National Synchrotron Light Source Readied

Industrial and university "participating research teams" will provide most of the instrumentation for Brookhaven's new synchrotron radiation center

On 1 October, the National Synchrotron Light Source made the jump from a construction project to an operating division of the Brookhaven National Laboratory. The $24 million light source is the first U.S. synchrotron radiation facility to be designed from the ground up to provide the highest possible flux of ultraviolet radiation and x-rays for spectroscopic, scattering, and diffraction studies of materials ranging from biological macromolecules to metal alloys. When the light source completes a gradual commissioning process and reaches full operation early next spring, it will serve 45 experiments simultaneously and will have room for many more. John McTague, a UCLA chemist, has been offered the job as light source director.

For the first time, in the x-ray region of the spectrum particularly, researchers will not have to scramble to get limited beam time but will be able to carry out long-term investigations. "After some years of complaining about limited facilities," said one researcher, "now we will have to demonstrate the potential of synchrotron radiation that we have been talking about for so long but have been unable to exploit."

The light source finds itself by chance in tune with the Reagan Administration philosophy of seeking more industrial support for basic research. The $24 million from the Department of Energy (DOE) is buying Brookhaven two electron storage rings to produce the synchrotron radiation, one for x-rays and one for ultraviolet, but only a few experimental stations to use the wondrous light. Martin Blume, who is now an associate director of Brookhaven, and others there hit upon the idea of participating research teams (PRT's). A group (industrial, university, or government laboratory) accepted as a PRT would build and finance one or more experimental stations in exchange for unrestricted use of the facilities for 75 percent of the running time. The PRT would also have to give outside users access to its instrumentation for the remaining 25 percent of the time. Included in PRT's selected so far are IBM, Bell Laboratories, Exxon, and Xerox, who together account for about 40 percent of the PRT-supplied experimental stations.

Almost all synchrotron radiation research has been done with machines originally built for high energy physics and often still used primarily for that purpose. Synchrotron radiation is the light emitted by charged particles moving at high speed through a curved trajectory, and the ultraviolet and x-ray light of so much current excitement comes from electrons orbiting in circular accelerators. Until now, U.S. researchers have journeyed to the University of Wisconsin's Synchrotron Radiation Center at Stoughton (see box) for ultraviolet light or to the Stanford Synchrotron Radiation Laboratory for both ultraviolet and x-ray light. Smaller facilities also exist at the National Bureau of Standards (ultraviolet) and Cornell (x-rays).

Brookhaven got into the synchrotron radiation act in the mid-1970's at a time when demand was swamping the available facilities and when the Europeans seemed to be ready to invest much more heavily than the United States in this field. A 1976 National Academy of Sciences report called attention to both of these imbalances and recommended that new sources dedicated to the production of synchrotron radiation be constructed. The report also recommended that an eye be kept on the geographical distribution of facilities. The previous year, Brookhaven had submitted a proposal to build for in-house use an electron storage ring sufficiently energetic [2 billion electron volts (GeV)] to produce high fluxes of x-rays but was turned down. Following the Academy report, a revised proposal for a national facility was prepared.

After a call to the research community for suggestions, the National Science Foundation (NSF) and the Energy Research and Development Administration (DOE's predecessor agency) reached an agreement whereby the latter would fund Brookhaven's National Synchrotron Light Source and NSF would pay for an expansion of the facilities at Stanford and for a new, intermediate energy machine at Wisconsin. Stanford finished its construction more than a year ago, but must still share its 4-GeV storage ring with the high energy physicists, and Wisconsin's schedule is more or less paralleling Brookhaven's.

Arie van Steenbergen, who headed the just-ended light source construction project, explained to *Science* how the machine will work. A short linear accelerator shoots pulses of electrons to an energy of 70 million electron volts (MeV). Then a booster synchrotron raises the energy further to 700 MeV. At this energy, the electrons can emit copious quantities of ultraviolet light, and the particles are shunted off to a storage ring where they circulate for hours. The electrons are kept in orbit by eight bending magnets, each with two ports for extracting the light from the storage ring. At first, ten of the ports will have evacuated beam lines attached to them that lead to the experimental stations. However, one beam port can service more than one experiment; the synchrotron light is so intense that the radiation entering one port can be shared.

