The National Laboratory for Synchrotron Light

THE BRAZIL EXPERIENCE

by CYLON GONÇALVES DA SILVA

The Director of the Brazilian synchrotron light source relates his experiences in building a complex scientific instrument in a developing nation.

WHY IS BRAZIL BUILDING a synchrotron light source? Have synchrotron light sources become the technological status symbol of the 90s for developing countries, as nuclear reactors were in the past? Not very likely. However, how can one explain that so many of these countries—Taiwan, South Korea, India, China, Brazil, Thailand—have built, are building, or are talking about building their own synchrotron facilities? The lure of "Big Science"? The "keeping up with the Jones'" syndrome? In spite of many differences—historical, cultural, economic, and political—I believe that the role of science and technology in modern life is the prime reason behind all of these projects. Unfortunately, nothing is more difficult to pinpoint in a clear and immediately perceivable way than the elusive relationship between science and technology on one hand and economic development on the other. In the major industrial nations, this relationship—which was taken for granted at least since the last World War—is now the object of serious questioning. In a developing country, a project such as a synchrotron light source may spark debates that compare in acrimony with those surrounding the Superconducting Super Collider project in the United States.

A view of the LNLS under construction.

N. Chinaglia, March 1996

Synchrotron light sources are assumed to be evidences of and contributors to a modern advanced economy. Industrial applications are an important selling point, even when in practice they still account for only a small—not to say, insignificant—fraction of their use. What counts for a developing country, at least initially, is not actual applications of synchrotron light, but building a complex scientific instrument. The technologies behind a storage ring are seen as “enabling” tools for further developments. If we can do this (the storage ring), then we can do that (modern production technologies) also. A country must break into the virtual circle of economic development on many fronts simultaneously. Building capability to do quality R&D is one of the most important social functions of large scientific projects in these countries. The process is rarely uniform or follows an efficient, logical path. It is instead history dependent owing to chance events, highly non-uniform, and messy (witness the somewhat empty experimental halls of many new synchrotron laboratories).

CONCEPTUALLY, the Brazilian project was sold on what I have called—in homage to the high-energy physics of my student days—the three-fold way: a strategy combining engineering, science, and organization. The three-fold way is depicted schematically in the pie chart on the right. Engineering meant designing and building as much as possible of the storage ring and instrumentation in Brazil, with the help, whenever possible, of local industry. The idea was to have accelerator technology without going into costly high-energy physics, in which we could not be competitive. This settled the choice for science: materials science done with photons from a storage ring. The third leg of the three-fold way was the concept of a national laboratory. A synchrotron light source would serve a broad community—practically all disciplines in exact, life, and earth sciences would benefit. The best devised strategy, however, still has to survive the tests of real life. Where did the Brazilian National Laboratory for Synchrotron Light (LNLS) stand back in the mid-1980s?

There was only one person in Brazil, Ricardo Rodrigues, a young physicist from the University of São Paulo, who was available, willing, and qualified to be the technical leader of the project. When he agreed to be Technical Director, I knew there were no challenges we could not meet. Rodrigues was given the task of running the construction of the accelerators (with very profitable side incursions into everything else!).

The engineering leg of our strategy depended on a huge bet that in a short time LNLS could train a minimal staff to design and build the accelerators. At this point a decision was made—we would bootstrap ourselves into the business by training the staff in-house as much as possible. (From three-fold way to bootstrap, we held firm, albeit tongue-in-cheek, to particle physics.) The argument made a lot of sense to Rodrigues and to myself—there was no time to send people abroad for extended training periods; whatever experience they gained would not be

The three-fold way: the basic strategy for setting up LNLS may be summarized as an engineering effort to build a synchrotron light source and its scientific instruments to be used for materials research in the institutional setting of a national laboratory. International scientific cooperation, especially in Latin America, but also with similar laboratories in other countries, in addition to the participation of local industry in the construction of the light source, form an integral part of this basic strategy.

Why Build a Synchrotron Light Source in a Developing Country?

