Lawrence Berkeley National Laboratory
LBL Publications

Title
Advanced Light Source Report Vol 6 No 2

Permalink
https://escholarship.org/uc/item/17g3r7z3

Author
Lawrence Berkeley National Laboratory

Publication Date
1993-12-01

eScholarship.org Powered by the California Digital Library
University of California

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. While this document is believed to contain correct information, neither the United States Government nor any agency thereof, nor the Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or the Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or the Regents of the University of California.

ADVANCED LIGHT SOURCE
REPORT
Vol. 6, No. 2 December 1993
Lawrence Berkeley Laboratory / University of California

ALS Celebrates Grand Opening

Brilliance was in abundance as supporters of the Advanced Light Source from around the world gathered at the Official Dedication Ceremony on October 22. Bright sunlight and the crowd's beaming faces added plenty of sparkle to the grand opening celebration.

Government officials, scientific leaders, directors of other synchrotron facilities, and newspaper and television reporters joined hundreds of LBL staff members to watch the ribbon-cutting ceremony that marked the official opening of the $150 million state-of-the-art facility. The event was honored by the attendance of Gayle Wilson, wife of California Governor Pete Wilson, who, as former U.S. Senator, helped procure funding for ALS construction.

Watching former LBL Director Dave Shirley cut the ALS ribbon were (from left) Jay Marx, Don Pearman, Martha Krebs, Gayle Wilson, Brian M. Kincaid, Charles V. Shank, and Hermann Grunder.

LBL Director Charles V. Shank opened the festivities by describing the dedication ceremony as both an end and a beginning: "We have finished the construction project on time and on budget and we are now beginning the scientific program which will be the ultimate measure of our success. Today we celebrate the truly extraordinary accomplishments of everyone who made this project succeed."

Shank called special attention to six individuals who were critically important to the project's success: Jay Marx, Dave Attwood, Ron Yourd, Alan Jackson, Klaus Halbach, and Klaus Berkner. "Without Jay Marx's initial leadership, this project would not be the success it is today. Our laboratory takes special pleasure and pride in his unique talents. Dave Attwood kept the ALS flame burning in the scientific community. Ron Yourd displayed remarkable project management skills. Alan Jackson led an international accelerator team that designed an ALS that worked the first time. Klaus Halbach gave enormous creativity and spiritual leadership. And finally, Klaus Berkner drove the technical design and formed the organization that brought the Light Source to fruition."

Shank also paid tribute to all of the other LBL staff members who worked on the ALS and to key Department of Energy (DOE) personnel, including Don Stevens, Lou Ianniello, and Ed Temple (now with Argonne National Laboratory). Judy Bostock was thanked for being a "key ALS advocate" while with the Office of Management and Budget.

Second to speak was Dave Shirley, former director of LBL and now senior vice president for research and dean of the graduate school at Penn State. Often referred to as the "father of the ALS," Shirley explained how the concept for the ALS developed in early 1982. "The scientific case for a third generation light source seemed so compelling that we couldn't resist going ahead. We were, as the phrase goes, running a little out in front of our headlights. It took a while for the rest of the world to catch up, but the whole concept came together and it has been moving forward at a fast pace ever since."

Shirley concluded by speculating on what the future has in store for the ALS. "I think that when people look back from the perspective of the 25th anniversary of this Dedication, they will see experiments done that we couldn't imagine today in a variety of fields that span all the way from materials science to biology. I think we will see nanostructures, micromachining, and many other new fields opening up that we can

IN THIS ISSUE

PUB 601

only dream of. So for me, this is the culmination and the realization of what was once referred to by Dave Attwood as the impossible dream."

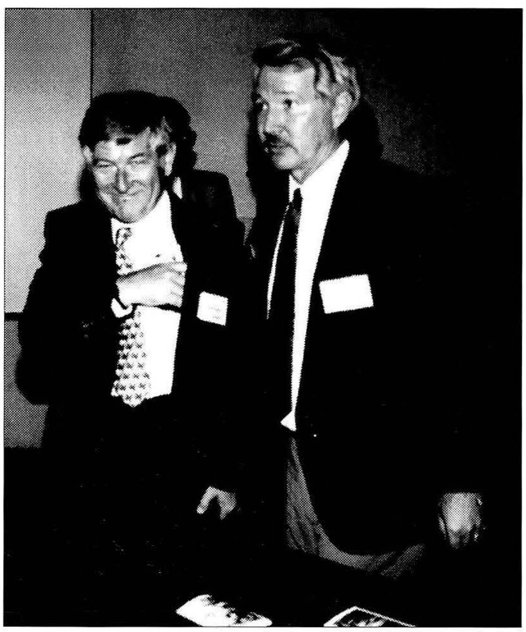
ALS Team Shares Credit

LBL Associate Director Martha Krebs took the podium as it was officially announced that she was President Clinton's nominee for the director of DOE's Office of Energy Research. She pointed out that one of the greatest challenges she will face in going to Washington is "to try and convey what institutions like LBL and the other national laboratories can bring to the performance of science—that we have something very special." Krebs said the teamwork approach, where diverse groups of people pull together to make a facility like the ALS possible, is what big science is all about.

A very entertaining talk was given by Hermann Grunder, who now directs the Continuous Electron Beam Accelerator Facility in Newport News, Virginia. Grunder was the head of LBL's Accelerator and Fusion Research Division when the ALS was first proposed and played a major role in bringing the ALS to LBL. He described Berkeley as the place where big science was invented (a reference to E.O. Lawrence's 184-inch Cyclotron on the present site of the ALS) and a place where it still happens.

Brian M. Kincaid, director of the ALS, thanked members of LBL, the DOE, and the scientific community for their extraordinary work to make the project a success. "We have a very, very special team at the ALS and the work that has been done here is absolutely amazing to me. You can't go out and buy one of these things—you have to have a group of people who are willing to take responsibility to do it." He concluded by thanking Jay Marx for his exceptional leadership as ALS Director from 1987 until 1992.

Japan's Synchrotron Radiation Research Institute's Vice President Kazutake Kohra presented Brian M. Kincaid with an engraving commemorating the success of the ALS project.



Ron Yourd (right), who supervised the construction of the ALS, returned for the celebration from his one-year post at DOE offices in Washington, D.C. He is pictured with Hermann Grunder, director of the Continuous Electron Beam Accelerator Facility.

