colliders onto the SLAC site.

Denis Keefe (LBL) stresses, however, that the present SLAC linac is far from being limited by sparking. Its gradient could be increased by a factor of seven, he told us, before breakdown became a worry. But that would raise the power bill by a totally unacceptable factor of *fifty*—most of it wasted in the accelerating structure and the waveguides. The key issue, he argues, is finding a way to develop high-power microwave sources that supply energy to the beam with reasonable efficiency.

Taking Salam's challenge seriously, Robert Palmer is seeking to miniaturize the rf linac by *another* three orders of magnitude. Powered by 10-micron CO_2-laser light, the linac structure would be reduced to a glorified diffraction grating, generating an accelerating gradient on the order of 10 GeV/m. "If I can't improve things by several orders of magnitude, he told us, "I'm not interested." Conventional rf linacs, he argues, can almost certainly be pushed another order of magnitude. LEP is expected eventually to achieve a collision energy of 260 GeV, and rf linac sections with 100-MeV/m gradients have been built as laboratory prototypes. The laser-accelerator pioneers should therefore be looking much further down the road, he contends. "100 TeV may be pie in the sky, but sooner or later we'll need pie in the sky."

A metallic diffraction grating, like any other periodic conducting structure (glass will also do at optical frequencies) serves the basic linac function of converting plane-wave transverse modes of incident radiation at comparable wavelengths to accelerating modes whose slower phase velocities match the velocity of the particles to be accelerated.

Two potential problems of the 10-micron grating accelerator have raised doubts about its usefulness as an ultra-high-energy accelerator: The high field intensities necessary for 10-GeV/m would turn any grating surface into a plasma. Secondly, electron beams would be limited to very low intensities. Palmer addresses these concerns by talking of a "consumable" grating. The grating (or the beam) moves over a few millimeters to a fresh patch after each beam pulse. Plasmas generated at surfaces diffuse slowly enough, he argues, that the plasma retains its periodic structure throughout the accelerating pulse. With regard to low electron-beam intensities, he points out that this could be compensated for by very high repetition rates. A pulsed CO_2 laser operating at a megacycle would provide adequate luminosity for a multi-TeV linear collider, he calculates. No such laser has yet been built, he concedes, but he is optimistic that it can be done.

"The potential of laser-driven accelerator devices justifies the devotion of resources for their further study and experimental exploration," the executive summary of the recently published Workshop *Proceedings*[1] says. "A similar workshop in a year or two will again be most valuable in assessing progress ... and defining new goals and directions." Present assessments of the relative merits of different schemes, Sessler cautions, must be regarded as highly tentative. "Our view of the inverse free-electron-laser accelerator, for example, has twice been radically changed in the last two years." —BMS

Reference

1. *Laser Acceleration of Particles*, P. J. Channel, ed., AIP Conf. Proc. No. 91, New York (1982).

Lynch report on synchrotron radiation

Last summer the Solid State Sciences Committee of the National Academy of Sciences convened a subcommittee on synchrotron radiation facilities. The subcommittee was established to help assess the present status of the facilities and make projections for their future utilization.

The National Synchrotron Light Source has just been dedicated by DOE at Brookhaven. At the start of FY 1983, the Stanford Synchrotron Radiation Laboratory was transferred from NSF to DOE. One reason for the transfer was that the Office of Management and Budget wanted to consolidate support of the two major US facilities in one agency with the goal of improving management processes for facilities support.

NSF supports the University of Wisconsin Synchrotron Radiation Center, which has operated Tantalus for 15 years, and where Aladdin is now coming into operation. NSF also supports CHESS, the synchrotron radiation source at the 4–8-GeV Cornell Electron Storage Ring.

Besides studying the status of synchrotron radiation research and facilities in the US, Donald Stevens, who is deputy director of the DOE Office of Basic Energy Sciences, told the Solid State Sciences Committee that his Office needs guidance on the relative merits of synchrotron radiation and neutron sources, the two most expensive research fields Basic Energy Sciences supports. In addition, there is pressure on Basic Energy Sciences to establish a committee resembling the High Energy Physics Advisory Panel, a committee to identify and establish priorities for future facilities. The question he posed to the subcommittee was, "Compared to other needs, is the US overextended in synchrotron radiation?"

By the end of September, the subcommittee, headed by David Lynch (Iowa State University), provided information needed for the FY 1984 budget process. And in January the subcommittee's report was released by the National Academy.

The subcommittee found that the use of synchrotron radiation (see the special issue of PHYSICS TODAY in May 1981) has undergone rapid growth in the last five years, even more than was anticipated in 1976, when a similar group was also convened by the Academy's Solid State Sciences Committee. The 1976 report led to construction of the two storage rings at the Brookhaven National Synchrotron Light Source (an 800-MeV ring for uv and soft x rays and a 2.5-GeV ring for x rays, both just

Aladdin's first stored beam with a reasonable lifetime (halflife 20 min) was celebrated in May at the University of Wisconsin Synchrotron Radiation Center by Ed Rowe (left) and Bill Winter.

coming into operation) and Aladdin (a 1-GeV ring for uv and soft x rays, also just coming into operation) at the University of Wisconsin Synchrotron Radiation Center.

