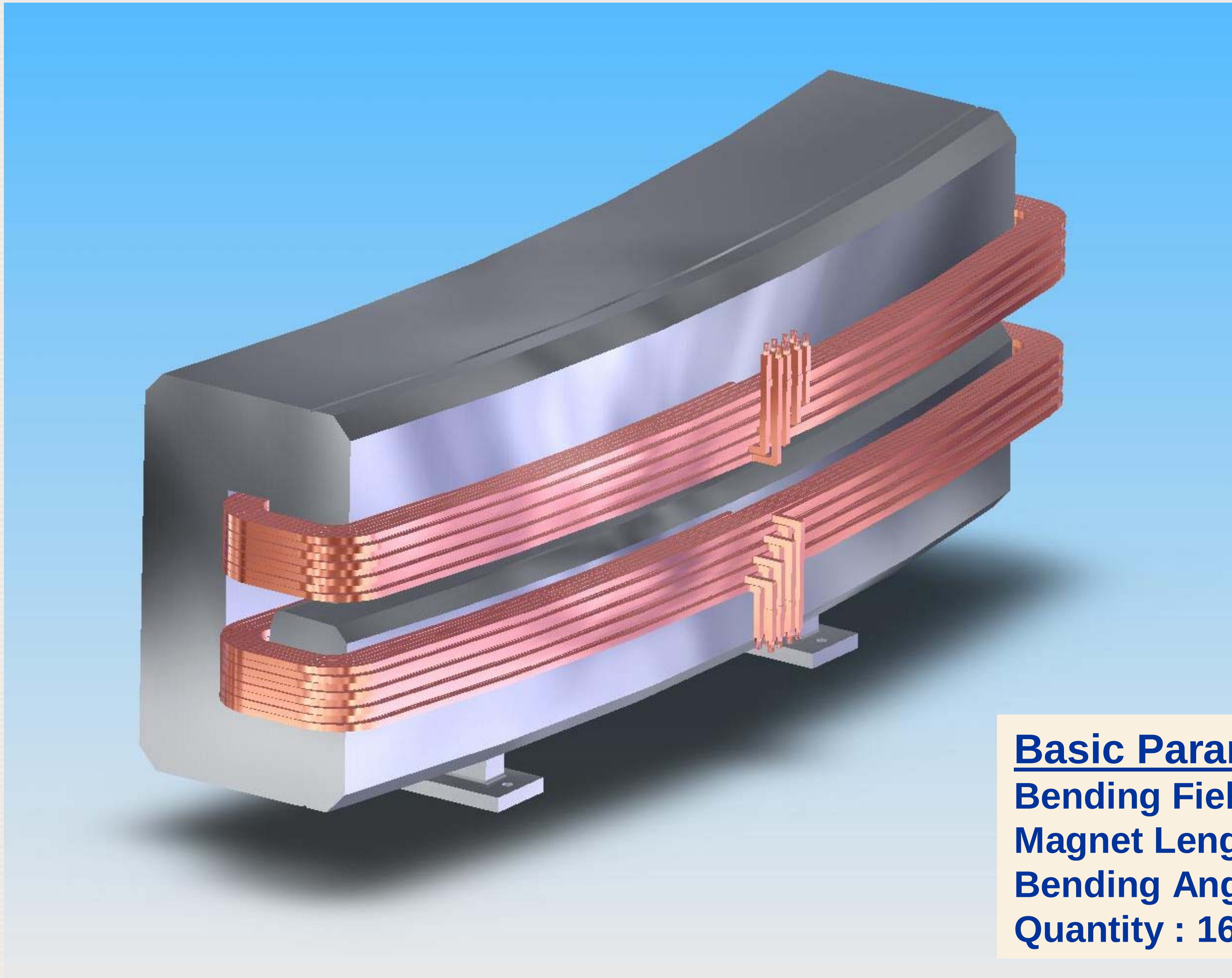


Field attenuation due to the coating (Ti, 2μm, ceramic chamber)

(3μs half-sine wave)



