

Synchrotron Radiation Facility in the Middle East

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Abstract

A summary of results on synchrotron radiation is presented along with notes on its properties and applications. Synchrotron radiation facilities are described briefly with a special attention to the upcoming synchrotrons, in particular the Middle East Synchrotron. Other upcoming synchrotrons are also described briefly.

Introduction to Synchrotron Radiation

Charged-particles when accelerated radiate electromagnetic energy. This interesting physical phenomenon, now known by the name synchrotron radiation had its theoretical beginnings a long time ago at the time of classical electrodynamics. At that time, only the very basic features of this physical phenomenon were studied and expressions were derived for several quantities such as the total radiation intensity, spectral distribution and angular distribution¹. These theoretical studies had to wait for about half a century till the development of charged-particle accelerator technology for a direct observation and experimental verification. It was experimentally observed for the first time in 1947 in a 70 MeV electron synchrotron, hence the name synchrotron radiation. This observation generated a renewed interest in synchrotron theory. Synchrotron radiation was an irritant in early electron synchrotrons and storage rings. But it was soon realized that synchrotron radiation was a very valuable product in itself for research applications requiring intense and bright sources of light over a wide range of wavelengths. Electrons lose a large amount of energy in the form of synchrotron radiation, putting a limit on the maximum attainable energy in a given type of accelerator. For instance the limit is about 300 MeV for a betatron. This challenge of the synchrotron radiation stimulated the development of accelerator technology and further increased the energy of the accelerated particles.

Here it would be relevant and very interesting to mention the case of the hyperbolic motion which occurs when the charged-particle experiences a constant force. This force can be produced, for example, by a constant uniform electrostatic field. Does a charged-particle under uniform acceleration (hyperbolic motion) radiate? The answer to this question is not completely resolved! This topic is listed as one of the several surprises in theoretical physics in the compilation due to Peierls².

Synchrotron radiation is extremely intense over a broad range of wavelengths from the infrared through the visible and ultraviolet range and into the vacuum ultraviolet and soft and hard X-rays parts of the electromagnetic spectrum. The high intensity over a very broad spectrum range and certain other properties (including collimation, polarization, pulsed-time structure, partial coherence, high-vacuum environment, ...) make synchrotron radiation a very powerful tool for a variety of applications in basic and applied research and technology. It is particularly important in those parts of the electromagnetic spectrum where laser sources are (presently) not widely available such as the vacuum ultraviolet, soft and hard X-rays, parts of the infrared, etc.. The applications of the synchrotron light span a wide range of domains in fundamental science (chemistry, physics, biology, molecular medicine, etc.) applied research (materials science, medical imaging,

pharmaceutical R&D, advanced radiology, etc.) and industrial technology (micro-fabrication, micro-analysis, photo-chemistry, etc.).

A synchrotron radiation facility is based on the technology of charged-particle accelerators. Bunches of charged-particles (usually, electrons) are made to circulate for several hours inside a ring-shaped, long tube under high vacuum. These rings have several beam lines with experimental stations and serve several sets of users simultaneously. Contrary to the expectation there are not very many synchrotron facilities to meet the huge demands of numerous users. This is due to the high costs (hundreds of millions US\$) and the required optimum technological expertise. Currently, around the world there are about fifty storage rings in operation as synchrotron radiation sources, located in twenty-three countries. About a dozen are under construction and another dozen or so are being planned. This small group leaves out not only many countries but several regions (such as the Middle East, the Continents of Africa and Australia) without a single synchrotron facility.

Storage rings are very flexible devices. By reusing most of the major components their performance can be upgraded at an incremental cost that is small as compared with the cost of construction of a new synchrotron. In recent years this flexibility is being innovatively exploited to relocate the very generously donated synchrotrons to those locations which are under-represented in the World Synchrotron Map³.