A beam line with a single experimental station can easily cost $500,000 and in some cases can be three times that price.

To produce x-rays, the electrons must have a still higher energy. So, when the ultraviolet storage ring is filled and can accept no more electrons, electrons from the booster synchrotron are directed to a larger storage ring that also has the capability of ramping the energy up to 2.5 GeV. The x-ray storage ring has 16 bending magnets, again with two ports each. For now, 18 ports will have beam lines installed.

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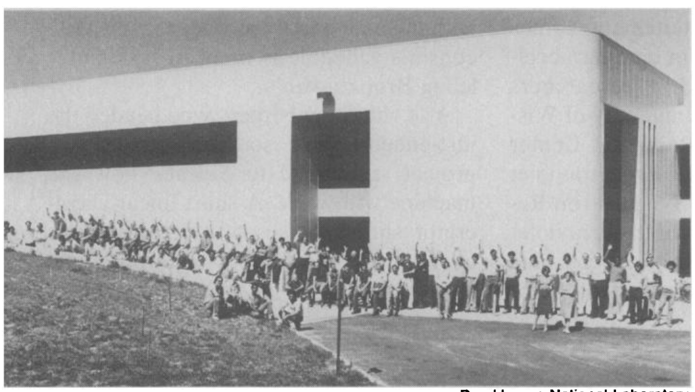
Since the higher energy x-ray ring also produces ultraviolet light, an obvious question is, why have a separate ring for the longer wavelength radiation? (At one point, Brookhaven considered the possibility of building only one ring, but a revolt of potential ultraviolet users quickly quashed the idea.) The answer is that the presence of the x-rays needlessly complicates the optics of the beam lines and experimental stations and also raises safety issues. Van Steenbergen says that the ultraviolet ring should produce respectable fluxes of light with wavelengths as short as 10 angstroms (soft x-rays), whereas the x-ray ring will emit hard x-rays with wavelengths down to 0.6 angstrom. At the long wavelength end of the spectrum, the ultraviolet ring also emits appreciable amounts of infrared radiation of 1 micrometer and longer, and there are plans to tap this capability.

Although construction is complete, the process of learning how to operate the system is just beginning. In August Brookhaven accelerator engineers succeeded in injecting an electron beam into the ultraviolet ring and guiding it around for a few turns. Still to come is storing an intense 1-ampere beam for long periods. Gwyn Williams, who is working on the non-PRT beam lines and experimental stations that Brookhaven will provide to the general user, predicts that the beam lines on the ultraviolet ring will be installed and aligned by the end of this month. But it may take 3 or 4 months to get fully established.

William Thomlinson, who is working on x-ray beam lines for Brookhaven, indicates that the higher energy ring is following 2 to 3 months behind the ultraviolet ring. Injection of a beam may come this month. The first experiments, which may not require hard x-rays, could begin in the spring, but most will have to wait until reliable operation of the ring is more certain.

A feature of both rings that Brookhaven scientists are especially proud of is the brightness of the light emitted. The number of photons per second at a given wavelength depends both on the electron beam current and energy, but a high brightness also requires a small electron beam cross section. If the machine works as well as computer simulations predict, Brookhaven's light source will be about ten times brighter than the best existing synchrotron radiation sources. Brightness is important because it determines the resolution that can be obtained (in spectroscopic experiments) or, alternatively, how short a data-gathering time is required to obtain a given resolution. Brightness also determines how small a sample can be used. An 800-MeV electron storage ring under construction in Berlin will match Brookhaven's brightness in the ultraviolet region of the spectrum, and Wisconsin's new ring will also come close. It is in the x-ray region that Brookhaven's light source will reign supreme for some time.



Brookhaven National Laboratory

NSLS milestone

National Synchrotron Light Source staff members express their excitement after the first electron beam is injected into the ultraviolet ring.

Just as important as the high brightness in ensuring the scientific productivity of the light source is the establishment of the PRT's. The initial motivation for inventing PRT's was to minimize the bureaucracy. But there turned out to be important financial benefits as well. A beam line with a single experimental station can easily cost $500,000 and in some cases can be three times that price. The 26 beam lines and associated experimental stations that are beginning to be put in place now could cost as much as the light source itself. The PRT's provide a way to get the light source instrumented at a much faster pace than would otherwise be possible given the available funding, says Donald Stevens of DOE.