Bending Magnet Assembly



Basic Parameters

Bending Field at centre: 1.4554 T
Magnet Length : 2.2200 m
Bending Angle : 22.5 Degree
Quantity : 16 Magnets

SESAME Construction Schedule

ACTIVITY	START DATE	END DATE
Machine Detailed Design	Jan 2005	Dec 2007
Component Procurement		
Call for tender for all the Subsystem Contracts for all the Subsystem Prototypes Construction and Acceptance Subsystem construction	Feb 2008 May 2008 May 2008 May 2008	Jul 2009 Nov 2010 Jul 2009 Apr 2011
Installation		
Installation of Microtron and Booster in the new building Commissioning of Microtron and Booster Floor preparation, Utilities and Main Ring installation Commissioning of Main Ring Beamlines commissioning	Mar 2008 May 2008 Jun 2008 Sep 2011 Dec 2011	April 2009 Jan 2010 May 2011 Mar 2012 ------------

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Technical Team

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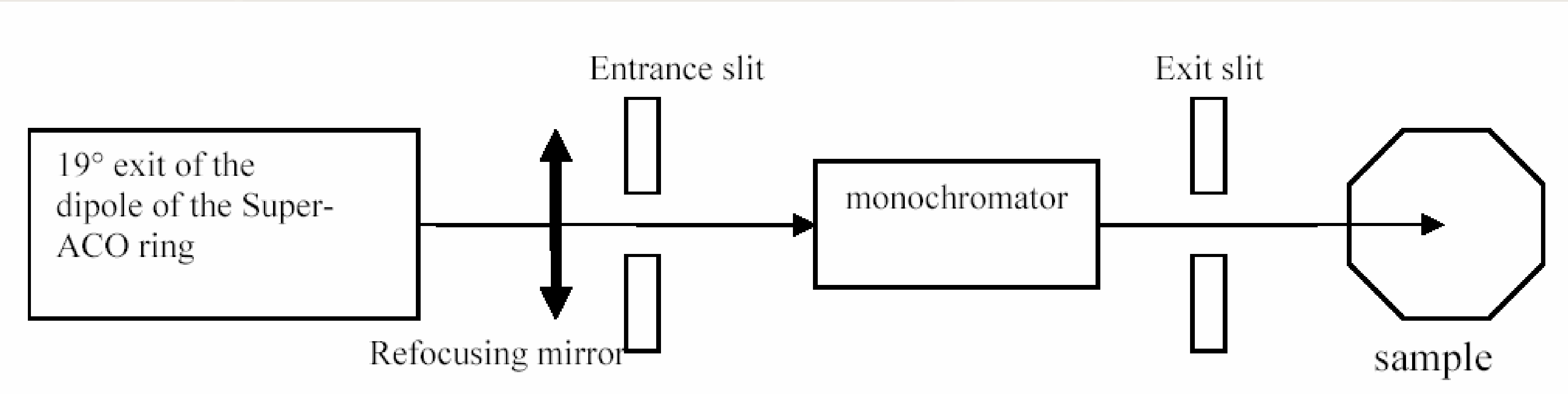
Beamline 7, VUV Spectroscopy