SESAME

Jordan is the first country from the Middle East to join the elite group of countries possessing a synchrotron light source⁴. This became possible as Germany decided to generously give the BESSY-I, a 800 MeV synchrotron, fully functioning since 1982 in Berlin, to the region of Middle East. BESSY stands for Berliner Elektronen-Speicherring für Synchrotronstrahlung. BESSY-I is to be replaced by the more powerful BESSY-II, a 1900 MeV synchrotron located in another part of Berlin. Germans are well-known for their environmentally responsible attitude towards reusing and recycling, and now they have very successfully extended that attitude to the large-scale research facilities! The idea of donating the BESSY-I Synchrotron came from Herman Winick of the Stanford Linear Accelerator Center (SLAC) in California, a member of the Machine Advisory Committee of BESSY-II, and the fellow committee member Gustav-Adolf Voss, a former director of Deutsches Elektronen-Synchrotron (DESY) in Hamburg, Germany. The Project is known by the acronym SESAME (Synchrotron-light for Experimental Science and Applications in the Middle East)⁵. The SESAME Project reached a major milestone with the selection of a site in Jordan at a Meeting of the SESAME Interim Council in Amman, Jordan during 21-22 June 2000. SESAME will be the upgraded reincarnation of BESSY-I. The upcoming joint synchrotron radiation facility, which would be the first regional centre for cooperation in basic research in the Middle East will also serve as a seed for an International Centre built around the facility. SESAME will be located at the Al-Balqa' Applied University in Al-Salt and will be open to scientists from any country in the region or elsewhere. Because of this openness, organizers see its potential as not only a world-class research centre, but also as a politically important example of scientific cooperation in the region. Such a centre has been long overdue and it shall be the first of its kind in the region. The Centre will be operated and supported by its eleven member countries (Armenia, Cyprus, Egypt, Greece, Iran, Israel, Jordan, Morocco, Oman, Palestine and Turkey) with support from countries including, France, Germany, Italy, Japan, Russia, Sweden, Switzerland and USA. Other countries which have expressed an interest to join this new fount of science and medium of international cooperation include, Bahrain, Tunisia and Yemen. It is hoped that the new centre will be able to mirror the CERN in stimulating regional research collaboration. Very much like CERN, SESAME is under the very valuable political umbrella of UNESCO and is expected to promote science and foster international cooperation⁶. A broad-spectrum of planned research programmes

include structural molecular biology, molecular environmental science, surface and interface science, micro-electromechanical devices, X-ray imaging, archaeological microanalysis, materials characterization, and medical applications. A detailed account of events leading to the SESAME are available in reference 7.

It is very disheartening to note that many countries from the Middle East are yet to participate in the novel project of SESAME. These countries are missing an excellent opportunity in the arena of International Scientific Collaboration. Same is the sad state of affairs for countries in rest of Asia and the continent of Africa. Many of these countries have had very old ties with the countries of the Middle East since very ancient times. In recent decades, these ties have been further strengthened by their large presence in the region, leading to active economic collaboration. They could have taken a keen interest in the SESAME. Nature in one of its editorials aptly advised, “any potential funder is not to hold back, for this would be a worthwhile investment. Initiatives such as this do not come around often. When they do, they should be supported unhesitatingly”⁸. Scientific cooperation across the geographical and cultural borders helps stimulate not only the advancement of ideas in the professional field, but also the building of lasting bridges and the establishment of contacts on the personal and more importantly the international level. The costs involved for participation are not much, for any country.

Here, it would be essential to recall the earlier attempts (though unsuccessful and now almost forgotten) to build Institutions (including, synchrotron radiation facilities) in the Middle East^{9,10}. The originator of these attempts is none other than Abdus Salam, a 1979 Nobel Prize winner in Physics, the founder and long-time director of ICTP (recently renamed in his honour as Abdus Salam ICTP) and a humanitarian who devoted much of his life to uplifting the status of science and technology in the third world¹¹. Salam dreamed of creating twenty international centres like the ICTP, spread throughout the world^{12,13}. ICTP attracts thousands of visitors every year, mostly from the developing countries for whom it was created. For the period 1970-1998, Nationals from the Middle East have been benefited by about 2,500 visits totaling to about 3,500 person-months¹⁴. As part of that vision, Salam actively promoted the idea of advancing the cause of science and technology in the Middle East, not only by having researchers from the region work with their colleagues in the developed world, but also by having the region develop its own facilities including a synchrotron laboratory! In May 1983, at the Symposium on the Future Outlook of the Arabian Gulf University, held in Bahrain, Salam delivered a paper entitled “The Gulf University and Science in the Arab-Islamic Commonwealth”, in which he reminded his listeners that, “We forget that an accelerator like the one at CERN develops sophisticated modern technology at its furthest limit. I am not advocating that we should build a CERN for Islamic countries. However, I cannot but feel envious that a relatively poor country like Greece has joined CERN, paying a subscription according to the standard GNP formula. I cannot rejoice that Turkey, or the Gulf countries, or Iran, or Pakistan seem to show no ambition to join this fount of science and get their men catapulted into the forefront of the latest technological expertise. Working with CERN Accelerators brings at the least this reward to a nation, as Greece has had the perception to realise” (p. 45 in reference 12). He then went on to make the following points: “I have mentioned an international laboratory in materials sciences for Bahrain, with specialisation in microelectronics and modern electronic communications, including space satellite communication, to help also with the banking communications needed at Bahrain.” Such a laboratory was in fact proposed for the University of Jeddah. The idea was to emphasise science transfer in addition to technology transfer and to create international laboratories in the fields of materials sciences, including surface physics and a laboratory with a synchrotron radiation light source. The facilities created would have been of the highest possible international order; the laboratories would have been opened to teams of international researchers, who would congregate and work at Jeddah, just as they congregate now at the great laboratories in Hamburg, Geneva or Paris (p. 53 in reference 12).