#1 A SYNCHROTRON LIGHT SOURCE (SLS) may be used to introduce a novel type of science organization—a national laboratory—in a developing country. National laboratories may initially be seen as spending money that would be better spent by spreading it throughout the scientific community. However, if they are properly managed as open facilities, with access based on the quality of the proposals and peer review, they are eventually accepted. The resources that can be amassed at one site are much larger than anything a university department can offer. The crucial point is open access.

L. Camara, September 1993

#2 SYNCHROTRON LIGHT SOURCES produce photons for materials research in the broadest description of the term—organic and inorganic—encompassing fields as varied as engineering, exact, life, and environmental sciences. They are not restricted to a small constituency of users. By serving a majority of the scientific community in a country, they can gain political support across disciplines and institutions.

#3 ANOTHER IMPORTANT ASPECT of an SLS for the development of science is the dynamics of the experimental hall floor. All disciplines are represented; graduate students from different backgrounds and their advisors rub shoulders (sometimes literally, as the floor can get very crowded). This leads to many fruitful cross-disciplinary interchanges and helps to break down artificial barriers between domains of science that are normally departmentalized in universities.

#4 DESIGNING AND BUILDING a SLS can be an opportunity for the scientific community to experience the process of technological development. It exposes the individuals involved to real-life situations where they can interact with the industrial and private sectors of the economy.

immediately applicable to the working environment in Brazil, and construction had to start immediately. It is not clear it made sense to anybody else. Fortunately, the LNLS Board of Directors bought our idea. This decision was complemented by two related ones: (i) send technical staff abroad for short periods to learn specific techniques or to solve clearly defined problems after they had tackled the difficulties by themselves for a while; (ii) from time to time have experts review the project (for a variety of reasons this actually happened only twice, in 1989 and again in 1991).

As to the Science leg of our strategy, LNLS had to start by building up a users' community. A community of users of synchrotron light is, first and foremost, a research community, the size and composition of which will vary from country to country, owing to local historical experiences. One comment about the recent Brazilian efforts to develop science and technology may be of interest. The National Council for Scientific and Technological Development, CNPq, the organization which sponsors LNLS, was created in the early 1950s. Influenced by the post-war American example and constrained by the lack of industrial demand for R&D, emphasis was given to basic research. CNPq was, and still is, an agency dedicated to the support of basic research. Thanks to its efforts, over the last four decades Brazil built up a small, but politically visible, scientific community. In the meantime, industrial development was geared to imported technological black boxes and turnkey installations, so that science has remained largely isolated from mainstream economic life. For most scientists, technology still smacks of lower quality, not a calling for higher talents and better brains. This led to the somewhat paradoxical situation in which it was easy to build rapidly a community of users but there was widespread initial opposition to the idea of building a synchrotron light source.

Late in 1986, Aldo Craievich accepted the position of Deputy Director of LNLS, responsible for the scientific program. Hence, in parallel with the effort to build the accelerators, LNLS began a series of workshops to "market" research with synchrotron light sources. These topical workshops, in addition to advertising LNLS and the potential of light sources as research tools, allowed the local community to establish useful links with users abroad. This was instrumental to increase the number

R. Medeiros, LNLS

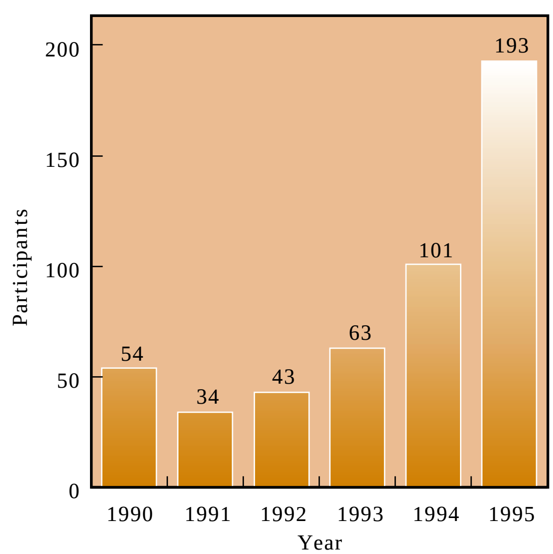
Participants at the 5th Annual Users' Meeting, December 1994.

of trained users in Brazil. The bottom figure shows the evolution of the number of participants in the Annual Users' Meeting. What is not shown, but is perceptible to those who have followed these meetings, is the qualitative evolution in the profile of participants, thanks to the training obtained in foreign synchrotron light laboratories.