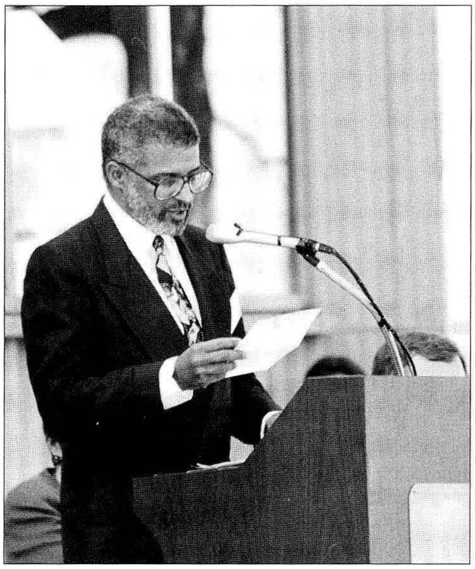
Hundreds of people gathered to celebrate the grand opening of the ALS at the official dedication ceremony.

Critical Support from DOE

Shank introduced the next speaker, Don Pearman, as one of the best friends that LBL has. Pearman is manager of DOE's San Francisco Operations Office and acting associate deputy secretary for Field Management. He described the ALS as "a shining example" of Energy Secretary O'Leary's vision for accelerating the technology of partnerships into every one of the missions of the department. He said the fact that the ALS works, and was completed on time and within budget, is a magnificent testament to the fact that total quality management really is alive and well at LBL and in DOE. Pearman read a personal note from Secretary O'Leary who was unable to attend the Dedication: "I want to express my appreciation to the ALS team for a job well done. This facility will make an important contribution to providing the scientific and technical foundation for a more productive and competitive economy and more efficient use of energy. We can all be proud to declare the ALS open for business."

A highlight of the dedication was the attendance of Gayle Wilson (left), wife of Governor Pete Wilson and a longtime advocate of science and science education. She is talking with Martha Krebs, former LBL associate laboratory director, and Charles V. Shank, LBL director.

The ceremony ended on a high note with the presentation of DOE Distinguished Associate Awards to Jay Marx and Brian M. Kincaid for their outstanding contributions to the ALS project. As DOE representative Ron Thomas presented the awards, he remarked that the ALS project has been characterized as a textbook example of how to carry out a complex construction project. He thanked Marx for his exceptional leadership of the ALS team during project design and construction and complemented Kincaid for his outstanding contribution as project director during commissioning and initial operation.



Don Pearman, manager of DOE's San Francisco Operations Office, reads a message from Energy Secretary Hazel O'Leary expressing her appreciation to the ALS staff for a job well done.

ALS Director Brian M. Kincaid shares a smile with former ALS Director Jay Marx and his wife, Katya Hope, after Kincaid and Marx received Distinguished Associate Awards from the DOE for their outstanding contribution to the success of the ALS project.

Report from the ALS Director

The pace of accomplishments at the ALS during the last several months has been truly remarkable. Three beamlines operating in October 1993, with two more close to completion, are impressive feats considering we stored our first beam just last spring. Many of the promises the ALS made to the user community in the way of undulator light and beam stability have been delivered in an amazingly short period, giving us every expectation that our first year of operation will be as successful as the past few months.

ALS Director Brian M. Kincaid leads members of the University of California Regents on a tour of the facility.

After a highly productive accelerator commissioning in the first part of 1993, the ALS scheduled a three month summer shutdown to prepare for the start of user experiments. Several beamlines and two undulators were installed on the experimental floor, the storage ring's vacuum system was fully baked, and every critical component was realigned. We stored beam on the first day after resuming operations and achieved a beam lifetime of 10 hours with a current of 100 mA within a matter of days. Everyone at the ALS is to be congratulated on their hard work and dedication during this extremely busy period.

First Beamlines in Operation

Our much-anticipated transition from being a new accelerator to an operating user facility took place on October 4. On that day, the ALS delivered the first light to a user experiment: the CXRO x-ray microprobe beamline. Two weeks later, on October 18, a transmission grating spectrometer began recording undulator spectra on Beamline 7.0. The diagnostic beamline was commissioned shortly thereafter, allowing the first measurements of the electron beam size. The rapid re-start of the accelerator system after a major shutdown, and the amazing progress in beamline commissioning, demonstrate that the ALS team is truly the world leader in this business.

Initial analysis of the data taken with the transmission grating spectrometer indicate the undulators are working as predicted—a testament to the skill of the ALS Insertion Device Group responsible for their design and construction. The photon-beam position monitors installed in Beamline 7.0 show the beam to be very stable (2 μm at 10 m from the source over a few minutes) with extremely little drift (around 1 μm per hour at 10 m)—all with no feedback! These are exceptionally good values, one to two orders of magnitude better than most other storage rings, and are a confirmation that the time and effort expended on making a high-quality machine are already paying off.

Teamwork is Key to Success

The ALS Dedication Ceremony on October 22 was a reminder that projects like the ALS are built on teamwork. The Dedication brought together all the different groups that make up the "ALS Team" and who have contributed so much to its success. This includes not just the ALS staff, but also LBL personnel, the Department of Energy, the user community, and local and state government officials. Putting together this team, and fostering the cooperative relationships within, is largely due to the work of my predecessor Jay Marx. During his six years as ALS Director, he established the foundation on which our current and future achievements are based.

Commitment to Quality

My goal is to make the ALS the location of choice for both scientific and industrial projects utilizing synchrotron radiation. This means the ALS must continue to develop new, state-of-the-art technologies and instrumentation to meet the needs of our users—a challenge we gladly accept. I look forward to working with government, industry, and the user community to establish a world-class scientific program to match the unique capabilities of this facility.

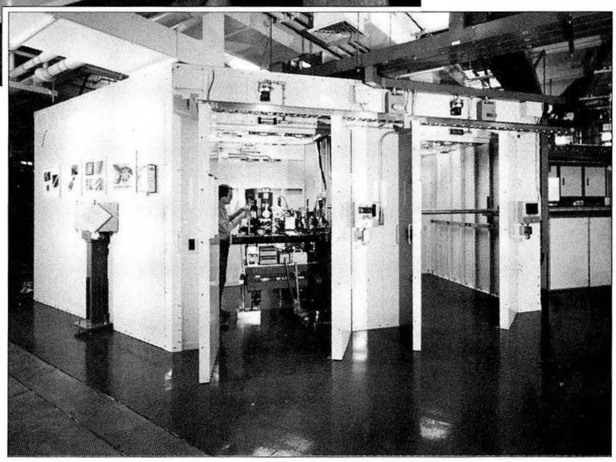
Brian M. Kincaid
ALS Director

First Beamlines See the Light

October 4 was an exciting day at the ALS as a bright orange glow from a phosphor signaled the start of user experiments. This noteworthy event marked the successful conclusion of the ALS' transition from construction project to operating user facility.

