Choosing the Next Synchrotron Light Source

Berkeley's proposal for a new Advanced Light Source accelerates plans for new facilities at existing centers; a DOE committee will sort it all out

If money and the number of practitioners are the measures, synchrotron radiation research has reached the big time. Future facilities are likely to cost in excess of $100 million each to construct and will have yearly operating expenses of $20 million or so in support of hundreds of experimenters. Their high price limits how many will be built. Even to obtain just one, a very heterogeneous body of researchers will have to speak to the politicians with a unified voice.

In August, the Department of Energy (DOE) established a study committee whose job is to be the community's voice. The committee's first priority is to discern what synchrotron radiation facilities researchers want in the next decade. In this light, it must then recommend for or against the Advanced Light Source (ALS) originally proposed last year by the Lawrence Berkeley Laboratory as part of its Center for Advanced Materials (*Science*, 18 February, p. 827).

DOE has not given the committee much time to do its work. If the ALS is to make it into the fiscal 1985 budget, DOE must have the committee's statement of priorities by mid-November. A polished, written report is not expected before next February, however.

To meet this timetable, committee cochairmen Peter Eisenberger of the Exxon Research and Engineering Company and Michael Knotek of Sandia National Laboratories slated three meetings for the purpose of hearing laboratory plans and researchers' views. Knotek told those attending the opening meeting at Albuquerque, New Mexico (8 to 10 October), that the membership of the 17-man committee spans a wide range of experience in and out of synchrotron radiaton research. A high premium was placed on the ability to bargain and make decisions.

The last qualities are of special importance because the committee has to choose among proposals for specific facilities. This is in contrast to the last big synchrotron radiation study conducted by a subpanel of the Solid State Sciences Committee of the National Academy of Sciences, which did not consider specific proposals.

Although the panel's general recommendations amounted to about a $40-million expansion program, economic realities cut that figure. Brookhaven National Laboratory, then a new entrant in the field, emerged with $24 million from DOE to build the National Synchrotron Light Source (NSLS) to generate both ultraviolet and x-ray radiation. The University of Wisconsin's Synchrotron Radiation Center and the Stanford Synchrotron Radiation Laboratory received considerably smaller amounts from the National Science Foundation for their oversubscribed facilities.

As the cost of future light sources soars above the $100-million mark, it is apparent to all that a more orderly selection process is required. The model usually pointed to is that of high energy physics. High energy physicists, however, constitute a rather homogeneous group. Almost all experimentalists work at accelerators, and their common drive is to ever higher energies.

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The users of synchrotron radiation could hardly be more inhomogeneous, with research running the gamut from biology to solid-state physics and possible commercial applications ranging from medical imaging to microelectronics fabrication. Moreover, a substantial fraction of these researchers do not even use synchrotron radiation as their primary tool. Throw in the still potent issue of whether traditional "small science" researchers should flock to centralized facilities to carry out projects in a "big science" style, and it is obvious there are problems in consensus building.

The committee has its work cut out. The long lead time for the planning, design, and construction of a synchrotron light center ordinarily would make it appropriate to begin now the process for a facility to be on line in the 1990's. However, partly because of the unrealistically low funding that came out of the budget conditions of the mid-1970's, the NSLS and the new Wisconsin light source (Aladdin) are still not completely commissioned (*Science*, 21 October, p. 313). The lack of operating experience with the new machines makes planning the next generation seem premature. But Berkeley's proposed ALS has thrust the issue to the fore right now.

The ALS was the centerpiece of Berkeley's National Center for Advanced Materials (NCAM), when it appeared, to the surprise of many, in the fiscal 1984 budget. However, opposition stalled NCAM in Congress, and a DOE ad hoc committee chaired by Albert Narath of Sandia then recommended that the NCAM initiative be split into separate proposals, one for a materials center and one for a synchrotron light source (*Science*, 21 October, p. 308). Narath's committee also recommended that a new body be set up to look at the question of what synchrotron radiation facilities the research community desired. This directly led to the establishment of the present Eisenberger-Knotek committee, DOE officials acknowledge.

Most synchrotron radiation researchers feel that Berkeley jumped the gun by quite a bit with the ALS. Nonetheless, at the Albuquerque meeting, the committee heard presentations from Stanford, Brookhaven, Wisconsin, Cornell University, and the National Bureau of Standards, each with its own wish list.

The technical imperative driving most of these plans is the development of so-called insertion devices (*Science*, 18 March, p. 1309). These are special magnets that can sit in straight sections of the electron storage rings that serve as synchrotron light generators. The radiation from insertion devices is considerably more intense than that from the dipole bending magnets in the curved portions of a storage ring, which have been the traditional sources of synchrotron light. Although the present synchrotron radiation centers use insertion devices, the ALS is the first electron storage ring specifically designed to have them as the primary source of light.

Bending magnets produce a smooth spectrum of radiation set by the size and energy of the storage ring. The NSLS 2.5-billion electron volt (GeV) storage ring has a minimum wavelength in the x-ray region and will produce useful fluxes at wavelengths as short as 0.3 angstrom, for example.

One kind of insertion device, a wiggler, acts to lower the minimum wavelength and to increase the light output at all wavelengths. Stanford has operated such devices for over 2 years and has just commissioned a new one with an ultrahigh intensity. Wigglers have demonstrably enhanced already scientifically productive techniques, such as photoemission spectroscopy, x-ray absorption spectroscopy, and x-ray diffraction. A second form of insertion device, the undulator, compresses the broad bending-magnet spectrum into a number of relatively sharp peaks. The intensity in the peaks is even larger than that available from a wiggler, and the peak wavelengths are controllable.