But there is an important philosophical principle involved as well, Brookhaven's Blume says. The question is how does a national facility simultaneously serve two broad categories of researchers. The first group is those who want to devote a good part of a career to synchrotron radiation and therefore require regular access to facilities. The second includes what is generally called the user community, researchers with only an occasional need to use synchrotron radiation. Blume argues that PRT's provide a way to serve both groups equitably.

In addition to their guaranteed 75 percent access to the light source, PRT members decide among themselves what experiments to run. (Proposals by other users are screened by a program committee.) They are therefore free to plan the kind of long-term, coherent research programs that many people think are necessary if synchrotron radiation is to make significant contributions. Blume warns, however, that the freedom is not unlimited. For one thing, the PRT agreement is renegotiated at 3-year intervals, and there is an explicit condition that the PRT will live up to its preferred treatment by doing first-rate science.

As can be imagined, some researchers have expressed alarm at the prospect of Brookhaven "giving away two-thirds of its machine." In addition to the well-heeled industrial groups, which are the cause of much of the alarm, the physics, chemistry, and biology divisions of Brookhaven, the Oak Ridge National Laboratory, the Naval Research Laboratory, the National Bureau of Standards, and several universities are involved in PRT's. Among the academics, the New York state university system has an entire beam line to itself, and the Stony Brook campus is participating in two other collaborations.

There is also some question as to how open-armed the PRT's will be to the general users. Some PRT people have said that they are not completely happy with the idea of untrained, outside users messing with their equipment. The concern is natural because, as Brookhaven's Williams reminds, maintaining the complicated beam-line optics is a full-time job for one person and "things tend to go wrong anyway." It clearly will be an interesting first year or two as PRT and general user researchers learn how to work side by side.

Everyone seems to agree that the workability of PRT's depends on the balance of supply and demand. Ednor Rowe, who heads the University of Wisconsin Synchrotron Radiation Center, notes that there has long been an informal PRT system at Stoughton. Researchers would come, set up equipment, and run an experiment. In between runs, they would leave the equipment for others to use. "We always had enough facilities to meet user demand, so people were given the time they needed," says Rowe. At Stanford, demand so greatly exceeded the available facilities that users were limited to only short periods (2

Wisconsin Unveils Its Magic Lamp

A visitor driving down highway 51 south of Madison could easily miss the turnoff to the University of Wisconsin Synchrotron Radiation Center. A sign pointing the way is so faded as to be almost unreadable. They really ought to get a new sign because it would be a shame to miss what lies a short way down that road. Sitting in the midst of farmland alternately planted with corn and tobacco is Aladdin, a 1-billion-electron-volt (GeV) electron storage ring that will be one of the world's most intense sources of ultraviolet and long-wavelength (soft) x-ray light. The construction phase of Aladdin is complete and Wisconsin scientists are learning how to operate their new machine. As this is a lengthy process, it will probably be early next year before research gets under way.

Aladdin is one leg of a triad upon which most synchrotron radiation in the United States will be based in the next several years. The others are the National Synchrotron Light Source at the Brookhaven National Laboratory (see story) and the Stanford Synchrotron Radiation Laboratory. All three are designated as national facilities and are open to users from universities, government laboratories, and industry.

Synchrotron radiation research started earlier at Wisconsin than at the other two centers. In 1968, investigators began journeying to the laboratory, which is located near the town of Stoughton, to use the ultraviolet light from a smaller, 0.24-GeV electron storage ring named Tantalus I. Ednor Rowe, who has been the director of the center almost from its beginning, correctly guessed that the next logical step for synchrotron radiation was a higher energy ring to produce x-rays. In the early 1970's, however, the National Science Foundation decided not to build a new facility but took the more cautious and less expensive step of establishing some experimental stations around an already existing, high-energy storage ring at Stanford that was built for (and is still used for) high energy physics. Later in that decade, as the clamor for more x-ray facilities grew to a high pitch and Stanford and Brookhaven vied for funds to satisfy the demand, Rowe decided that Wisconsin should concentrate on serving the ultraviolet research community. Aladdin was designed with this in mind, although with its 1-GeV energy, it also produces a high flux of soft x-rays with wavelengths as short as 4 angstroms.

