SESAME

Synchrotron-light for Experimental Science and Applications in the Middle East

SESAME: WHAT IT IS, WHAT IT BRINGS TO ITS MEMBERS, WHAT THE OBLIGATIONS OF ITS MEMBERS ARE

I. What is SESAME?

SESAME is a major intergovernmental science facility in Allan, Jordan, that was formally opened by H.M. King Abdullah II of Jordan on 16 May 2017. It is the first synchrotron light source in the Middle East, and also the region's first true international centre of excellence. It was created under the auspices of UNESCO (United Nations Educational, Scientific and Cultural Organization), but is an independent intergovernmental organisation. It is modelled on CERN (European Organization for Nuclear Research), although it has very different scientific aims.

The heart of SESAME is a 2.5 GeV synchrotron light source (133m in circumference), providing radiation from the infrared light to X-rays of unparalleled quality, a unique tool to expand the boundaries of scientific investigations into new materials and living matter.

SESAME is:

- Fostering scientific and technological excellence in the Middle East and neighbouring regions by enabling world-class research in subjects ranging from medicine and biology, through materials science, physics and chemistry to healthcare, the environment and archaeology,
- Building bridges between neighbouring countries and fostering mutual understanding and tolerance through international cooperation, and
- Helping to prevent and reverse the brain drain that is holding back science education and research in the region.

The Members of SESAME are currently Cyprus, Egypt, Iran, Israel, Jordan, Pakistan, Palestine and Turkey. SESAME is actively seeking new Members both from across the Middle East and neighbouring countries and elsewhere. The Observers are Brazil, Canada, China, France, Germany, Greece, Italy, Japan, Kuwait, Portugal, Russia, Spain, Switzerland, Sweden, the UAE, the UK, the USA, as well as CERN and the European Union.

SESAME is an Associate of LEAPS (League of European Accelerator-Based Photon Sources) (https://leaps-initiative.eu). It appears on Wayforlight (https://www.wayforlight.eu/en/), a web site created by the EU FP7-funded CALIPSO project that offers a single entry point for information about the European synchrotrons + SESAME and the European free electron lasers. This testifies to the full confidence the international scientific community has in SESAME's success and its role as a centre of excellence.

SESAME forms part of the INFN-CHNet network dedicated to cultural heritage of the Italian INFN (National Institute for Nuclear Physics) and it hosts an INFN-CHNet laboratory on its premises.

Since 26 February 2019 when SESAME's solar power plant was inaugurated, SESAME is the world's first large accelerator complex to be fully powered by renewable energy, thus making it the world's first carbon neutral accelerator laboratory. This makes SESAME economically, as well as environmentally sustainable. It has signed the UN's Climate Neutral Now pledge.

A synchrotron light source is an accelerator-based facility that uses electromagnetic radiation emitted by circulating electron beams to study a range of properties of matter. It is equipped with beamlines that focus the light on samples that scientists wish to study. Each beamline can support several experiments in series and in parallel. Synchrotron light sources have become prime factors in promoting scientific and technological progress, and an essential tool in a vast range of applied and basic sciences. There are currently over 50 light sources in more than 20 countries serving around 50,000 scientists. This is the largest scientific community in the world. There are a few such sources in developing countries, but until SESAME there was none in the Middle East and neighbouring countries.

II. Governance of SESAME

SESAME is 'owned' by its Members which have full control over its development, exploitation and financial matters.

Through the Council, which is the governing body of SESAME, the Members participate in decisions on:

- the Centre's policy in scientific, technical and administrative matters;
- the Centre's financial regulations and staff rules;
- the establishment of staff posts at the Centre;
- the installation, operation and upgrading of the Centre's facilities;
- the scientific programme of the Centre;
- the training programme of the Centre;
- the election of the President and two co-Vice Presidents of the Council, and the appointment of the Directors of the Laboratory, and chairpersons and members of the Council's advisory committees;
- all financial issues, including adoption of the yearly budget, review and approval of expenditures, etc.

III. Returns for Investment in SESAME

SESAME groups the efforts of a number of countries, is located on land provided by the Jordanian Authorities in a building they funded, and has benefited from important external contributions in cash and in kind, as well as from scientific expertise. It therefore offers an extraordinarily cost-effective way to access excellent wide-ranging research opportunities.

