# *THE IMPACT OF SYNCHROTRON LIGHT SOURCES ON SCIENCE AND SOCIETY IN DEVELOPING COUNTRIES*

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At present there are more than 50 synchrotron radiation light source research facilities in operation in 19 countries around the world, with more in construction and design (see www.lightsources.org). Although most facilities are in technologically advanced countries, there is significant activity in the developing world. Twenty to thirty years ago several developing countries (Brazil, China, India, Korea, and Taiwan) began light source projects. These have now been completed and have been in operation for about 10 or more years. More recently a light source has started operation in Thailand (http://www.nsrc.or.th/Eng/index.htm). In this paper we describe the benefits that operating synchrotron light source facilities in developing countries have had.

Other projects are in progress. The SESAME project in Jordan (www.sesame.org.jo) is now constructing a 2.5 GeV third generation light source. A 3 GeV third generation light source is in design in Armenia (http://www.candle.am/index.html) and discussions are underway for a light source for southern Africa.

In the UNESCO-sponsored SESAME project eight countries (Bahrain, Cyprus, Egypt, Israel, Jordan, Palestinian Authority, Pakistan and Turkey) have joined to create a regional international synchrotron radiation research center which is now in construction in Jordan. The project started with equipment donated by Germany. In endorsing SESAME, the UNESCO Executive Board and General Assembly called it ***"a model for other regions"*** and ***"a quintessential UNESCO project for capacity building through science"***. Although the project is still in construction, significant benefits to the region have come from many workshops, schools, and Users' meetings in which hundreds of scientists from the region have met with scientists from around the world who have had experience using synchrotron radiation. Most of these have focused on the many applications of synchrotron radiation to basic and applied research. In addition, fifty young engineers and scientists from the Middle East have been trained in accelerator technology in a 10 day school and eighteen of them have spent two years working with accelerator groups in European laboratories. Several of these are now on the accelerator staff of SESAME.

Pakistan has been a strong member of SESAME and is planning to construct a beam line on the storage ring. Several other countries have also announced their intention to build beam lines at SESAME. In addition, plans are being developed in Pakistan for a future 2.5-3 GeV third generation national light source, in anticipation of the growing community of users there.

Why is a synchrotron radiation facility relevant to a developing country? Before a light source is approved in a developing country a committee is usually formed to study the matter. The objectives and potential benefits identified by these committees include:

- Create a world-class interdisciplinary research laboratory
- Promote basic & applied research & technology
- Address regional biomedical & environmental issues/concerns
- Provide an environment for collaborations & individual development
- Train graduate students who will no longer have to go abroad
- Attract scientists working abroad to return
- Promote international scientific collaborations
- Promote development of high-tech industry (capacity building)

One of these, the UNESCO-sponsored SESAME Project in Jordan (www.sesame.org.jo), has an additional objective:

- Use scientific cooperation to promote peace & understanding between people from different traditions, religions, races, & political systems.

Below we summarize the impact that operational synchrotron radiation research facilities have had in several developing countries. The information presented was obtained from

- facility web sites
- presentations made at SRI2006 in Korea (see http://sri2006.postech.ac.kr/)
- inquiries in early 2006 to directors of operating facilities in developing countries

***1. Laboratório Nacional de Luz Síncrotron (LNLS); Campinas, Brazil (ref. 1)***
http://www.lnls.br/index.asp?idioma=2&opcaoesq

A 1.35 GeV light source has been in operation in Campinas since1997. In 2004 there were more than one thousand external users. Demand for beam time exceeds available time by a factor of two. Twelve beam lines are in operation.

Since 2000 more than 29 PhD theses and 21 Masters Dissertations have been completed based on work done at LNLS. Almost all of the technical components of the facility were built in Brazil, largely by LNLS, which now has skills unique in Brazil in certain technical areas (ultra-high vacuum, magnets design and construction, controls, rf, etc). For example, as a result of the experience gained in constructing the storage ring, LNLS now supplies UHV equipment at cost to universities in Brazil. Of sixteen staff scientists four returned to Brazil after their postdoctoral research abroad.

LNLS plays an important role in the Latin-American scientific community (15% of LNLS users come from outside Brazil, including 9-10% from Argentina). Others come from Africa, Europe, and the USA.

LNLS has made significant contributions to industrial development in Brazil. One company got its start by building flanges for LNLS. In a permanent program to train industrial scientists, about 15 students work each year at LNLS for 6 months before taking industry jobs. Seven joint projects with industry are underway (e.g. catalysis). LNLS develops special instrumentation to meet the needs of industrial users. Seven LNLS staff are dedicated to service to industry.

LNLS has introduced the concept of a national research facility, equipped with world-class equipment and open to all.

***2. Beijing Synchrotron Radiation Facility (BSRF); Beijing, China: (ref. 2)***
http://www.ihep.ac.cn/bsrf/english/main/main.htm

A 2.5 GeV light source has been in operation since the early 1990's. The storage ring is primarily used as a high energy physics colliding beam facility, and partly used for synchrotron radiation research. A major upgrade program for both high energy physics and synchrotron radiation has recently been completed. This included a new experimental hall and a new wiggler beam line.