To document the delivery of the first light to a beamline, a specially prepared target was placed in the experimental hutch of the x-ray microprobe beamline. When the shutter was opened, the anxious onlookers could see an orange glow through the hutch windows confirming that the beam was striking the target. Just a few weeks later, a transmission grating spectrometer designed by the ALS was recording undulator spectra on Beamline 7.0, and the ALS diagnostic beamline was taking the first images of the electron beam. User experiments will be underway at two more beamlines by January 1994.

Collaborators on the design of Beamline 10.3 include CXRO scientists Phil Batson, Al Thompson, Karen Chapman, and Ron Tackaberry.



Jim Underwood of CXRO adjusts the microprobe instrumentation in one of the experimental end stations for the 10.3 beamline.

Experimental program begins

Al Thompson of LBL's Center for X-Ray Optics (CXRO) led the development of the first operational beamline which is an x-ray fluorescence microprobe providing high-resolution elemental analysis of a wide variety of samples in near-natural environments. The beamline (designated 10.3) is designed to achieve a spatial resolution approaching 1 μm using multilayer-coated mirrors in a Kirkpatrick-Baez configuration. Tunable, broad-band excitation of samples at photon energies from 6 to 10 keV, as well as white-light excitation, is possible.

The microprobe quantitatively detects elements by means of the characteristic fluorescent x rays emitted by the irradiated sample. The photon energy identifies the element and the intensity measures its quantity. At present, the elemental sensitivity of the microprobe reaches the femtogram (10^{-15} g) level for elements from potassium to zinc in the periodic table. Additional detection sensitivity is imparted by the ability to select the x-ray photon energy to avoid interfering fluorescence from elements other than those being sought. A major advantage of the x-ray microprobe is that the specimen does not have to be kept in vacuum or subjected to special contrast-enhancing preparation.

The first microprobe experiments will focus on the widely studied propensity of high-strength ceramics to fracture comparatively easily; that is, to be brittle. Defects and cracks are key elements in any mechanism for fracture, and these will be investigated in a wide variety of ceramic materials of technological interest. Since the elements in the materials have low atomic numbers and K absorption edges below 5 keV, the microprobe is well matched to their study. Additional applications of the microprobe occur in materials science (distribution of doping materials in semiconductors), geology (composition of inclusions in geological materials), environmental science (profiles of pollutants in animal tissue), and archeology (analysis of ancient documents and artwork).

The beamline Participating Research Team (PRT) consists of members of LBL's Materials Sciences, Applied Sciences, Earth Sciences and Engineering Sciences divisions as well as scientists from the Oak Ridge National Laboratory and the Lawrence Livermore National Laboratory. The PRT Spokesperson is Al Thompson of LBL's Center for X-Ray Optics.

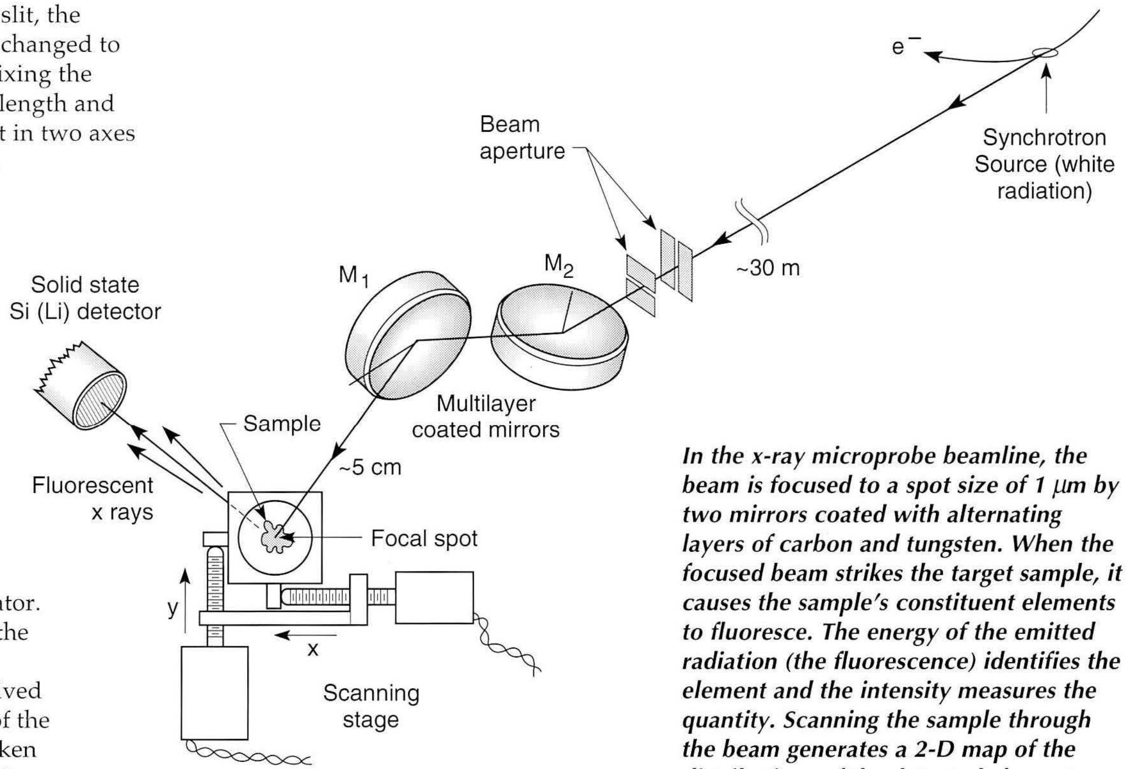
U5 Undulator passes the test

One of the most important "tests of readiness" for the insertion device beamlines at the ALS was the observation of the first undulator light. The ALS passed this test on October 18 when the undulator installed in sector 7 of the storage ring became operational. The gap of the 5-cm-period undulator was closed to 23 mm, giving a value of the deflection parameter K= 2.3, with no noticeable effect on the lifetime of the stored electron beam. The measurements of the undulator light taken during the next several weeks showed that it is behaving as predicted, giving excellent higher harmonic performance.