SESAME is bringing scientific excellence to the Middle East and neighbouring countries thereby permitting science institutes in the region to stand as equal partners with laboratories in the scientifically more advanced countries. The possibility for scientists to carry out experiments at SESAME while remaining based in national universities and research institutes is helping to prevent or reverse the brain drain that is holding back science education and research in the region.

The extensive SESAME training programme has been playing an important role in strengthening scientific and technical capacity in the SESAME region ever since the inception of SESAME. Moreover, since 2014 scientists from the Members have been able to carry out research with the FTIR (Fourier Transform Infrared) microscope that was then producing science at SESAME with a conventional IR source - this microscope is now coupled to synchrotron infrared radiation. However, it is only since 2018 when the first two beamlines at SESAME came on stream that the Members started to derive the full benefits of membership in earnest. These benefits are spelled out in detail in Section VII below. Briefly they include:

- Priority access to wide-ranging research opportunities to execute national priority projects;
- Opportunities to collaborate with scientists from the other SESAME Members and beyond, including scientists from Asia, Europe, the USA and other countries who are involved in experiments at SESAME;
- Experience in up-to-date experimental techniques, which opens up opportunities for collaboration with other synchrotron-light sources around the world;
- Valuable experience for any countries that may in due course wish to build their own light source;
- On-going opportunities for training through workshops, Users' Meetings, visits to other light sources, etc. that SESAME organises;
- A voice in the governance of SESAME, including in the choice of future beamlines and the scientific strategy behind the programme;
- Opportunities for appointments at SESAME;
- Opportunities to obtain SESAME contracts, which is an effective way to transfer technical capabilities;
- Raising the standard of research and education in the SESAME Members' national universities and institutes by exposure to international standards through collaboration and international peer review as has been the case in the national universities and institutes of Members of other international organisations (for example, CERN); and
- Easier access to SESAME for users granted beam time there, thanks to the Seat Agreement between SESAME and Jordan that facilitates the delivery of entry visas to Jordan, than could be the case to synchrotron light sources located in some countries for which an entry visa may be more difficult to obtain.

IV. SESAME's Accelerators

Particle acceleration at SESAME starts with the Microtron (the pre-injector) that produces electrons and accelerates them to 20 MeV. These electrons are then transferred to the Booster where they are accelerated from their initial energy of 20 MeV to 800 MeV. From the Booster, electrons are passed through a transfer line to the Storage Ring that on each fill keeps an electron beam of 250 mA (eventually to be 400 mA) at 2.5 GeV circulating for many hours. Bending magnets on the Storage Ring force the electrons to change trajectory as they circulate, causing them to emit synchrotron light. This light is transmitted to beamlines that focus the light on samples that scientists wish to study.

SESAME's Microtron is that of BESSY I that was donated to SESAME by Germany. It has been, and continues to be, greatly refurbished and upgraded. There is nonetheless a plan to replace it by a 100 MeV Linac and this will be done once the required funds have been secured. This will be followed in the second stage by a full energy Booster in order to provide top-up injection in the storage ring. This will allow a more stable beam by keeping the heat loads and the current in the storage ring and beamlines constant over long periods, which will be greatly beneficial for the users.

SESAME's 2.5 GeV Storage Ring is completely new. It was built from scratch with European Union funding (€5 million) for construction of the key magnetic system for the Storage Ring, and also part of the power supplies. The project, which was led and coordinated by CERN with support from SESAME, put CERN's expertise at the service of SESAME, while the ALBA-CELLS (Consorci per a la Construcció Equipament i Explotació del Laboratori de Llum de Sincrotró) light source in Barcelona played an important role in magnet testing. Three key contracts were placed in SESAME Members (Cyprus, Israel and Pakistan), with the rest placed in Europe, and CERN received in-kind support from three SESAME Members (Iran, Pakistan and Turkey), which facilitated valuable knowledge transfer.

V. Science at SESAME

Four of SESAME's beamlines are currently in operation, and the Centre's scientific programme is now spanning fields ranging from medicine and biology, through materials science, physics and chemistry to healthcare, the environment, agriculture and archaeology. In April 2023, the number of peer-reviewed papers presenting data obtained at SESAME's beamlines in scientific journals stood at 67. Moreover, part of the results presented in one PhD thesis was based on data collected at SESAME's BM08-XAFS/XRF beamline.