The machine is laid out in the form of a square with rounded corners. Three dipole magnets at each corner bend the electron beam into the required curved trajectory. The synchrotron radiation, which is emitted only where the electrons follow curved paths, comes out of the machine through 36 ports, three in each bending magnet. The intense light from each port can be divided up and shared by three beam lines that funnel the radiation to experimental stations. At first, only 14 ports with single beam lines will be instrumented. Later on, the straight sections are to house special magnets (wigglers) for x-ray production.

The limitation is in part financial. The collection of beam lines and experimental stations in a fully instrumented synchrotron radiation facility can cost much more than the storage ring itself. At Aladdin, five of the beam lines will be built and paid for by outside groups. Following the practice initiated at Brookhaven, these are called participating research teams or PRT's. The Canadian National Research Council is one of the PRT's, and its beam line will be maintained exclusively for the use of Canadian researchers. The other PRT's are from U.S. universities. There are no industrial PRT's as yet. In exchange for building and maintaining beam lines, the PRT's get unrestricted use of their facilities for 75 percent (negotiable) of Aladdin's running time; the remaining 25 percent of the time, the instruments must be made available to the general user community.

Of the remaining nine beam lines, Rowe says there are funds to build for the full-time use of the user community four new instruments. One of the most interesting of these will be a double crystal monochromator for the soft x-ray region between about 6 and 16 angstroms. The monochromator will use natural beryl crystals that have large spacings between the crystal lattice planes. The large spacing means that x-rays of longer wavelength than usual can be accommodated. The use of beryl crystals was pioneered at Stanford and closes a previously inaccessible wavelength gap between the ultraviolet, for which one can use diffraction gratings, and x-rays, for which one uses crystals to disperse the light. Finally, as Aladdin completes its initial shakedown, five more ultraviolet instruments will gradually be brought over from Tantalus I. The old machine may then be reserved for special experiments.

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In one technical detail, Aladdin departs considerably from other large electron storage rings. The latter typically have associated with them a small linear accelerator and a booster synchrotron because no storage ring is capable of taking an electron beam from zero energy to 1 GeV or more. Aladdin has a different kind of electron injector, a device called a racetrack microtron. A similar microtron has served as the injector to Tantalus I for several years.

The racetrack microtron, as the name implies, drives the electrons in racetrack-shaped orbits. As the energy increases (5 million electron volts each orbit in the case of Aladdin's injector), the size of the orbit increases, as in a cyclotron. But rather than being spiral-shaped, the ever larger racetracks have one straight section in common. The acceleration cycle requires 20 orbits, whereupon the 0.1-GeV electron beam will be squirted into Aladdin. Aladdin will bring the energy up to the full 1 GeV, then store the beam at constant energy for several hours, after which a fresh beam must be created.

After some early problems, Wisconsin scientists recently succeeded in getting the racetrack microtron to accelerate electrons through the full 20 orbits. The next step, nearly accomplished at press time, is to inject the electron beam into Aladdin itself. In the accelerator business, injecting a beam successfully and then storing it is the crucial test that shows whether the machine will work. Passing this test is usually cause for breaking out the champagne.—A.L.R.

weeks for example) of beam time and then had to get back in line. When Bell Laboratories researchers early on were granted priority access, because of their work in developing and building new instruments, there was what could charitably be called grumbling. Now, with Brookhaven's light source draining off the excess demand, says Arthur Bienenstock, the director of the Stanford laboratory, PRT's are being instituted. In fact, he adds, with a more even balance between supply and demand, PRT's even become necessary as a means of attracting a stable group of highly talented people.

Blume uses the example of wigglers and undulators to further illustrate that PRT's will not work in every situation. A wiggler is a special magnet that fits into one of the straight sections of a storage ring between the bending magnets. The wiggler bends the electrons into a sine wave–shaped path whose local radius of curvature is smaller than that of the smooth circular arc of the bending magnets. The resulting synchrotron radiation spectrum is enhanced in intensity and is shifted toward shorter wavelengths. With a wiggler, a low-energy storage ring that would not produce x-rays can be made to do so. An undulator is similar to a wiggler but has the effect of compressing the smooth synchrotron radiation spectrum into a few narrow peaks, thus greatly increasing the brightness of the light at these wavelengths. Some people think that in the future all synchrotron radiation will come from wigglers and undulators. In any case, Brookhaven has left room for four wigglers in its x-ray ring and so far has built one prototype magnet. Blume says that the demand for these few wigglers will be so great that the laboratory is reserving them for general user operation.