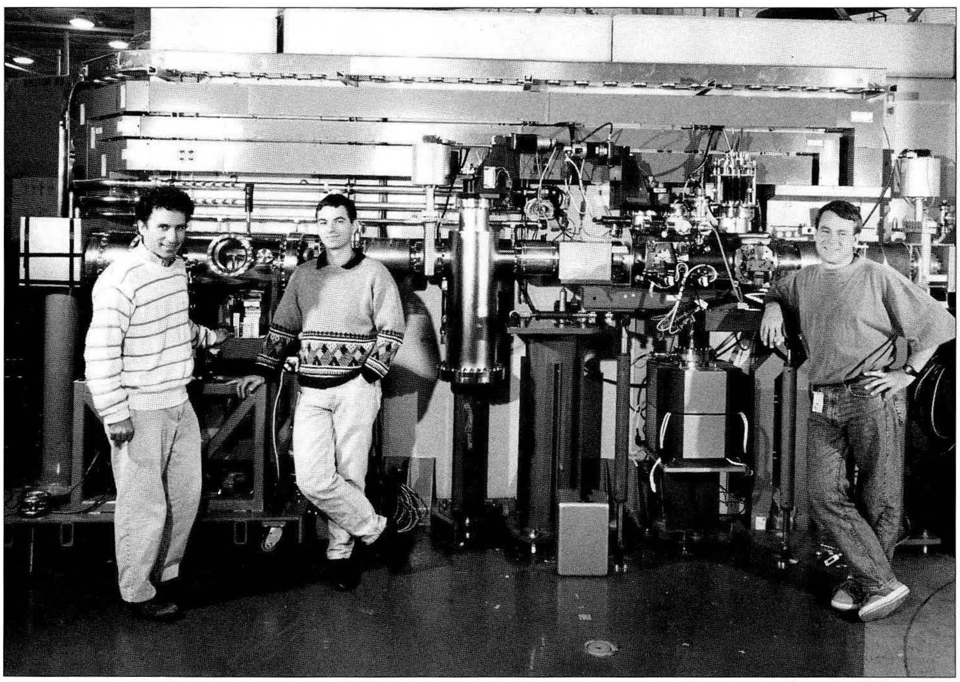
The ALS installed a transmission grating spectrometer (TGS) designed by ALS scientist Phil Heimann to measure the spectrum of the undulator beam. The TGS is used to disperse and focus radiation from the undulator onto a slit and detector. By moving the slit, the analyzed wavelength can be changed to produce a spectral scan. By fixing the detector at a particular wavelength and moving the entire instrument in two axes perpendicular to the beam, a plot of the spatial and spectral distribution can be produced.

The spectral sensitivity and resolution of the TGS were measured before its installation in Beamline 7.0 making it possible to determine the relative intensity and the width of the undulator harmonics—a very sensitive measure of the magnetic errors in the undulator. Data from the TGS validates the theoretical predictions of the undulator's performance derived from detailed measurement of the magnetic field distribution taken by the ALS Insertion Device Group before the undulator was installed.

The TGS will be removed when the undulator measurements are completed and the final components for the beamline will be installed; commissioning will begin in early January. Beamline 7.0 will be used for high-resolution photoelectron diffraction, fluorescence spectroscopy, and absorption and photoelectron spectromicroscopy at photon energies from 80 eV to 1200 eV. The PRT Spokesperson is Brian Tonner of the University of Wisconsin.



In the x-ray microprobe beamline, the beam is focused to a spot size of 1 μm by two mirrors coated with alternating layers of carbon and tungsten. When the focused beam strikes the target sample, it causes the sample's constituent elements to fluoresce. The energy of the emitted radiation (the fluorescence) identifies the element and the intensity measures the quantity. Scanning the sample through the beam generates a 2-D map of the distributions of the detected elements.



Members of the ALS Experimental Systems Group responsible for the design and calibration of the transmission grating spectrometer and Beamline 7.0 instrumentation are (left to right) Phil Heimann, Dimitri Mossessian, and Tony Warwick.

Diagnostic beamline measures emittance

The diagnostic beamline which provides precise imaging of the electron beam recorded its first image on October 20 after only a few hours of fine-tuning. The ALS machine-physics group is using the data being collected on the beamline to study the stability of the stored beam as well as to measure the horizontal and vertical beam sizes and to deduce the emittance and coupling.

The diagnostic beamline's imaging system employs two crossed spherical mirrors in a Kirkpatrick-Baez configuration, operating at almost unity magnification, to minimize distortions. A focused image of the source is produced on a single-crystal scintillator screen and the resulting visible image is then focused onto a CCD camera by a standard microscope. The resolution of the system is approximately 5 μm.

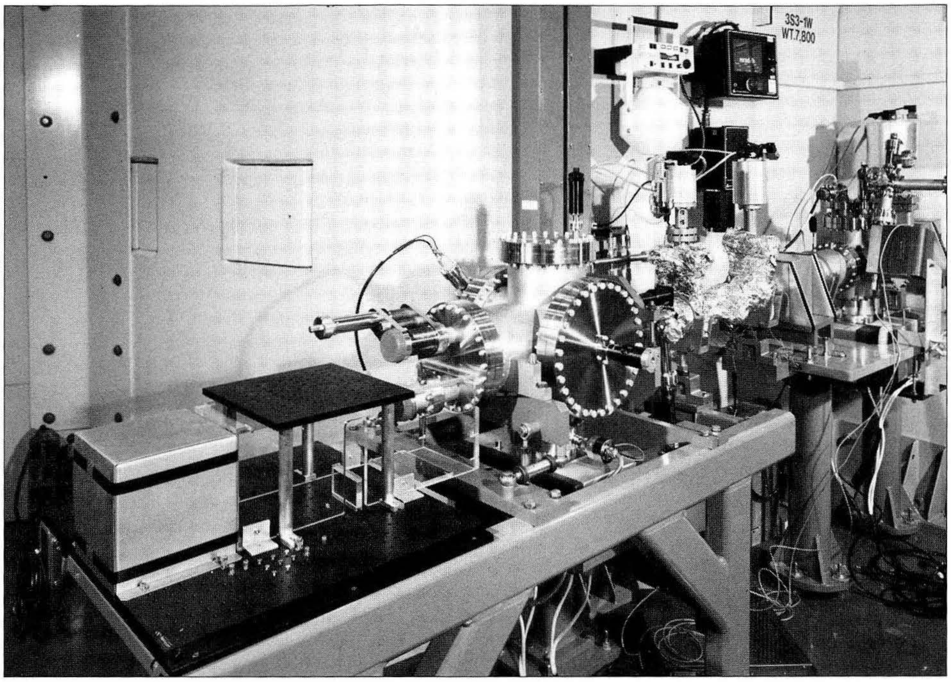
The image data collected by the beamline is transmitted to computers in the control room, permitting the control room operators to interpret the data to optimize the performance of the storage ring. A notable feature of the beamline is its special shielding that allows it to be operated while the storage ring is being filled. This has already proved to be invaluable in studying injection processes.