The Laboratory will be exploited in up to 20 or more experiments operating simultaneously on independent beamlines, which will focus the synchrotron light on samples of materials. In the first phase, there will be eight beamlines. These beamlines, which have been selected on the basis of requests from scientists in the region, are the following:

- BM02-IR (Infrared) spectromicroscopy beamline;
- BM08-XAFS/XRF (X-ray Absorption Fine Structure/X-ray Fluorescence) spectroscopy beamline;
- ID09-MS/XPD (Materials Science/X-ray Powder Diffraction) beamline;
- ID10-BEATS (BEAmline for Tomography at SESAME) beamline;
- ID11L- HESEB (HElmholtz-SEsame Beamline) beamline and ID11R-TXPES (Turkish soft X-ray PhotoElectron Spectroscopy) beamline;
- MX (Macromolecular/protein crystallography) beamline;
- SAXS/WAXS (Small-Angle and Wide-Angle X-ray Scattering) beamline; and
- VUV (Vacuum Ultraviolet) spectroscopy beamline.

The BM02-IR, BM08-XASF/XRF and ID09-MS/XPD beamlines are already hosting users, and the ID11L-HESEB beamline will be receiving its first users in 2023. The ID10-BEATS beamline will be inaugurated in June 2023, and it too will be receiving its first users in 2023. Construction of the TXPES (**T**urkish soft **X**-ray **P**hoto**E**lectron **S**pectroscopy) beamline, which will share the undulator source of the HESEB beamline, has started, and construction of the already-designed

MX beamline will commence immediately the required funds are secured. Plans for the SAXS/WAXS and VUV beamlines are yet to be drawn up.

The **BM-02-IR beamline** is a completely new beamline. It was designed and built at the D02 dipole of SESAME in collaboration with the French light source Synchrotron SOLEIL. It allows the application of infrared microspectroscopy and imaging in a wide range of fields, including surface and materials science (e.g. characterization of new nano-materials for solar cell fabrication and for drug delivery mechanisms), biochemistry, archaeology, geology, cell biology, biomedical diagnostics and environmental science (e.g. air and water pollution).

The **BM08-XAFS/XRF beamline** is based on the donated Helmholtz Zentrum Dresden-Rossendorf beamline, originally installed at the European Synchrotron Radiation Facility (ESRF) in Grenoble (France). It utilizes a monochromator donated by the Diamond Light Source that allows the *in situ* exchange of crystals to increase the useful energy range. The source is the D08 dipole magnet of SESAME which is optimized for X-ray spectroscopic studies in all fields of science including *in situ* studies of functional materials. It can be used in materials and environmental science, in designing new materials and improving catalysts (e.g. for the petrochemical industries), and to identify the chemical composition of fossils and valuable paintings in a non-invasive manner. It is equipped with a new state-of-the-art silicon detector (funded by Italy) that has a sensitivity that is at least 50 times higher than any other currently available in synchrotron light sources elsewhere.

The **ID09-MS/XPD beamline** is based on components donated by the Swiss Paul Scherrer Institute (PSI), with modifications to match the characteristics of the SESAME Storage Ring. It is the first SESAME beamline to be equipped with an insertion device (the ID09 wiggler, also donated by PSI) which enhances the brightness of the synchrotron light, thus reducing the time needed to make measurements, and making it possible to follow fast processes. A powerful PILATUS 300K area detector, donated by DECTRIS (Switzerland), provides the fast read-out time that is required to investigate the evolution of nano-scale structures and materials in extreme conditions of heating and cooling under gas flows. The MS/XPD beamline is used in applications of the X-ray powder diffraction (XRD) technique in materials science. It provides a powerful tool for studying microcrystalline or disordered/amorphous material on the atomic scale, the evolution of nano-scale structures and materials in various environmental conditions, and for developing and characterising new smart materials.