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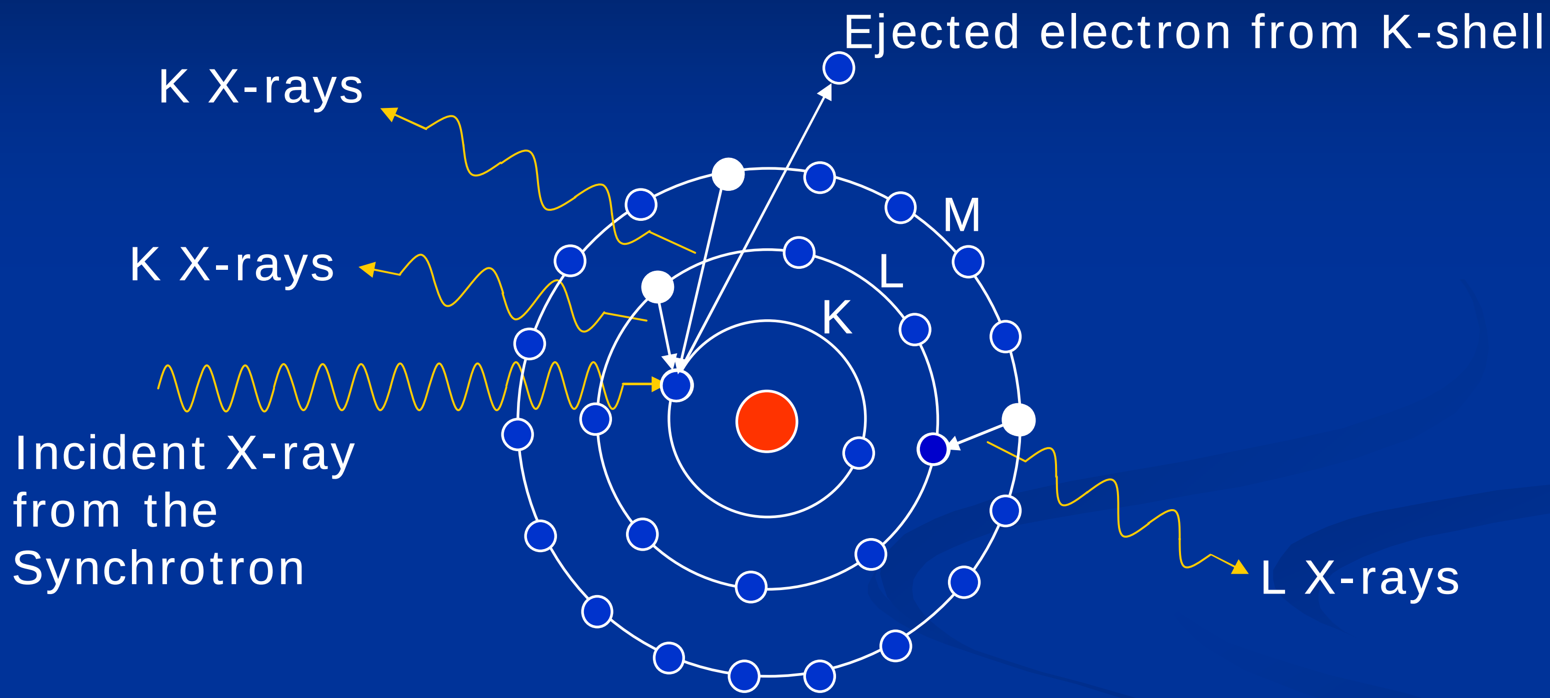
Beamline 4, XAFS / XRF:
Principle of X-Ray Fluorescence (XRF)