Additional beamlines underway

Soon two more beamlines will be in operation: the undulator beamline 8.0 and the bend-magnet beamline 9.3.2. The initial research program for Beamline 8.0 will be the investigation of the electronic and crystallographic structure of surfaces using various spectroscopy techniques. It will be the first beamline to use undulator light at high power and is scheduled to start full operations in December 1993. The beamline's PRT is led by Joachim Stöhr and Franz Himpsel (both at IBM), and by Thomas Callcott (University of Tennessee) and David Ederer (Tulane University).

The 9.3.2 beamline is scheduled to receive its "first light" in January. Testing is underway of one of the electron analyzers to be used in the beamline, a state-of-the-art system capable of better than 4 mV resolution. The 9.3.2 beamline will be dedicated to the study of problems in materials and chemical sciences using high-resolution electron spectroscopy. Charles Fadley (U.C. Davis and LBL) is spokesperson for the PRT operating the beamline.

The ALS is focusing its efforts on creating an efficient working environment for users now that the first beamline experiments are underway. This includes holding weekly meetings with representatives of user beamlines to schedule accelerator operations, providing users with safety training and a new *ALS Safety Handbook,* and coordinating the various aspects of beamline operations under a new Beamlines Operations Group headed by Bob Miller. Overseeing the day-to-day operation of the ALS to make sure all goes smoothly is Ben Feinberg, head of ALS operations. Fred Schlachter, as leader of the user liaison group, is responsible for coordinating the scientific research program.

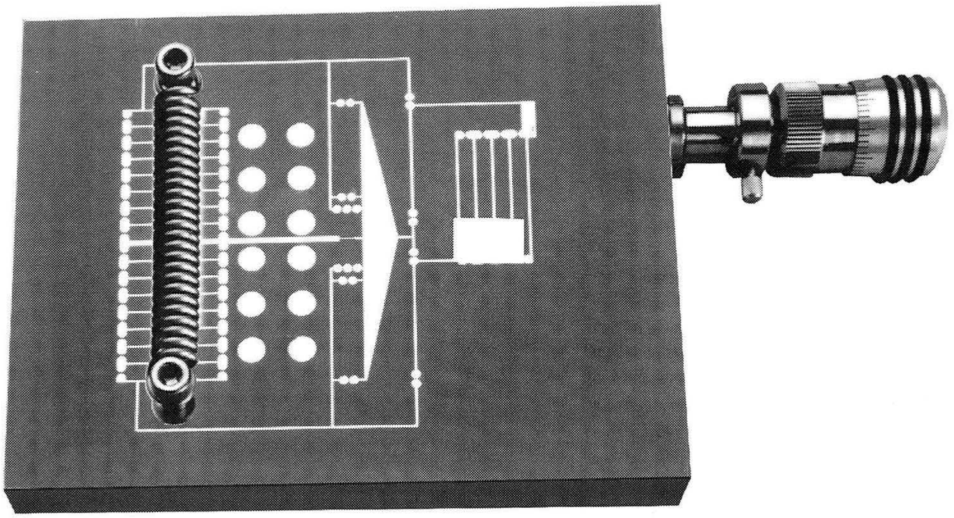


The diagnostic beamline, designed by ALS scientist Ed Melczer, provides precise imaging of the electron beam and collects data about the positional stability of the beam and the timing of the electron bunches.

Beamline	Source	Research	Energy Range	Avail.
3.1	Bend magnet	Diagnostic beamline	200 eV	Now
6.1	Bend magnet	High-resolution zone-plate microscopy	250–600 eV	1994
6.3	Bend magnet	Metrology and standards	50–4000 eV	1994
7.0	U5 undulator	Surfaces and materials, spectromicroscopy	70–1200 eV	Now
8.0	U5 undulator	Surfaces and materials	70–1200 eV	Now
9.0.1	U8 undulator	Atomic physics and chemistry	20–300 eV	1994
9.0.2	U8 undulator	Chemical dynamics	5–30 eV	1994/95
9.3.1	Bend magnet	Atomic and materials science	700 eV–6 keV	1994
9.3.2	Bend magnet	Chemical and materials science	30–1500 eV	Now
10.3	Bend magnet	Materials science and advanced microprobe instrumentation	3–12 keV	Now
11.0	EW20 elliptical wiggler	Materials science and biology, magnetic materials	50 eV–10 keV	1995
12.0	U8 undulator	X-ray projection lithography, optics development	60-320 eV	1995

The beamlines and areas of research for 1994–1995 operations.

Beamline Engineering Group Faces Many Design Challenges



Prototype flexure assembly with actuator and antibacklash spring attached.

The dawning of first light in an ALS beamline comes as a particular satisfaction to the Beamline Engineering Group, an aggregation of mechanical and electrical engineers, fabricators, and technicians formed to focus engineering expertise on the design, fabrication, installation, and ongoing support of ALS beamlines. Under the leadership of Dick DiGennaro and working closely with the personnel of the ALS Experimental Systems Group, the Beamline Engineering Group has developed the basic designs for ALS beamline front ends, position monitors, apertures, mirrors, and monochromators.

These designs represent solutions to a formidable array of engineering problems. Included among these are the "ordinary" challenges of beamline design—the requirements for ultra-high-vacuum (UHV) integrity, accurate beam optics, precise component alignment, and personnel and component safety. Added to these are a number of complications arising from the brightness and small spot size of ALS photon beams. The small spot size creates exceptional requirements for dimensional stability and precision adjustability in beamline components. At the same time, focusing such a bright beam to a small spot increases the thermal loading on these components, making it difficult to maintain the required dimensional stability and adjustability. High thermal loading also threatens the survivability of certain components in the event of a mis-steered beam.

Solving these problems while remaining on time and within budget posed a daunting challenge for the Beamline Engineering Group. To meet this challenge, the group made heavy and innovative use of computer-aided engineering, refined existing designs wherever possible, and employed common-element design to maximize component interchangeability and adaptability.

Meeting Design Requirements

The development of the monochromator entrance slit provides an excellent example of the Group's design approach. The spherical grating monochromator consists of three optical components: the entrance slit, the diffraction grating, and the exit slit. The size of the entrance slit's opening is one critical determinant of the spectral resolution achievable at the exit slit (i.e., how narrow the range of wavelengths selected by the exit slit can be). An entrance slit width of 10 µm is optimal for most wavelengths, but an 8-µm slit provides better resolution for a narrow range of higher wavelengths. In addition, for some experiments, users will want to open the entrance slit as wide as 100 µm, sacrificing optimal spectral resolution in order to maximize photon flux.