The tomography **ID10-BEATS beamline** is also a completely new beamline. The source is a three-pole wiggler with a peak field of 3 T (more than twice the field of SESAME's bending magnets, thus shifting the critical energy from about 6 to about 12 keV) inserted in the short straight section 10 of the SESAME Storage Ring thereby giving the best combination of flux and coherence in the energy range from 8 keV to 50keV. In order to preserve these characteristics of the source, a Double Multilayer Monochromator (DMM) was built and the sample stage is at a long distance (40m) from the source. Although this necessitated some modifications to the SESAME building, the advantages in terms of spacial resolution will be enormous, allowing BEATS to image submicron details of the samples under investigation. This beamline will have important applications in archaeology and cultural heritage, which is particularly relevant given how rich the region is in archaeological sites and artefacts, but also in health and biomedicine, geology (i.e. geological rock samples relevant for oil/gas/water exploration, reservoir engineering, mining, etc.) and materials and nano science and engineering. Construction of the beamline is being funded by the European Union through its Horizon 2020 programme, and the beamline is being developed by a consortium of leading research facilities in the Middle East (SESAME and The Cyprus Institute), well established European synchrotron radiation facilities and high-energy laboratories (DESY,[1] ELETTRA, ESRF, INFN and PSI) with decades-long experience in synchrotron radiation research and technology, and more recently established synchrotron laboratories (ALBA-CELLS and SOLARIS).

The **ID11L-HESEB beamline** is a state-of-the art beamline in the soft X-ray energy range (between ~70 - ~1800eV). Soft X-ray spectroscopy is a collective name for a wide range of techniques with which the electronic structure of atoms, molecular bonds and chemical characteristics of materials can be investigated. It has applications in the fields of health sciences, photonics, advanced materials, environmental sciences, nanostructures, petrochemistry and energy. The optical, mechanical and vacuum components of the beamline, as well as the related infrastructures, are completely new. They have been constructed by five research centres of the Helmholtz Association of German Research Centres (DESY, FZJ,[2] HZB, HZDR and KIT) under the leadership of DESY. The source is an EPU (Elliptically Polarized Undulator) of the APPLE II (Advanced Planar Polarized Light Emitter) type previously installed at HZB. It has been fully refurbished and inserted in the long straight section 11 of the SESAME ring. SESAME provided all the necessary infrastructure for the installation and operation of the beamline. The Helmholtz Association funded the source, the front-end and the beamline in full, and provided all the necessary support for the installation and alignment of the beamline.

The **ID11R-TXPES beamline** is being funded by the Turkish Government. It is being constructed by Bilkent University, TARLA[3], Koç University and TENMAK[4] in a consortium led by TENMAK. TXPES will be the first beamline at SESAME to be designed and built by the national community of one of its Members. It will share the source of the HESEB beamline to provide a soft X-ray photoelectron spectroscopy branchline for high resolution core-level photoemission spectroscopy. Although Turkish scientists will have priority beam time on this beamline, it will also be open to the user community of other Members and countries. It is a beamline that will allow in-depth investigations on the electronic and structural properties of a variety of samples that range from single crystals to thin films and new nanostructured materials.

The **MX beamline** will be a completely new beamline. It will be a state-of-the-art beamline, and will be used to elucidate the mechanisms of proteins and nucleic acids at molecular level and provide guidelines for developing new drugs and therapies. It is envisaged that in the early stages there will be strong collaborations with recombinant protein production and crystallization laboratories in the region. MX is of high priority for SESAME since by offering research opportunities in structural biology and macromolecular crystallography it will raise the level of scientific research in the Middle East and neighbouring countries to one of high prestige that would rank it as world-class. Most of the current discoveries in medicine related to structural biology are to be attributed to recent developments in synchrotron radiation and its applications. A recent important example is how most synchrotron radiation facilities joined forces to face the coronavirus pandemic and offered their capacities to the global scientific community. Protein crystallography studies at synchrotrons have contributed to the award of six Nobel prizes, the first in 1997 and the most recent in 2020. The conceptual design of SESAME's MX beamline, based on an in vacuum undulator source, variable energy monochromator, robotic sample handling and high-performance photon counting detector, is being updated to take account of

[1] DESY (Detaches Elektronen-Synchrotron), Elettra (Elettra-Sincrotrone Trieste S.C.p.A.), and INFN (Istituto Nazionale di Fisica Nucleare)

[2] FZJ (Forschungszentrum Jülich), HZB (Helmholtz-Zentrum Berlin), HZDR (Helmholtz-Zentrum Dresden-Rossendorf) and KIT (Karlsruher Institut für Technologie)

[3] TARLA (Turkish Accelerator and Radiation Laboratory)

[4] TENMAK (Turkish Energy, Nuclear and Mineral Research Agency)

the most recent developments in the structural biology landscape, such as the increased use of cryo electron microscopy and the capabilities of artificial intelligence (AI) networks in solving a protein's 3D shape from its amino-acid sequence.