In the period from 1999 to 2006 about 100 students completed a PhD or Masters Degree and fifteen completed postdoctoral work. Three former students returned after periods abroad as postdocs or staff members at other institutions.

Before the shutdown for the upgrade 13 beam lines and 13 experimental stations were in operation (6 wiggler beam lines and 7 bending magnet beam lines) serving 1087 users from 21 domestic cities. Users came from 86 (including 6 foreign) Universities, Institutes and companies (catalysis, micro-electronics and others).

***3. National Synchrotron Radiation Laboratory (NSRL); Hefei, China (ref. 3)***
http://en.nsrl.ustc.edu.cn/

An 0.8 GeV light source has been in operation since 1991. A major Phase II upgrade was carried out from 1999 to 2004. NSRL now operates 14 photon beamlines and experimental stations, three of them from a 6 Tesla superconducting wave length shifter (SLS) and one from a 29-period permanent magnet undulator. The facility operates for 4,800 hours per year and serves 400 users.

58 PhD and 53 Masters Degrees have been produced by the University of Science and Technology of China alone. This now continues at the yearly rate of 20 PhD and 20 Masters Degrees per year. A total of about 150 graduate students are now involved. Several senior scientists have returned to NSRL from abroad, including Chen Gao from LBNL, now Vice-Director of NSRL.

***4. Pohang Accelerator Laboratory (PAL); Pohang, Korea (ref. 4)***
http://pal.postech.ac.kr/eng/index.html

A 2.5 GeV light source has been in operation since 1994. Twenty seven beam lines, inclduding six from insertion devices, are in operation, serving 1500-2000 users each year. About 500 papers are published each year based on work at the light source.

Ten scientists returned to Korea to join the laboratory. Four became directors. Thirty professors who returned to the Pohang University of Science and Technology (Postech) are now users of the light source. Many others returned to become faculty at other Korean Universities and are now as users at PLS. At least 40 PhDs have already been completed at Postech using the light source. About 100 PhDs have been completed at other universities in Korea using the light source.

Many parts of PLS have been built in Korea (magnets, power supplies, vacuum chambers, ion pumps, klystrons, modulators, beam position monitors, etc.). The 2.5 GeV linac injector was designed and constructed in collaboration with China, although China & Korea did not have diplomatic relations until 2 years after this collaboration started. Collaborations with other countries included France, Italy, Japan, the UK, and the US.

Several new companies were formed as a direct result of the light source project. These include Geumryong (magnets), VMT (ion pumps), a controls company, and an alignment company. Samsung & LG studied defects in LSI chips & LCDs for cellular phones.

A comment by a former director: "As a result of the success of the PLS project, ordinary Koreans and the Korean government trust Korean scientists since they spent a large amount of money and achieved, and even exceeded, project goals. Initially there was some doubt that this could be done."

***5. National Synchrotron Radiation Research Center (NSRRC)***
***Hsinchu,Taiwan (ref. 5)*** http://www.nsrrc.org.tw/

A 1.5 GeV light source has been in operation since 1993. A total of 28 beamlines, 45 end stations, and 8 insertion device magnets are in operation. These serve about 1000 users on 660 experimental proposals in 2005. Also two hard x-ray beam lines (one from a bending magnet and one from an undulator) have been constructed at Spring 8 in Japan for use by scientists from Taiwan. These have been in operation since 2001.

So far more than 140 students have received the PhD based on work done at the light source. More than 25 overseas Taiwanese scientists returned to NSRRC, universities, and national research institutes in Taiwan due at least in part to the light source.

There has been significant benefit to companies in Taiwan which have collaborated with the light source to develop capabilities to design, fabricate, and measure many technical components. This includes magnets, insertion devices (including superconducting devices), ultra-high vacuum chambers and other components, survey and alignment technology, beam line components, x-ray energy analyzers, cryogenics technology, radio frequency components, digital electronics, and brazing technology.

As part of the international synchrotron radiation community, the light source has had many interactions with other facilities, including Spring 8, ANKA, ALS, SSRL, CHESS, the Australian light source, and SESAME. The Taiwan light source has provided full support for three fellowships for scientists from the Middle East who worked at NSRRC for one year. Three more have been offered.

A new 3-3.3 GeV third generation light source is proposed at the same site. This proposal is currently under evaluation by the National Science Council of Taiwan.

***6. National Synchrotron Research Center (NSRC)***
***Nakhon Ratchasima, Thailand (ref. 6)*** http://www.nsrc.or.th/Eng/index.htm

A 1 GeV light source has been in operation since 2001 using equipment donated by Japan. It has recently been upgraded to 1.2 GeV. Three beam lines are now in operation. A 6.4 T wavelength shifter is now being installed. This will provide a spectrum with a critical photon energy of 6.15 keV and useful intensity up to 20-25 keV. Seven students have completed PhDs and two have completed Masters Degrees. Presently, ten PhDs and four Masters Degrees are in progress.

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