These experimental requirements mean that the width of the entrance slit must be precisely controllable. The initial entrance slit specifications called for a slit width that would be adjustable between a minimum of 5 µm and a maximum of 200 µm. A further requirement was that the two slit blades should move as symmetrically as possible throughout their adjustment range. This meant that the two blades must move equal distances (within tight tolerances) whenever adjusted, so that the slit's horizontal center line would remain stationary as its width was changed. It was also critical to ensure that the slit blades would remain parallel (again, within narrow limits) throughout their adjustment range, so that the rectangular shape of the slit would not change.

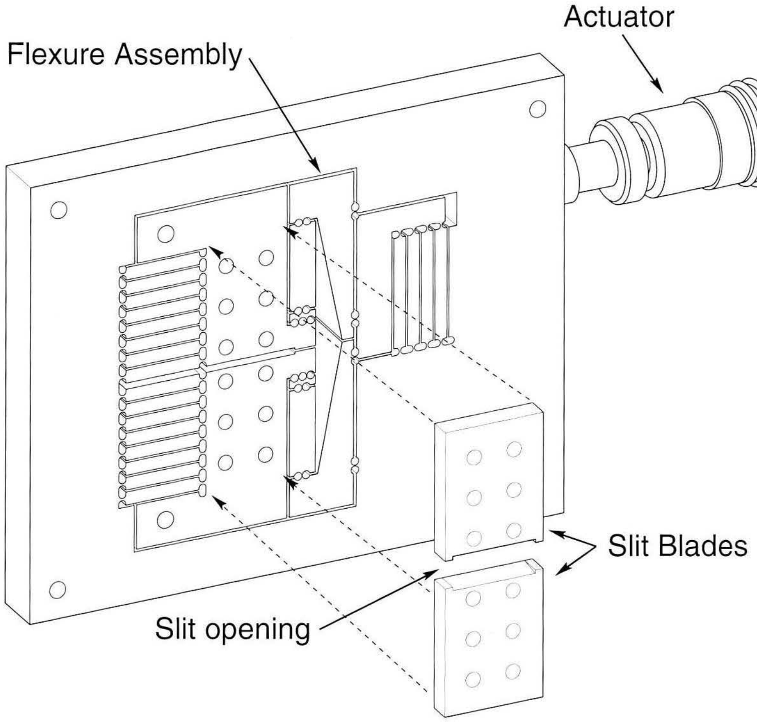
This precise mechanism had to be designed to operate within a UHV environment, where the potential for contamination severely restricts the mechanical designer's options. Metal-against-metal movement, for example, becomes problematical because of the possibility that frictional movement will generate metallic particulates. Similarly, the use of traditional lubricants is prohibited because of the likelihood that they will create vapors that will degrade the vacuum. The design task was further complicated by the thermal effects of the exceptionally bright, highly focused x-ray beam produced by the ALS. If not dealt with properly, these thermal loads would distort the slit, alter its width, or seriously damage portions of the slit assembly.

Finding Solutions

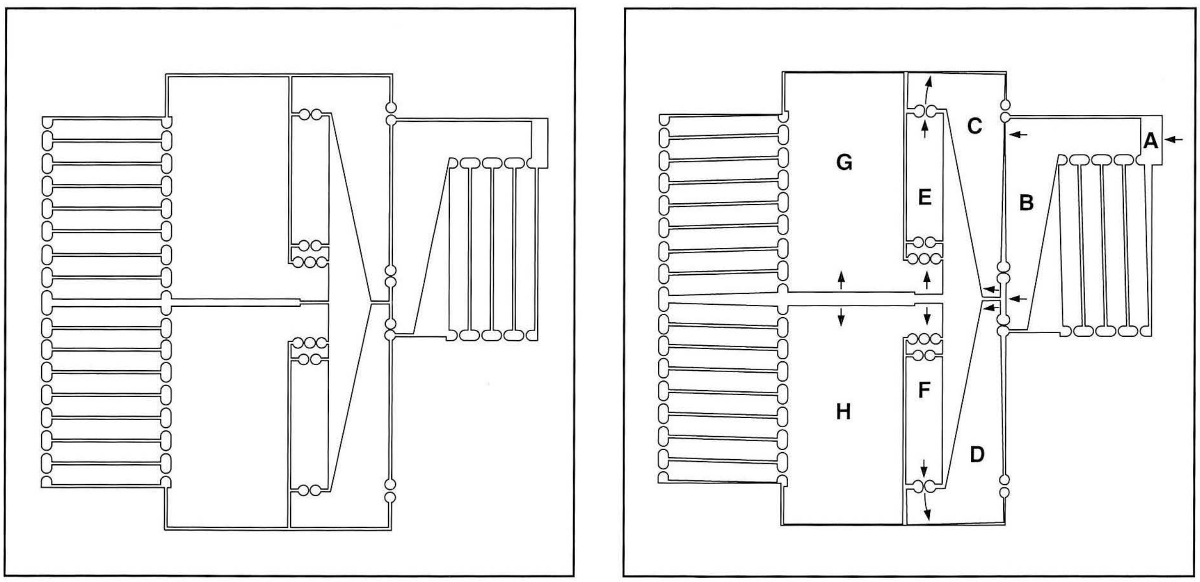
To meet the demanding design requirements dictated by the ALS operating environment, the Beamline Engineering Group designed a flexure assembly that transfers the actuation forces to the slit blades and allows them to open and close. In the completed design, the two blades that actually define the slit opening are mounted securely on the flexure assembly, which deflects as the actuator is adjusted in or out. The flexure assembly transfers the actuation forces without metal-on-metal contact, and the resulting slit blade movement is almost perfectly symmetrical and parallel. The actuator is a differential-pitch micrometer that allows submicron resolution of the slit width.

The group made heavy use of 2-D and 3-D CAD programs in the development of this mechanism, as they did in the design of the entire entrance slit assembly. The designers also made innovative use of finite element analysis (FEA), a 2-D computer modeling technique widely used for the analysis of large-scale mechanical processes but not commonly applied to optical microstructures. FEA was used to study the kinematics of the flexure assembly and to determine the material and configuration that would yield the required combination of strength, flexibility, and thermal properties.