Planning for the **SAXS/WAXS beamline** and for the **VUV beamline** is yet to start.

VI. Users

The users of SESAME are based in universities and research institutes principally, though not exclusively, in the region, thereby permitting networking with scientists both in and beyond the Middle East and neighbouring countries. They visit the Laboratory periodically to carry out experiments, generally in collaboration, where they are exposed to the highest scientific standards. There are now (April 2023) 1,331 users registered on SESAME's database. The potential user community, which continues to grow rapidly, is being fostered by a series of Users' Meetings and by excellent training opportunities (supported by the IAEA, the European Union, various governments, many of the world's synchrotron laboratories, and foundations and small charities) which are already bringing significant benefits to the region.

SESAME also regularly organises webinars for institutes in the SESAME region to allow prospective users to better understand what SESAME may do for them and what users need from SESAME.

The number of users applying for beam time is constantly growing, and a total of 572 proposals were received in the six calls issued in the years 2017-2023. This number is all the more impressive when one considers that the first two calls were limited to beam time at the XAFS/XRF and IR beamlines, the fourth to the MS/XPD beamline, and at the beginning of 2020 the COVID-19 pandemic erupted and greatly slowed down activities. This large number of applications points to the clear need for a synchrotron light source in the region.

Some of these proposals were from new users and others from users having already utilized SESAME's facilities seeking to return to carry out further experiments. This demonstrates that SESAME's facilities are fully meeting users' expectations.

SESAME's reputation as a state-of-the-art synchrotron light source has extended beyond the borders of its Members, and although preference in the allocation of beam time is given to scientists in the SESAME Members, in one or a number of the six calls there have also been proposals from users in the following countries: Algeria, Belgium, Colombia, France, Germany, India Italy, Kenya, Malaysia, Malta, Mexico, Morocco, Netherlands, Oman, Qatar, Russian Federation, South Africa, Sweden, the UAE, and the U.K.

All proposals are reviewed by SESAME's Proposal Review Committee (PRC), an international advisory body responsible for evaluating the scientific and technological merit of proposals and determining their priority using criteria based on IUPAP's (International Union of Pure and Applied Physics) Recommendations for the Use of Major Physics Users Facilities.

Beam time has been granted for 294 of the proposals received. The experiments carried out so far (April 2023) ranged from topics such as novel materials for energy applications such as batteries and fuel cells; the biological analysis of algae; synchrotron-based infrared investigation of shock features in Martian and Lunar meteorites; the possible use of herbs for treating Alzheimer's Disease; the study of arsenic in the rice grains and rice farm soils in Iran; and ancient manuscripts from the Quran.

Users visiting SESAME for their experiments are accommodated at SESAME's Sergio Fubini Guest House located on the SESAME campus. This is a three-storey building consisting of 48 bedrooms, each equipped with a range of modern amenities. Two are accessible to disabled persons. There is a small kitchenette and laundry room on each floor, and a large dining area and meeting room on the ground floor. During periods when they are not needed by SESAME, the meeting room, as well as the Guest House provide a venue for regional meetings on other topics (such as agriculture, water resources and pollution) in secure and easily accessible surroundings, thus furthering SESAME's mission as a focal point for regional cooperation.

VII. Opportunities for National Institutions and Scientists and Engineers from the SESAME Members

SESAME provides the scientists of its Members with an exceptionally powerful tool for their work that allows them to reach a degree of precision in their experiments that would otherwise not be possible. It also provides them with a unique environment for training and research in a field that is at the frontiers of science. Young scientists and engineers are not only able to benefit from the fellowships provided through SESAME, but they also have greater opportunities for hands-on training and research through more generous beam time allocations than would be available elsewhere, *ad hoc* training on SESAME's instruments, and use of the instruments in research for a Master's or PhD degree. Furthermore, through international cooperation enabled by SESAME, scientists and engineers from the Members of the Centre are brought to world-level standards and will become equal partners in the world scientific community.