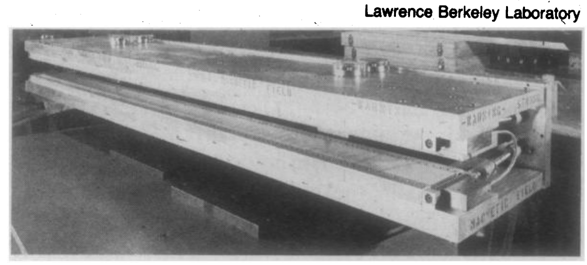
Although relatively unused until now, undulators are the form of insertion device that researchers have most in mind when they plan new synchrotron light facilities. The enthusiasm for undulators derives from the peaked character of their radiation spectrum. Only a small part of the extremely intense but broad wiggler spectrum is usable at any instant, and the rest of this light simply heats up the optical elements in the beam pipe that transmits light from the storage ring to an experimental station. In particular, the total power of the light emitted by a wiggler can be large enough to distort, melt, or burn holes through these elements. Undulators generate a much lower total power, avoiding this problem. And the light that they do emit is concentrated in narrow-wavelength bands and is mostly usable.

Undulators also take full advantage of new electron storage ring technology. The NSLS, Aladdin, and the ALS are designed to circulate electron beams with extremely small cross sections (0.2 millimeter or less in diameter). Thus, light from these machines should be brighter than that from previous storage rings, as well as more intense. Brightness is the property of a source that is small in size and emits a highly directional light into a small solid angle. The light from an undulator is more tightly collimated than that from bending magnets or wigglers, making undulators the brightest of sources. High brightness is expected to open new avenues for synchrotron radiation. To name just one example, noted by David Attwood of Berkeley at the Albuquerque meeting, it might be possible to do x-ray holography with the light from an undulator.

The disadvantage of undulators is that their most intense radiation comes at wavelengths longer than the minimum wavelength of a bending magnet in the same storage ring. To obtain undulator radiation at short wavelengths, one must build a higher energy storage ring.

Nearly everyone agrees that the optimum energy for a storage ring with undulators that produce x-ray wavelengths as short as those emitted by bending magnets in a 2.5-GeV machine is 5 to 6 GeV. The proposed European Synchrotron Radiation Facility, which has yet to sort out the usual siting problems of a multinational project in Europe, is centered on a 5-GeV storage ring that is 900 meters in circumference. The estimated cost in 1982 dollars is $129 million.

Lawrence Berkeley Laboratory



Undulator

An electron beam passing longitudinally through the array of 60 vertically alternating dipole magnets oscillates horizontally and thereby generates synchrotron radiation in the direction of the array.

The European facility is designed to maximize the production of x-rays, although it will necessarily also generate high fluxes of ultraviolet light. For both technical and practical reasons, synchrotron radiation users prefer separate electron storage rings for the two wavelength regions, each optimized for its purpose. The NSLS, for example, includes a second 0.75-GeV ring for ultraviolet and soft x-ray users. The equivalent storage ring with undulator sources would have an energy of 1.3 GeV.

Berkeley's proposed ALS in fact is a facility of just this sort. It is 182 meters in circumference and has a beam energy of 1.3 GeV extendable to 1.9 GeV in a pinch. Originally its cost was about $84 million for a 6-year construction period, beginning in fiscal 1984. The delay in getting started raises the price to over $95 million. The facility would serve up to 60 experimental stations simultaneously when fully developed. Since beam lines are priced at roughly $1 million apiece, the final ALS cost will easily top the $100 million mark.

An important technical issue for all new electron storage rings concerns the accelerator that injects the electron beam into a ring. In its simplest form, a storage ring does not accelerate a beam but only circulates a beam created in another machine. For reasons of lower cost, the usual practice is to inject the beam at less than the full energy and complete the acceleration in the storage ring. The recent troubles at the NSLS and at Wisconsin point clearly to the desirability of an at-energy injector.

For this reason, the NSLS will shortly have at-energy injection into its ultraviolet ring, and a plan was presented at the Albuquerque meeting for a $31-million electron synchrotron to act as a 3-GeV injector to the x-ray ring. Ultimately, said NSLS director John McTague, the hope is to upgrade the synchrotron to 6 GeV to serve as the injector for a third storage ring of the same energy.

At Stanford, the injector presents no problem because of the existence of the 22-GeV electron linear accelerator belonging to the Stanford Linear Accelerator Center. Last October, as word of NCAM began to leak out, Stanford established a planning group to study a new facility. At Albuquerque, Stanford's deputy director, Herman Winick, discussed the current vision. It comprises two rings of the same 530-meter circumference lying one atop the other in the same tunnel: a 6-GeV ring for x-rays and a 2-GeV ring for longer wavelengths. No costs were projected.

It was evident at Albuquerque that Berkeley's ALS is ready to go the moment approval is given and money appropriated. It was equally obvious that it will be 2 years or more before there is a serious proposal for an x-ray facility. One issue the Eisenberger-Knotek committee will have to resolve is, given the limited resource available, can synchrotron researchers have the ALS and a future x-ray machine too? Another is, if researchers turn down the ALS for which money seems to be available now, can they count on an x-ray machine surviving the political process and being funded in a few years?

DOE's Donald Stevens perhaps put these questions in perspective when he retold an old joke cited 3 years ago when after a brief trial the late National Resource Center for Computational Chemistry was closed for lack of community support: "How do you tell a chemist from a physicist? When threatened from outside, both pull their wagon trains into circles. The difference is that the physicists shoot outward while the chemists shoot inward." Which way will synchrotron radiation researchers shoot?

—**Arthur L. Robinson**