SESAME envisages a road map for science, technology and cooperation in the Middle East, but at the same time, SESAME does not totally fulfill the dreams of Salam for several reasons: Many countries from the Middle East are yet to participate. The driving force is coming from outside of Middle East and not from within.

The SESAME Training Committee at ICTP is coordinating programmes which will enable the trainees to join research groups and technical teams at several synchrotron laboratories. They will get training in research and experience to work on the current technical issues relevant to the maintenance, running and repairing of a synchrotron light source. The participating laboratories include: Elettra (Trieste), Daresbury Synchrotron Radiation Source (Daresbury), EMBL-DESY (Hamburg) and LURE (Paris).

Other Upcoming Synchrotrons

Siam Photon Source:

Recently the Japanese donated a 1000 MeV synchrotron to Thailand¹⁵. Thus, Asia-Pacific region became the birth-place for the Era of the Relocated Synchrotrons. Located 250 km North-East of Bangkok in the city of Nakhon Ratchasima, the "Siam Photon Source" is Thailand's first synchrotron light facility and is intended to serve scientists throughout Southeast Asia. The original synchrotron light source, called SORTEC, was located in Tsukuba Science City, near KEK, Japan's High Energy Accelerator Research Organization. Thailand's Ministry of Science, Technology, and Environment got the machine as a gift and is investing about US\$ 15 million to move and upgrade it. This includes the doubling of the circumference to 81 m and tailoring the machine to produce narrow bright beams of soft X-rays and ultraviolet radiation. Scientists from the KEK have helped in the redesign and are training the scientists from Thailand to operate their new facility. Professor Tokehiko Ishii, the retired Director of the Synchrotron Radiation Laboratory at University of Tokyo is the key figure in orchestrating the donation. He is also overseeing the technical and scientific aspects of the transfer and upgrading of the synchrotron. The plan is to use the Siam Photon Source for physics and chemistry research, with some industrial research in semiconductors, medicine, pharmaceuticals, and agriculture. Siam Photon Source is scheduled to go on-line in 2002¹⁶.

DELSY:

A Dutch accelerator and storage ring used for nuclear physics is being moved to Dubna, to add to Russia's Synchrotron capability¹⁷. The original facility, was located at Institute of Nuclear Physics and High Energy Physics (NIKHEF) in Amsterdam, The Netherlands. This shall be the 1200 MeV "Dubna Synchrotron Radiation Source (DELSY)", located at the Joint Institute of Nuclear Research (JINR) in Dubna.

Siam, SESAME and DELSY are very unique facilities as they are being built by relocating the very generously donated synchrotrons. There are several countries which are in the process of building their own synchrotrons. Armenia is planning to build the 3200 MeV CANDLE: Center for the Advancement of Natural Discoveries using Light Emission¹⁸. There is the proposal to build the 3000 MeV BOOMERANG¹⁹ under the Australian Synchrotron Research Programme (ASRP). Spain has the project for a 2500 MeV National Synchrotron Laboratory (LLS) at Barcelona²⁰.

Concluding Remarks

The upcoming synchrotron facilities will be able to bridge the gap in several of the under-represented regions of the World Synchrotron Map³. These, when built, will immensely benefit the

scientific community in the concerned regions by enhancing international cooperation and providing them the latest technological expertise. Among the upcoming synchrotrons, SESAME is the most international project and offers an excellent opportunity for participation and active international collaboration. This is more true for the countries in the Asian region and they should get involved and play a significant role^{21,22}.

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