1. Scientific and Technical Activities

Scientists from the Members of SESAME have full access, free-of-charge, to the facilities in the Laboratory, including existing beamlines and instruments as outlined in the SESAME User Policy. They are able to propose to design and conduct experiments according to their specific interests/needs, without being limited to what is offered under routine operational conditions at synchrotron radiation user facilities elsewhere. For the SESAME User Policy please see:
(https://www.sesame.org.jo/for-users/user-guide/sesame-user-policy)

National universities of the Members also stand to benefit. The international synchrotron radiation community's enthusiastic response to SESAME gives rise to international collaborations and student exchanges, and this helps to enlarge local pools of know-how. Moreover, since many experiments are carried out in international collaborations by scientists from universities in the Members of SESAME and beyond, this enables universities to compare their standards with those of internationally-renowned universities which, in turn, contributes to raise the level of their competence. Universities also benefit from various spin-offs. For example, with the help of SESAME, the infrastructure of internet connections is being developed to enable the intensive exchange of electronic messages and huge scientific data produced by the SESAME beamlines. Furthermore, local high-technology capacity, in areas such as ultrahigh vacuum, high-specification electromagnet production, electronics and IT infrastructures, is being developed to support experiments conducted at SESAME, and also preliminary or complementary experiments that SESAME users may wish to conduct in their home country. Examples are the EU-funded LinkSCEEM and BioMERA projects at The Cyprus Institute, which not only helped to define the computing needs of SESAME, but also provided a user base for the supercomputing facility, and the establishment at The

Cyprus Institute of a Tomolab (tomography laboratory) complementing the BEATS beamline.

In the same way that the intense scientific activity of CERN in Switzerland led to the creation of other European scientific organisations, e.g. EMBL (European Molecular Biology Laboratory) in Germany, SESAME's activity may in the long term lay the seed for the establishment of other collaborative laboratories in the region, which in turn will bring greater prosperity to the participating countries and innovative openings for their scientists and engineers.

2. Training

Scientists and engineers from the SESAME Members are able to benefit from SESAME's large training programme. To date, some US$5.7 million have been invested in training (almost all provided by outside supporters). The training programme has three main elements:

(a) Users' Meetings that provide a forum for formulating SESAME's scientific strategy, and are fostering the formation of international collaborations which will carry out experiments at SESAME. So far, seventeen users' meetings have been held and more will be organised (for details see https://www.sesame.org.jo/sesames/events). At each there is an average of 90 participants. Regular funding for these meetings is generally provided by the American, British, French, German, Italian and European physical societies, the American, French and German chemical societies, the German Mathematical Society and the International Union of Pure and Applied Physics (IUPAP).

(b) Workshops, seminars, webinars and schools of which SESAME has organised some 51 in the Middle East and elsewhere. These events have attracted some 2,000 scientists and engineers. The workshops, seminars and webinars focus on specific topics, recently this has been more particularly on use of the ID10-BEATS and ID11L-HESEB beamlines, while the schools provide basic training for *inter alia* carrying out experiments at synchrotrons, machine commissioning, instrumentation, safety, science administration and management, and public outreach. Support for these activities has been forthcoming amongst others from the European Union (EU), which provided €2M through the Open SESAME project (http://www.opensesame-h2020.eu/en/) and is funding the BEATS project, the International Atomic Energy Agency (IAEA), the Abdus Salam International Centre for Theoretical Physics (ICTP), and the Helmholtz Association of German Research Centres through the HESEB project.

In 2023, SESAME is launching a summer school on its premises to provide a small number of scientists with hands-on training at the laboratory.

(c) Individual training through visits to leading laboratories around the world and hands-on training at SESAME.

Approximately 203 young scientists and engineers from the SESAME Members have been recipients of fellowships that allowed them to spend periods of up to two years receiving training, or working at synchrotron radiation facilities and other centres (mostly in SESAME Observer countries) in Europe, the USA, Asia and Latin America. These fellowships are being financed, or have been financed, by sponsors such as the IAEA, which has already provided more than €1.5 million for SESAME's training programme, the UK Department for Business, Energy and Industrial Strategy (BEIS) through the Rutherford Fund which provided some GBP1.2M, the EU, ICTP, the Helmholtz Association of German Research Centres through the HESEB project, the Swedish Institute, and synchrotron laboratories in different parts of the world, foundations and small charities.

