A Rescue for Wisconsin's Synchrotron Source

Three years after its completion, Aladdin glows only feebly; to get more light out requires new NSF money and help from DOE accelerator experts

The first steps have been taken in a new plan to save Aladdin, an electron storage ring at the University of Wisconsin's Synchrotron Radiation Center in Stoughton. Aladdin's purpose is the production of intense beams of ultraviolet and soft (long-wavelength) x-rays for spectroscopic and structural studies of matter. But, since its completion more than 3 years ago, Aladdin has barely been able to generate a faint glow, too weak for experimenters to use, and the project was being considered for termination.

Early last month Wisconsin synchrotron researchers and accelerator experts from several Department of Energy (DOE) national laboratories met at Stoughton to plan a 4-month study of Aladdin, which will determine once and for all exactly what needs to be done and how much it will cost.

Most observers say that the only hope for bringing Aladdin's performance up to specs resides in the purchase of a new $7-million synchrotron to inject electrons into the storage ring. However, even if the study group concurs in its report, due next May, that Aladdin is salvageable, it may still be 3 years from now before synchrotron radiation users see any of the light that was once promised for mid-1980.

Aladdin's situation is particularly embarrassing to the U.S. synchrotron radiation community, which is in the early stages of mounting a campaign for a $160-million facility centered around a considerably larger, next-generation electron storage ring similar to one being planned in Europe to make hard (short-wavelength) x-rays. A record of failure would not help at all in gaining approval for the expensive project when the number one budget priority is reducing the deficit. Last year, a DOE-sponsored planning study of advanced synchrotron radiation facilities placed expeditious completion of Aladdin at the top of its list (*Science*, 2 December 1983, p. 995).

Even apart from this, there is considerable pressure to bring Aladdin on-line, if at all possible. Aladdin is the main piece of the synchrotron radiation action for the National Science Foundation (NSF), which so far has spent $6 million on the machine and last year doubled the synchrotron center's operating budget in an effort to speed progress. NSF is tentatively agreeable (there is no formal proposal yet) to buying a new synchrotron, provided that Wisconsin can assemble an augmented team of accelerator experts to commission the machines and thereby "guarantee" that the project will succeed.

Most U.S. accelerator experts work at DOE national laboratories. Would DOE labs be amenable to loaning some of their scientists and engineers to help finish an NSF-sponsored project? Said one official, "it's a community problem, and the community must help out."

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Why should it be so hard to make Aladdin work? The answer is only partly technical. Electron storage rings circulate electron beams for hours at a time, and for this reason they put more stringent requirements on the control of particle orbits than do synchrotrons, which accelerate and dump a beam within a second or so. But high energy physicists have generally mastered this art.

Storage rings built specifically to maximize the production of radiation, though of much lower energy, carry beam currents ten or more times greater than those in high energy physics machines. Moreover, the beam has as small a cross section as possible to enhance the brightness of the emitted light (flux per unit cross section of the beam and per unit solid angle into which the radiation goes). Because high energy physicists never had to confront such large current densities, builders of synchrotron radiation sources are accelerator pioneers in their own right.

A particularly unfortunate difficulty is that of accumulating a high-current beam at low energy; it was also not fully appreciated when Aladdin was designed in the mid-1970's. Aladdin, which has a maximum energy of 1 billion electron volts (GeV), accepts electrons from a smaller accelerator called a microtron at an energy of 0.1 GeV. When a sufficient number of squirts of electrons from the microtron are accumulated to make the design current of several hundred milliamperes, Aladdin is supposed to take over and boost the beam to its final energy.

Aladdin has accumulated and accelerated small currents (2.5 milliamperes) to 0.75 GeV. However, significantly larger currents cannot be stored. Attempts to do so result in immediate loss of the entire beam. It is well known that electron beams are more subject to beam-disrupting instabilities at low energy than at high, where the emission of synchrotron radiation is more intense, which acts to calm the beam down. But high currents seem to cause more problems than anticipated. Somewhat related difficulties have plagued a 2.5-GeV storage ring at the National Synchrotron Light Source at Brookhaven National Laboratory, which has to accumulate electrons at 0.75 GeV before accelerating them (*Science*, 21 October 1983, p. 313), although these problems are being overcome.

The alternative procedure is to inject electrons in small doses at full energy, when the beam is better behaved. Machines contemporary to Aladdin in Berlin (a 0.75-GeV ring called BESSY) and in Tsukuba, Japan (the 2.5-GeV Photon Factory), have taken this approach and are working well. Full-energy injection requires a higher energy electron synchrotron and is therefore a considerably more costly path than low-energy injection.

When Aladdin and the NSLS were proposed, cost was perceived as a major factor in gaining approval. Ednor Rowe, who was the main designer of Aladdin and directed its construction, therefore chose the lower priced alternative, as did his counterparts at Brookhaven. A number of other "frills" that are now viewed as essentials, such as diagnostic instruments to monitor the position of the beam in the storage ring and equipment to scrub adsorbed gases from the inner walls of the ring and enhance the ultrahigh vacuum needed for storing high currents, were also omitted in the name of frugality.