Insertion devices—wigglers and undulators—give orders of magnitude brighter radiation than bending magnets, making some experiments possible that were not even dreamt of a few years ago. However, the report notes, there are significant uncertainties associated with multipole wigglers and small-gap undulators that should be resolved. For example, the 54-pole wiggler being installed at SSRL would produce a power density of about 10 kW/cm^2. Such a power density would create severe heat-transfer problems. Even higher power densities are technically feasible at present. The subcommittee urged that research on and with insertion devices should be pursued aggressively at several storage rings. Because progress could be substantial in one or two years, rather than the five-year time scale for storage rings, the subcommittee felt the devices and their research possibilities should be monitored regularly.

The number of synchrotron radiation users has grown at about 20% per year in the US since 1976, and the number of US and worldwide publications based on synchrotron radiation has grown at an even greater rate—about 30%. In 1981, 350 scientists traveled at least once to a US synchrotron radiation facility to take data (excluding NSLS, which was not operating, and CHESS). In 1982 the number grew to about 620. (The subcommittee counted those members of Participating Research Teams at NSLS who are funded for work there.) The US has about 100 synchrotron radiation experiment stations, including those at NSLS and Aladdin.

John McTague, NSLS director, remarked during a subcommittee meeting that the facility operating cost for a given experiment station (which supports about 12 average users) at NSLS is about \$35/hour. Rowe commented that facility operating costs at Wisconsin per published paper are comparable to the page charges for the paper.

The new study estimates that the number of users of the x-ray region is about equal to the US capability to handle them, using all the x-ray beam lines in the US that have been instrumented (including those funded but not yet operating at NSLS), while uv user demand is about 80% of the US capacity. By 1985 the subcommittee estimates that demand for x-ray and uv beams will exceed the additional supply that would be available if unused ports on current machines were developed.

The report identified research areas with exciting recent pasts and exciting futures—photoemission (uv and soft x ray), x-ray absorption and x-ray scattering (both elastic and inelastic).

▶ X-ray absorption studies began with EXAFS measurements in the transmission mode. One could work with minority elements present at levels down to one part in 10^3 and still determine the local environment. Once x-ray focusing optics was developed, one could detect one part in 10^4 by new detection methods—fluorescent x rays and Auger electrons. This improved detection also gave surface sensitivity and led to surface EXAFS (SEXAFS). Because SEXAFS is an inherently low-count-rate experiment, the availability of more wiggler and undulator beam lines should make SEXAFS a widely used tool.

▶ X-ray diffraction and scattering have also grown rapidly, the subcommittee said, and their progress may be similar in the next few years to that of EXAFS in the past years. The technique has benefited from higher intensities, first from focusing mirrors and then from insertion devices. Two significant advances occurred recently. One is the realization that x-ray damage to protein samples depends not only on dose but also on dose rate; so high-brightness radiation from insertion devices should prove very useful for protein crystallography. The second is the development of x-ray diffraction from two-dimensional structures. This approach has been used for structural studies on melting surfaces, adsorbates and membranes. Although this field is in its infancy, Lynch told us, it should grow into a major research activity very soon and should also have technological applications.

▶ Photoemission spectroscopy with synchrotron radiation is now probably the most versatile surface tool, according to Lynch. Synchrotron radiation allows many techniques not otherwise available, for example, varying photon energy to vary excitation probabilities and using polarization to get wavefunction symmetries and adsorbate orientations. Because the radiation is polarized, one can control the angle between the plane of polarization of the beam and the sample, thus allowing one to map the electronic band structure of solids and surfaces. Increased source intensities now allow even electron-spin polarizations to be measured, despite a loss of 99.99% of the electrons in the spin-analysis detector. The subcommittee cited impressive advances in atomic and molecular physics, too. The report said the future will emphasize the study of interfaces: semiconductor–semiconductor (heterojunction), semiconductor–metal (Schottky barrier), and semiconductor–insulator (as in MOS devices). The higher angular resolution provided by higher intensities should allow the study of reconstructed surfaces, which require higher momentum resolution than is currently feasible.

Although synchrotron radiation allows short-time-scale studies, this feature hasn't been widely employed in the past. The subcommittee singled out recent work at CHESS on the melting and subsequent crystallization of laser-annealed silicon; this work required x-ray diffraction on a nanosecond time scale. Studies on such short time scales are being developed for EXAFS, and some workers are considering it for photoemission studies of surface chemical reactions.

Subcommittee members were Boris Batterman (CHESS), Arthur Bienenstock (SSRL), Dean Eastman (IBM), Peter Eisenberger (Exxon Research and Engineering), Lynch, McTague, Ednor Rowe (SRC, Wisconsin), J. Michael Rowe (National Bureau of Standards), Steven Schnatterly (University of Virginia) and Neville Smith (Bell Labs). The report is available from the Academy.

—GBL □

John McTague (left) and George Keyworth (Presidential Science Adviser) in the control room of the National Synchrotron Light Source on 22 November, the day NSLS was dedicated.