The development of scientific instrumentation for using synchrotron light has been one of the main concerns of the Scientific Department of LNLS over the years. The existence of a reasonably strong research basis in the country made it possible to rapidly form high quality groups for VUV and X-ray instrumentation. This also allowed a considerable reduction in the cost of beam lines—so much so that in spite of severe budgetary constraints LNLS has seven beam lines scheduled to come into operation soon after synchrotron light becomes available, and the design of its four-crystal high resolution X-ray monochromator is being copied by the European Synchrotron Radiation Facility. In 1992, thanks to Volker Saile's enthusiastic support, LNLS installed its first beam line at the Center for Advanced Microstructures and Devices of Louisiana State University in Baton Rouge. To my knowledge, this was the first time that a complex scientific instrument manufactured in Brazil crossed the equator (thereby reversing the usual flux).

The third slice of the strategic pie turned out to be, as expected, the most difficult. There was no previous experience with a national laboratory for physicists, chemists, or biologists. The prevailing culture was that of small science done in a compartmentalized way. Laboratories in university departments were (and still are) very much self-contained. Hence, the reaction of the establishment against LNLS was fierce—it was seen as an unfair competitor for resources, dominated by a bunch of insolent youngsters. The idea that it could be something different—a laboratory operated on a professional basis, managed for efficiency and pooling of scarce resources, with allocation of time based on peer review of qualified projects—was entirely foreign to the majority of the scientific community. Even the Brazilian Physical Society publicly opposed LNLS. We quickly learned that technical problems are trivial compared with cultural ones. Fortunately, opposition got swamped by the growth of the scientific community. The younger generation without vested interests to defend supported LNLS. Influential scientists who initially opposed the project eventually changed their minds. We knew we had arrived when the president of the Brazilian Physical Society referred to LNLS as "our" light source.

The concept of a national laboratory concentrating resources but offering free access to the scientific and technological communities of a developing country may be the most important fringe benefit of a light source. National laboratories are a cost effective way to speed the



Participants at the LNLS annual users' meetings.

A BRIEF HISTORY

1981–1986 The Early Years

During this period there were extensive discussions with the scientific community and the National Science Council (CNPq) about the possibility of building a synchrotron light source in Brazil. LNLS was formally created at the end of 1984, but nothing really happened for another two years.

1987–1989 From Words to Action

In these three years, LNLS is set up by CNPq in Campinas, state of São Paulo; the technical staff is assembled and work starts on the linac injector and on the conceptual design of the storage ring. Only half of the planned injector linac gets built owing to insufficient funds to house the 100-MeV linear accelerator. In December 1989 the first beam is obtained.

1990–1993 From Action to Inaction

These four years were the crossing of the desert for LNLS. The political winds changed in Brasilia; a new President practically killed off Science. LNLS is forced to go slow, very slow. Even so, work proceeds on prototypes for various components of the storage ring and scientific instrumentation. The first beam line gets built and is installed in CAMD in Louisiana.

1994–Present Revival

Finally, funds begin to flow again. Construction of the experimental hall and storage ring begin. In December 1995 the linac is successfully operated. Storage ring construction proceeds at a healthy pace. Injection and first stored beam are expected for May 1996.

Cost

The price tag of a large project is usually the first issue raised by friends and foes alike. In developing countries the cost of a synchrotron light source may represent a substantial fraction of the budget allocated to science and technology. Since the inception of the project, LNLS has spent approximately $50 million, including salaries. To this should be added the cost of the land for the campus (approximately $6 million), donated by the State of São Paulo. Overall not an impressive sum compared with the annual budget of CNPq, the Brazilian National Research Council and LNLS sponsor, which has oscillated between $350 million and $600 million from bad to good years. It is even less impressive compared with the Brazilian GNP of the order of $500 billion. So, do not expect synchrotron light sources to have a large direct impact on the economy of a developing country. The impact is longer term and diffuse—upgrading of the technological basis of the country and a superb R&D and human resources training facility, with a useful lifetime to be measured in decades—that is, a large number of young people who were not even born when the installation was first discussed will benefit from its existence.