All in all, the National Synchrotron Light Source is a first-class facility. Together with the upgraded Stanford laboratory and Wisconsin's new source, it puts the United States on or above par with Europe. Nowadays that is no mean accomplishment.

—ARTHUR L. ROBINSON

Reevaluation of Cancer Data Eagerly Awaited

Cornell professor estimates it will take at least a year to repeat experiments in question

For the past year and a half, Efraim Racker's laboratory at Cornell University had a special air of excitement. A graduate student named Mark Spector was conducting seemingly spectacular experiments on a class of enzymes related to cell transformation. Spector's data brought research that others had been doing on RNA tumor viruses, growth factors, and the biochemistry of cancer cells together in a theory that Robert Weinberg of the Massachusetts Institute of Technology calls "as unifying and simplifying for studying the metabolic basis of cancer as Newton's work was for studying mechanics." Prominent scientists, including David Baltimore of MIT, Robert Gallo, George Todaro, and Edward Scolnick of the National Cancer Institute, and Tony Hunter of the Salk Institute were impressed by Spector's work and started to apply his results to their own research.

But now serious problems have come to light. Racker, convinced that at least part of Spector's work is not replicable, has retracted the papers the two coauthored in *Science* and *Cell*,* has withdrawn papers still in press, and is beginning the difficult and lengthy task of trying to repeat what Spector claims to have done. "I have to go back to square one. I will not believe anything that Mark did until I repeat it with my own hands," Racker told *Science* during an interview at his laboratory.

Spector, who has written a Ph.D. dissertation on his work in Racker's lab, was due to receive his degree this semester. But on 10 September, he withdrew his dissertation and withdrew from Cornell University at his family's urging. Spector maintains, nevertheless, that his research is legitimate and that his withdrawal is not an admission that he has any doubts about his data.

Spector was considered an extremely impressive student, brilliant and exceptionally talented technically. Racker, an eminent scientist on the verge of retirement, says he was grooming Spector as his own successor. As Volker Vogt, a Cornell University tumor virologist puts it, "Spector was a superstar."

Spector arrived at Racker's laboratory in January 1980 and began experiments related to Racker's long-held theory about the biochemistry of cancer cells. As Racker reports, Spector soon began getting interesting supportive data.

Tumor cells convert glucose to lactic acid much more rapidly than normal cells do. For years, Racker has wanted to know why. In 1973, Racker got a clue when he found that in Ehrlich ascites tumor cells in mice this conversion (glycolysis) depended on a high rate of activity of an enzyme in the cell membrane whose function it is to pump sodium out of the cell and potassium in. Energy for this enzyme, sodium-potassium ATPase, is supplied by the hydrolysis of ATP to ADP and inorganic phosphate, which are required for glycolysis. Racker hypothesized that the sodium-potassium ATPase is very active in tumor cells because it is inefficient and so must work overtime to maintain the proper sodium-potassium balance. Racker and Spector discussed their data and hypotheses in the *Science* article.

One of the first things Spector accomplished was the isolation of the sodium-potassium ATPase from mouse tumor cell membranes where, he demonstrated, it acts inefficiently. In contrast, he showed that a sodium-potassium ATPase isolated from the membranes of normal mouse brain cells is efficient as a pump.

Next, Spector reported that the reason the sodium-potassium ATPase is inefficient in tumor cells is because it is phosphorylated. When he removed a phosphate group from this ATPase, it became efficient. Moreover, he isolated an enzyme from the tumor cells, which he and Racker called PK_M (for phosphokinase) that added the phosphate group to the membrane pump. (A kinase is an enzyme that adds phosphate groups to a substrate—in this case to protein molecules.)

From then on, Spector's results be-

*Science, 17 July 1981, pp. 303–307, "Warburg effect revisited: Merger of biochemistry and molecular biology"; *Cell*, July 1981, pp. 9–21, "A mouse homolog to the avian sarcoma virus *src* protein is a member of a protein kinase cascade"; *Science* article retracted in *Science*, 18 September 1981, p. 1313; *Cell* paper retracted in *Cell*, September 1981, p. 827.