Perhaps even more impressive was the group's success in dealing with the assembly's thermal problems. The engineers employed FEA to obtain precise pictures of the thermal loading on the slit blades and the flexure assembly under various conditions. These analyses enabled them to optimize the heat transfer characteristics of these components so that heat would be carried toward the internal water-cooling channels on the opposite side of the assembly from the sensitive actuator. As a result of these FEA studies, the engineers were also able to determine the optimal routing and flow rate for the cooling channels. To balance the heat transfer so that distortion would be minimized, they designed twin counterflowing cooling channels. An



The slit blades are mounted as shown on the flexure assembly. As the actuator is adjusted in or out, the resulting movement of the flexure assembly changes the size of the slit opening.

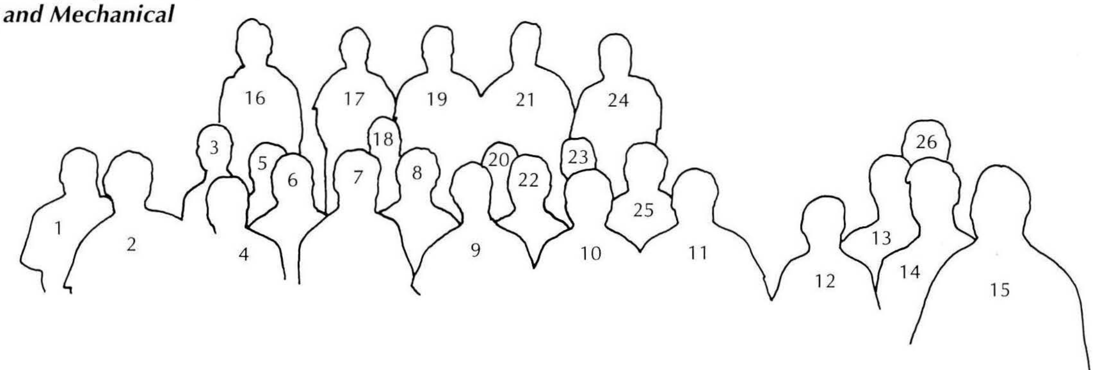


The flexure assembly is shown on the left in its neutral position, that is, with no actuation forces applied. The right-hand drawing shows what happens when the actuator is adjusted inward. As the actuator exerts force at point A, flexure B moves to the left, causing flexures C and D to counter-rotate away from the slit centerline. This rotation translates the horizontal motion of flexure B into the nearly-vertical motion of flexures E and F. As E and F move, they impart vertical motion to flexures G and H, which carry the slit blades. For clarity, the blades have been omitted from the drawings.

additional means of dealing with thermal problems was the use of GlidCop™, a special copper alloy, as the material for the flexure assembly and the slit blades. Under high heat loads this alloy provides seven times the strength of pure copper while retaining its high thermal conductivity.

These and other thermal control measures ensured that the entrance slit would meet its performance requirements under any foreseeable conditions. According to Dick DiGennaro, "The design of beamline components has progressed to the point where thermal problems are no longer a performance-limiting factor." Recognizing that this achievement is but one of several significant design advances incorporated into the entrance slit, LBL and the designers have applied for a patent on the device. They believe that the design has potential applications in other scientific and commercial facilities employing high-flux x-ray instrumentation.

It takes a lot of people to build a beamline, as evidenced by this gathering of only a portion of the ALS Mechanical Engineering and Mechanical Technician Groups.



1) Steve Abbott
2) Tom Miller
3) Andy Lunt
4) Bruce MacDonell
5) Ted Lauritzen
6) Frank Zucca
7) Jim Rounds
8) Greg Morrison
9) Dave Anderson
10) Bruce Rude
11) Don Davis
12) Don Yee
13) Al Boynton
14) Dick DiGennaro
15) Lou Tateo
16) Weyland Wong
17) Vladamir Moroz
18) Mike DeCool
19) Dennis Gibson
20) Dan Colomb
21) Curtis Cummings
22) Tony Catalano
23) Jeff Leifheit
24) Noel Kellogg
25) Nord Andresen
26) Greg Andronaco

Teaming Up with Industry

A significant role of the ALS as a national user facility is to build productive relationships with industry to share technology and expertise. The focal point of fostering these partnerships between the ALS and the private sector is Glen Dahlbacka of LBL's Technology Transfer Department. Dahlbacka, a physicist with extensive experience in x-ray science, has worked in both the public and private sectors, giving him the ability to see things from an industrial as well as institutional point of view.

Dahlbacka is enthusiastic about ALS management's desire to work with the industrial sector to develop new technologies with commercial potential. In fact, two areas in which the ALS is already planning for the needs of industry are micromachining and structural biology.

Microscopic machines, also known as micro-electromechanical systems or MEMS, are devices such as sensors, actuators, and microsurgical tools with tolerances measured in tenths of a micron. At the ALS, MEMS could be made using a process known as deep x-ray lithography which offers several advantages. Unlike the lithography techniques developed for integrated-circuit applications where the action takes place on the surface of a material, deep x-ray lithography is used to sculpt out material several hundred microns below the surface. According to Dahlbacka: "The penetration obtained with using x rays from the ALS will make possible the fabrication of 3-D MEMS that are up to 500 μm in thickness. Fabricated microactuators that are 500 μm tall, for example, can produce larger forces and torque than 2-D devices, meaning they can move heavier loads."

Workshop Focuses Interest on MEMS

To help develop the processes and instrumentation required to commercialize the production of MEMS, the ALS is developing plans for a deep x-ray projection lithography microfabrication facility. To discuss some of the technology issues involved in creating such a facility, LBL's Technical Transfer Department and Center for X-Ray Optics (CXRO) held a one day MEMS workshop on August 3. During the meeting, Keith Jackson of CXRO noted that light from an ALS bending magnet with its high flux at 2- to 3-Å wavelengths will enable scientists to get the exposures needed in a matter of minutes. He reported that by using x rays at about 5 keV (produced by ALS bending magnets), you can get deep exposures into a target material. If the target is then tilted through a series of such exposures, highly complex structures can be created.

Glen Dahlbacka of LBL's Technology Transfer Department believes industry could eventually account for as much as 30% of ALS beam use.

The proven applications of MEMS technology have excited private industry and the scientific community. Though too early to make accurate market forecasts for 3-D MEMS, current estimates put the present worldwide MEMS market at approximately $500 million with the potential to reach $10 billion by the year 2000. Dahlbacka recently initiated a cooperative agreement among several synchrotron sources to develop a common set of standards for deep x-ray lithography—a first step toward providing the stable processes and assurance of continuous manufacturing that industry requires (see accompanying article, *Regional Centers*).