Atom in the sample material

Synchrotron radiation x-ray fluorescence analysis

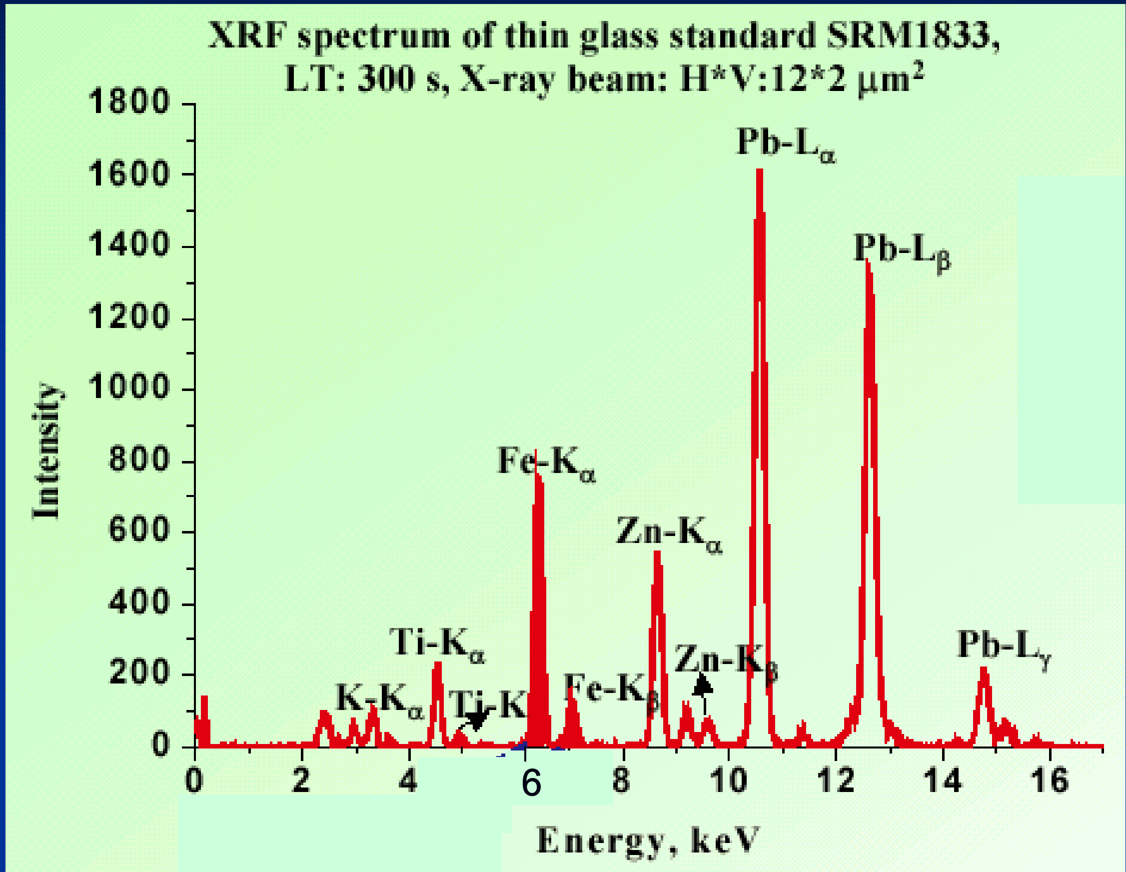
Advantages of synchrotron XRF over laboratory XRF

The synchrotron x-ray source provides:

- Many orders of magnitude more X-ray photons
- Polarized light
- ‘white’ X-ray continuum
- Well defined monochromatic excitation.

An interesting application in this respect is mineral exploration of heavy elements like Uranium.