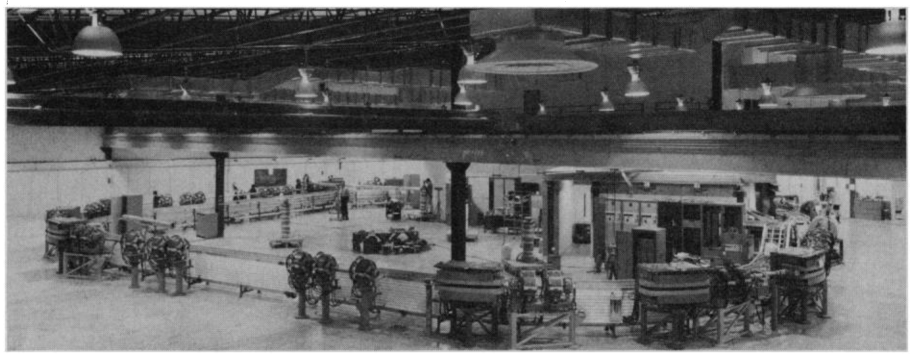
Most serious of all, in retrospect, the number of technical and managerial people appropriate for constructing, commissioning, and operating a complex machine was far from adequate. This was partly for financial reasons and partly because neither NSF nor the University of Wisconsin had the kind of experience that DOE and its contractors have had in running such projects. All in all, it seems that everyone who had something to gain by portraying Aladdin as a bargain has indeed gotten more than bargained for.

Originally conceived as a 3-year construction project, Aladdin appeared for the first time in the fiscal 1978 budget and all the hardware was in place by the fall of 1981. Initially, the microtron proved balky, but Rowe and his coworkers eventually succeeded in extracting electrons from it and then in storing small currents (less than 1 milliampere) and accelerating them to 0.75 GeV in Aladdin.

But, by the spring of 1983, they had been unsuccessful in achieving significantly higher currents. Anxious NSF officials overseeing the project and contemplating a Wisconsin proposal for a 3-year renewal then ordered a technical review of the accelerator and a scientific review of the proposed research. The two groups of reviewers concurred in their findings: there were no design flaws that prevented Aladdin from working; the scientific justification for its completion was strong; but significant additions of staff and resources, and changes in the management structure, were required for success. Subsequent reviews took place the following November and last June.

Wisconsin's initial response was to become more directly involved by establishing an executive committee of university scientists to oversee the project. It also began looking for more accelerator scientists and technicians. A year ago, it took the additional step of making the Synchrotron Radiation Center a separate administrative unit in the graduate school with a new director and associate director. Rowe was freed to concentrate on the technical aspects of Aladdin. A Wisconsin physicist, Keith Symon, is serving as acting director. David Lynch of Iowa State University was the first acting associate director, and Giorgio Margaritondo of Wisconsin holds the post now. Searches for permanent directors are under way.

The Synchrotron Radiation Center has an older, 0.25-GeV storage ring, Tantalus, that is so reliable that operators turn it off each night when researchers go home, an unheard of action in high energy physics. Because Tantalus requires so little attention, Rowe has been able to put his entire staff of technical people to work on Aladdin. Users agreed that the light from a 10-milliampere current at 0.75 GeV would be bright enough for them to work with, and the accelerator team guessed it could achieve this by April of last year.



Aladdin

The storage ring, shown before the vacuum chamber that holds the electron beam was completed, is in the form of a square with rounded corners. Three dipole magnets bend the electrons around each corner. Quadrupole magnets between the dipoles keep the electron beam focused. Synchrotron light will come from the bending magnets and from yet to be constructed insertion devices, special magnets that will sit in the empty strait sections of the ring. The enclosure on the right inside the ring houses the small injector accelerator, the microtron, that feeds electrons into Aladdin. The proposed injector synchrotron would fit inside Aladdin but most likely will go in a separate building adjacent to the present one. [Source: University of Wisconsin Synchrotron Radiation Center]

By last summer, however, the highest current accelerated was 2.5 milliamperes. In September, new NSF director Erich Bloch received a full briefing on the situation, with one of the options discussed being termination of the project. Electron accelerator experts Ewan Paterson of the Stanford Linear Accelerator Center and Boyce McDaniel of Cornell University reported that the only sure way to get stored currents of 100 milliamperes or more was by full-energy injection and that the technical staff was still too small. As it happens, accelerator scientists are scarce in the United States, where there are few formal training programs. Wisconsin has been largely unsuccessful in landing prospects, especially given the uncertainty surrounding Aladdin's future.

Representing the university, Symon reaffirmed Wisconsin's commitment to Aladdin's completion, as indicated by the establishment of tenured faculty positions and offers of top salaries for accelerator experts. He also noted that the Swedish firm, Scanditronix of Uppsala, which built the injector synchrotron for BESSY in Berlin, has said it could duplicate this machine for Aladdin. Finally, Lynch, speaking for synchrotron radiation users, said that the waiting experimenters unanimously supported the full-energy injector.

In October at the annual users' meeting, Symon passed on the word from NSF that it wanted to explore the full-energy injector option, provided that Aladdin's successful completion could be assured. The assurance rests on the recruitment of additional technical staff. Given the shortage of accelerator experts, the most likely source of such talent is the DOE national laboratories. High-level discussions between NSF and DOE officials concerning the possibility of "borrowing" national laboratory scientists for up to 2 years have resulted in a tentative agreement.

The agreement is partly conditional on the outcome of the 4-month study that began last month. There is a good chance that the national laboratory members of the study team will also be those that are borrowed, if the full-energy injector project proceeds. Most of these come from the Lawrence Berkeley Laboratory and Argonne National Laboratory, which are not currently building or operating synchrotron radiation sources but have accelerator scientists.

In the meantime, the long-suffering users will have to wait a little longer. Symon reported at the users' meeting that Scanditronix indicated it would take 20 months from the date of receipt of an order to build the injector synchrotron, plus an additional 6 months for onsite assembly and testing. While it is possible that Aladdin's performance will improve enough to make experiments feasible before the injector arrives, Symon also told the users that the first priority will be to prepare Aladdin to receive the injector by the addition of radiation shielding, accelerator controls, vacuum systems, and so on. Any conflicts between this and experiments will be resolved in favor of the former.—ARTHUR L. ROBINSON