N. Chinaglia, March 1996

Ricardo Rodrigues, part-time crane operator and full-time Technical Director, patiently explains to a largely unmoved Director the need to hire a new staff member, presumably to replace him at the crane in the storage ring hall.

The Stanford Linear Accelerator Laboratory (SLAC) and the Stanford Synchrotron Radiation Laboratory (SSRL) played an important role in the early history of the Brazilian Synchrotron Light Source. In the early 1980s, Roberto Lobo, then Director of the Brazilian Center for Physical Research (CBPF), in Rio de Janeiro, and Roberto Salmeron, a Brazilian expatriate working at CERN and the Ecole Polytechnique in Paris, were thinking about ways to stimulate experimental research in Brazil. They hit upon the idea of a synchrotron light source. A call to Stanford produced a visit by Helmut Wiedemann to Rio, where, in 1982, he gave an introductory course on synchrotron light sources. In this way, SLAC and SSRL played a major role in initiating the discussions about light sources in Brazil. (Wiedemann also helped design the first storage ring for LNLS—one that never got built but was instrumental in training the future Technical Director of the project, Ricardo Rodrigues.)

An early incident of interest involving Fermilab and SLAC centered around getting local industry to develop the capacitors needed for the linac modulator. Greg Loew of SLAC let us know that SLAC had a set of spare capacitors that could be made available to us; however, red tape on both Brazilian and US sides made it a very difficult operation. In those days, Fermilab, through Leon Lederman and Roy Rubinstein, was responsible for an NSF grant to help science in Latin America. The solution found was that Fermilab would buy these capacitors from SLAC and ship them to LNLS. However, by the time the whole operation could be set up, we had found an industry in São Paulo with whom we jointly developed the components with the required specifications. This was one of our first successes in interacting with local industry and, at the same time, it showed the interest and willingness of the international community to help.

scientific and technological development, provided they are outward looking in their policies. In addition, the broad spectrum of disciplines that can be covered by synchrotron light research is a vital element for the decision to build such a facility.

Interaction with local industry was an important part of the strategy for setting up LNLS. However, it was not an easy task given the paucity of the budget, the irregularity of the cash flow, government regulations concerning procurement, and industry's lack of experience with "high" tech demands. LNLS could not pay a premium price for components and equipment that had to be custom built or developed specifically for the Laboratory. The total cost of the project, thus far, has been about $50 million (in US dollars). Many times industry did not or could not respond to our requests for a reasonable price in a reasonable time. Curiously enough, given the substantial historical differences, LNLS had an experience similar to that of CERN, as related by Brian Southworth, ". . . when the CERN PS and even ISR were being built almost all technologically advanced design, prototype, and assembly work had to be done in house" (CERN *Courier*, June 1992, p.12).

Every synchrotron light laboratory around the world has its own experience to tell, strongly influenced by local history. The Brazilian experience is, perhaps, of interest to poorer developing countries for it shows that a light source can be affordable if the right strategy is chosen. In spite of many differences, the unifying principle of synchrotron light sources is the wide spectrum of the science that can be done with the photons they generate. Unfortunately, as a technology for producing photons, storage rings are pitifully inefficient machines, even if they are the best that we can produce right now. Bright and original ideas are urgently needed for new and more efficient ways to convert electrical power into high flux, brilliant, and tunable photon beams. The story is just beginning.

L. Camara, May 1995

Putting the finishing touches on a quadrupole magnet for the storage ring.

Progress Update

ON MAY 30, 1996, the first thousand turns of the injected beam at 111 MeV were observed in the LNLS storage ring. On July 30, the beam was successfully ramped to the design energy of 1.15 GeV. Commissioning is now under way to deliver the storage ring to the users' community according to schedule. The highest energy particle accelerator and storage ring in Latin America will then be a reality.