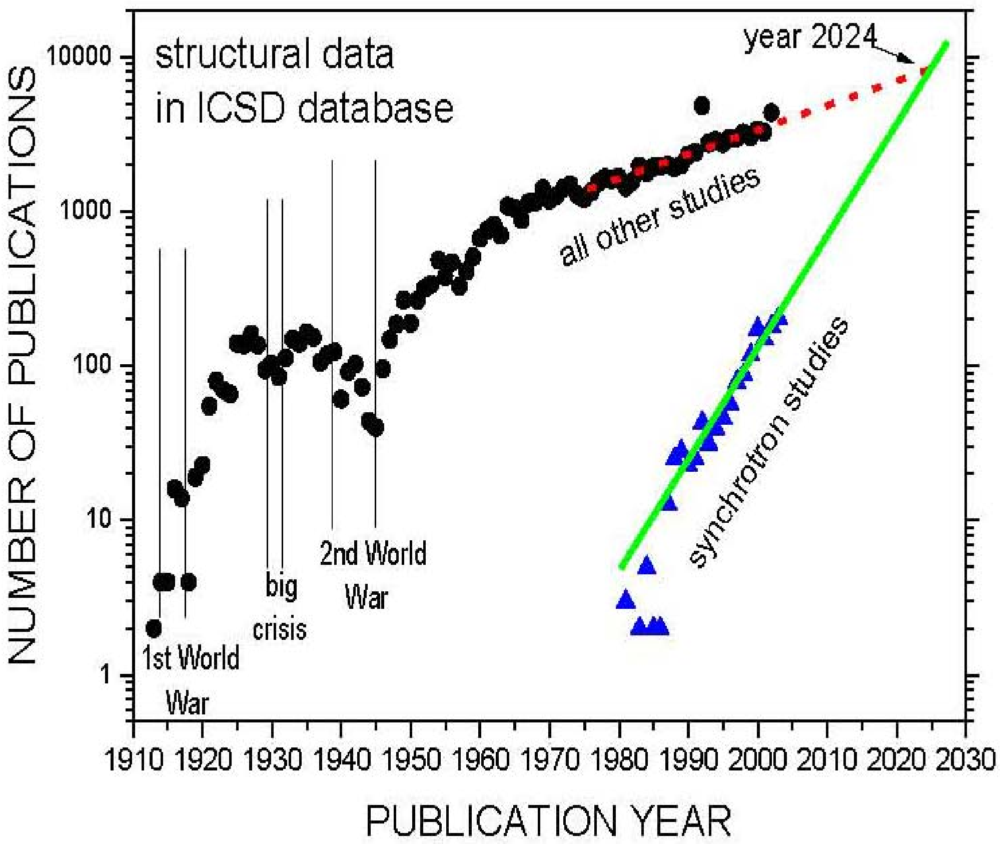
Example of SRXRF



Somogyi, *et al.*, X-ray Fluorescence Analysis, JASS'02, Al-Balqa' Applied University, Jordan, Oct. 19-28, 2002.

Elemental or chemical mapping of materials

Beamline 5, Powder Diffraction



Potential Users of

20 groups from 6 institutions in Iran

Jordan National Committee includes 17 groups

Research groups of Seven Israelen universities

More than 100 Turkish research groups from 30 universities

More than 50 days beam time required

Experiments needed at SESAME-PDB

using the high-angular resolution of the powder diffractometer

1. *Determination of the Crystal Structures*
2. *Phase Transitions*
3. *Microstructural Studies*

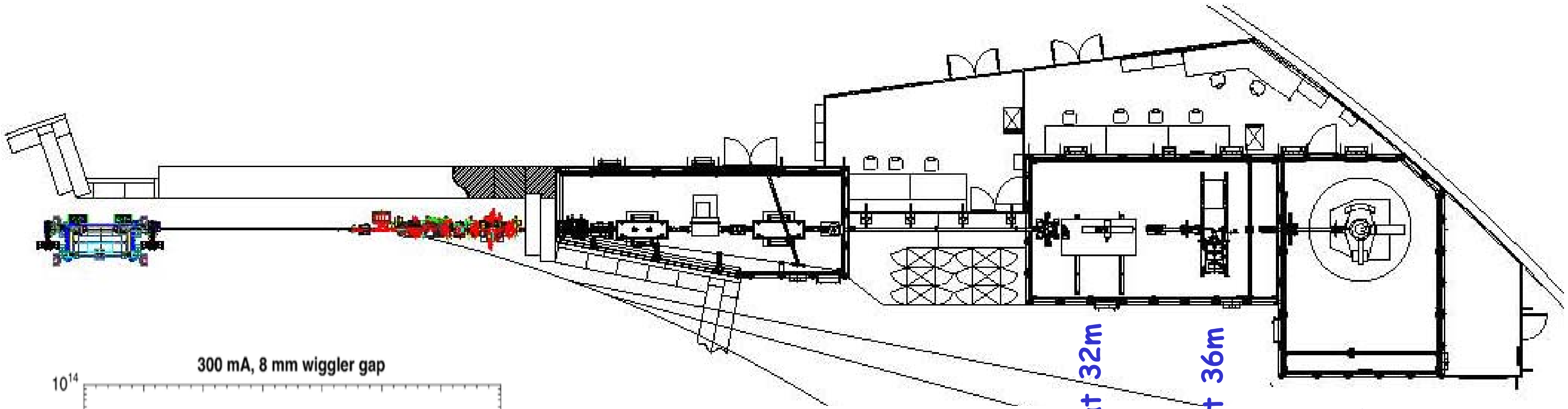
using the high flux of the powder diffraction station