Young scientists and engineers have also benefitted from *ad hoc*, hands-on training on SESAME's premises and the possibility of carrying out research there for their Master's or PhD degree. Generally of a duration of between two to six months (more in the case of research for a degree), this training/research in accelerator-related matters, now also being extended to beamlines, has allowed the scientists and engineers to take part in concrete tasks on the machine, thereby giving them the opportunity to acquire experience in unique one-time jobs. To date, SESAME has hosted over 30 university students and post-graduate students, principally from Jordanian universities, but through SESAME's secondment programme this on-site training/research may be extended to scientists and engineers of other Members who, during their stay at SESAME, may be offered free sleeping accommodation at SESAME's Guest House.

It should be pointed out that the engineers who received training in European laboratories on how to install and later operate a synchrotron radiation source in the early years of the SESAME project received this tuition thanks to the SESAME training programme and the generosity of their European hosts. A number of the engineers are now staff members of SESAME. A similar mechanism was subsequently established for scientists to learn how to install and operate beamlines, and how to carry out tests using synchrotron radiation techniques.

How much a Member benefits from SESAME's training programme depends on how active a Member is in proposing candidates. This training is not only useful for the exploitation of SESAME, but also has benefits for the Members' universities, and even industry - some of the people trained by SESAME have moved to high-tech jobs in the SESAME Members.

VIII. Staff at SESAME and Contracts for Equipment/Services

Although no definite quotas are foreseen, applicants from the Members are given priority when international staff are hired at SESAME.

Moreover, for contracts for equipment/services placed by SESAME preference is given to national companies from the Members (provided their bids are not more than 8% higher than any bid from a non-Member), and they have been awarded a number of contracts for components of the SESAME machine. Such contracts are not only interesting from a financial point of view, but in many cases are important tools for technology transfer. There are also several examples that show how the procurement of innovative components based on industry-research relations promotes the development of regional industrial ecosystems. The flow of contracts is expected to continue at SESAME as further beamlines are built, other facilities are added, and (in due course) SESAME is upgraded, as happens periodically at all light sources.

As in the case of the training programme, the number of nationals a Member has serving on the staff of SESAME and the number of contracts awarded to a Member's national companies depends on how active a Member is in proposing candidates and submitting offers in response to calls for tenders.

IX. Obligations of the SESAME Members

1. Intellectual and Other Obligations

The SESAME Members are to ensure that they are represented on the Council of SESAME by persons having the required experience and authority. Each Member may have up to two delegates on the Council. Ideally, one should be a scientist and the second a person entrusted with decision-making powers. They may be accompanied to Council meetings by up to two advisers.

The delegates to the Council should make known the Council decisions to their respective national authorities. They should be pro-active in responding to the Council's calls for representation on its advisory committees, candidates for training and vacant SESAME staff positions, bids for components that are to be purchased for the SESAME beamlines, etc. They should bring SESAME's activities to the attention of their national scientific institutions and universities so that their country may benefit to the full from the opportunities offered by SESAME.

2. Financial Obligations

The operational costs of SESAME (staff costs, materials for operating the machine, running the Centre……) are covered by the Members of the Centre, and the total yearly budget is distributed among them based on a system inspired from the principles of the UN scales. The yearly budget and its distribution among the various Members are presented to the Council every year and require unanimous approval by the Council.

The total yearly budget in 2023 is US$5,289. It is expected to gradually rise as the project expands and more beamlines are constructed.

X. Capital investment

Israel, Jordan and Turkey have each provided US$5 million as a voluntary contribution towards SESAME's capital investment.

Although contributions to the capital budget are not obligatory, it is hoped that current (and future) Members will provide such funding for construction of future beamlines, further development of SESAME's infrastructure, and the periodic upgrading of SESAME's facilities.

XI. Further Information About SESAME

A visit of the SESAME Centre may be organised on request.

More information about SESAME is available at https://www.sesame.org.jo

See also Science Opportunities at SESAME https://www.sesame.org.jo/sites/default/files/images/Brochures/science-opportunities-at-sesame.pdf

See also videos https://www.sesame.org.jo/about-us/what-is-sesame/video-about-SESAME

See also brochures https://www.sesame.org.jo/about-us/information-material/brochures

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