1. *In situ diffraction studies of catalysts*
2. *Kinetic studies of chemical reactions and dynamic studies of phase transitions in organics*
3. *Residual Stress Measurements*

using the microfocusing capability

1. *Microcrystal diffraction studies at ambient and non-ambient conditions*
2. *Powder diffraction studies at high pressures*

MS Beamline at SLS



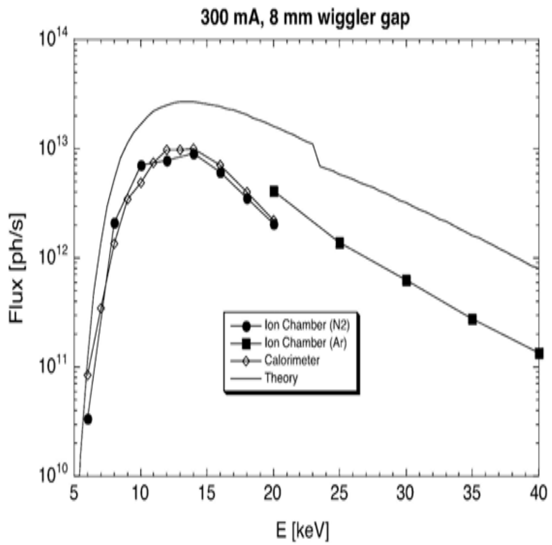


Table 1
Materials science beamline specifications

Energy range	5–40 keV
Accepted divergence	$0.23\ (v) \times 2.5\ (h)$ mrad^2
Flux at 10 keV	10^{13} photons/s
Energy resolution $\Delta E/E$	0.0139% (Si (1 1 1))
Focused spot size	$160\ (v) \times 450\ (h)\ \mu m^2$ FWHM

Beamtime Proposal Review and Scheduling Guidelines

- The key to the delivery of outstanding science is ***rigorous peer review*** that is fair, clear, and sensitive to the needs of users.
- Beamtime request is evaluated and rated by the ***beamline proposal review panel***
- Evaluation criteria include:
  - Scientific Impact
  - Past performance (if appropriate)
  - Need of requested beamline (ID vs BM or appropriate use of technique)
  - Technique or Instrumentation Development
  - Industrial impact, need of region
- Facility does all beamtime scheduling.

General User Access

- All the SESAME beamlines will have at least 50% General User (GU) time.

- Each beamline scientist will get 5% of beamtime for his/her professional growth. This is necessary for attracting outstanding beamline scientists and making them committed in maintaining high quality of the beamline. Beamline scientist will be allowed to compete for GU beamtime at other beamlines.

- GU proposals will be valid for two years (continuation request required for each 6-month cycle)

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Beamline Performance Review & Quality Control

- When SESAME will be operational (2011), a *Science Advisory Committee* (SAC) will be formed to advise on facility and beamline operations
- All SESAME beamlines will be reviewed annually by facility (organized by facility Science Director) to rate each in the areas of technical quality, staffing factors, and productivity
- Any suggestions for improving performance or critical needs will also be provided. The metrics for these evaluations will be public and transparent. Results will be reviewed by the SAC for their input and recommendations.
- Full reviews of each beamline will be conducted by the SAC on a triennial basis

IAEA activities

- 4 x 6 months Beamline scientist fellowships per year. IAEA Technical Officer participates to evaluation panel. Restricted to IAEA & SESAME Member States fellows.
- 4 x 1 months technical trainings per year. Restricted to SESAME staff.
- Expert missions
- Lecturers at users' meetings

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Directorate

- Prof. Sir Chris Llewellyn Smith, President of the Council
- Prof. Khaled Toukan, Director
- Prof. Hafeez Hoorani, Scientific Director
- Dr. Amor Nadji, Technical Director


Thank you