Keith Jackson of LBL's Center for X-Ray Optics explains the industrial applications of MEMS to the University of California Regents during their recent visit to the ALS.

Crystallography Attracts Industrial Interest

Another area in which the ALS can serve industry is in x-ray crystallography. One rapidly developing use of crystallography is in the pharmaceutical industry where knowledge of the 3-D structures of biological molecules aids in the investigation of how disease-causing agents work—thus leading to the rational design of new drugs. "In the past, designing new pharmaceutical drugs has been a discovery process because the structure of a given protein could only be estimated," says Dahlbacka. "Knowing the precise structure of a protein would enable the intelligent design of drugs to disable active sites in disease-causing organisms."

Several biotechnology companies have expressed interest in the ALS' plans for a crystallography beamline with a multi-pole wiggler source. A key feature of its design, which is in the initial stages, is the ability to provide quick and semi-automated turnaround of x-ray diffraction measurements for users.

Regional Centers To Develop Standards for MEMS X-Ray Lithography

Industrial participation is a key ingredient for the success of the ALS/ LBL MEMS (micro-electromechanical systems) project. When industrial groups were canvassed to see what they required in a microfabrication facility, at the head of the list were the need for a stable production environment and a guarantee of manufacturing availability without interruption of service. For example, companies need to know they will have access to alternative light sources with comparable equipment to meet production deadlines and delivery schedules if necessary.

As a first step toward providing a "duplicative infrastructure" for users of the ALS' microfabrication facility, the ALS and four other facilities have initiated a cooperative effort to adopt common standards and provide duplicative facilities for the deep x-ray lithography processes used in microfabrication. The participants are Lawrence Berkeley Laboratory (Advanced Light Source and Center for X-Ray Optics), the University of Wisconsin (Synchrotron Radiation Center), and Louisiana State University (Center for Advanced Microstructures and Devices) with Louisiana Technical University (Institute for Micromanufacturing). Representatives of these institutions met at LBL on October 23, 1993, to sign a Memorandum of Understanding (MOU) formalizing their agreement.

The MOU states the facilities will adopt common standards for the critical tools and processes required for MEMS fabrication so industrial users will have at least one interchangeable second source. Further, the facilities will coordinate their operation schedules to ensure industrial availability for critical manufacturing runs. The group welcomes cooperation with other U.S. facilities who have a demonstrated commitment to support synchrotron based microfabrication. A joint committee of representatives of the different institutions will be formed by the end of 1993 to facilitate the agreement. Organizing this new collaborative effort was the work of Glen Dahlbacka of LBL's Technology Transfer Department. Dahlbacka believes the agreement is fundamental to industrialize deep x-ray lithography technology and to put national user facilities like the ALS to work for industry.

Representatives who met at LBL to sign the MOU are Brian Kincaid (ALS Director), Glen Dahlbacka (LBL Technology Transfer Office), David Huber (University of Wisconsin), Brian Tonner (University of Wisconsin), and Volker Saile (Louisiana State University).

ALS Users' Association Meeting

The opportunity to see the first experimental results from ALS beamlines attracted a record number of persons to the Advanced Light Source Users' Association Annual Meeting held at Lawrence Berkeley Laboratory (LBL) on October 21 and 22, 1993. For most of the 220 attendees, this was the first chance to see the ALS in operation and view the initial set of beamlines on the experimental floor. The meeting program focused on the scientific opportunities offered by the ALS' ability to produce the world's brightest beams of ultraviolet and soft x-ray synchrotron radiation. A special highlight was the chance to participate in the formal ALS Dedication Ceremony held on October 22.

Organized by Users' Executive Committee Chair Dave Ederer (Tulane University), the program began with a welcome by LBL Director Charles V. Shank. Shank encouraged everyone to join LBL in the challenge of creating a world-class scientific program at the ALS that would fully exploit its capabilities.

Members of the Beamline 8.0 research group attending the users' meeting smile with anticipation at the thought of the first results from their nearly-completed beamline. From left: John Carlisle, Dave Ederer, George Castro, Franz Himpsel, John Yurkas, Jo Stöhr, Tom Callcott, Rupert Perera, and Jianjun Jia.

Following Shank's remarks, ALS Director Brian M. Kincaid gave an account of the facility's progress during the past year and outlined plans for the first year of operations. After a highly successful accelerator commissioning run in the spring, the ALS focused its efforts on installing the beamlines and instrumentation for the first phase of operations. Kincaid reported that three of the initial set of five beamlines were already operational: the x-ray microprobe bend-magnet beamline, an undulator beamline, and the diagnostic beamline. He concluded by thanking everyone involved for their contributions to the remarkable success of the ALS.

Dave Shirley (Pennsylvania State University), who was LBL's director when the ALS was conceived, noted with satisfaction that the completion of the facility brought the scientific community to the threshold of a dramatic new opportunity. He emphasized the importance of developing experimental apparatus, particularly high-performance detectors, that can take full advantage of the qualities of the ALS light.

Banquet speaker Albert Baez signs a poster held by Al Thompson commemorating the first light delivered to the Center for X-Ray Optic's microprobe beamline.

Neville Smith (AT&T Bell Laboratories) discussed his role as head of the ALS Program Review Panel. The Panel, whose membership provides a balanced representation of the major scientific and engineering disciplines covered by the ALS, gives advice on the disposition of proposals for the development and use of ALS experimental facilities. To illustrate how the committee works, Smith described the process by which the panel evaluated the initial beamline proposals.

The last speaker of the morning was Glen Dahlbacka from LBL's Technology Transfer Department who spoke about industrial opportunities at the ALS. He discussed two proposals currently under consideration of interest to industry: an x-ray crystallography beamline and a microfabrication facility. The crystallography beamline would form the heart of a user facility for protein study to assist industry in the areas of rational pharmaceutical design and development of new commercial catalysts. The proposed microfabrication facility would use deep x-ray lithography for the production of micromachines such as precision gears for watches, accelerometers for use in automobile airbags, and miniature instruments for microsurgery.

Results from First Beamlines

Howard Padmore, ALS Experimental Systems Group Leader, talked about the first experimental results from the operational beamlines along with plans for future beamlines. He showed an image of the beam taken from the CCD detector at the end of the diagnostic beamline and a spectrum obtained with the transmission grating spectrometer being used to measure the light from the recently operational 5-cm-period undulator. Padmore discussed initial plans for an 8-cm-period undulator branchline for chemical dynamics studies and a crystallography beamline for industrial users.

Part of the research team for Beamline 7.0 gather at the popular Chinese banquet on Thursday evening. Pictured are (left to right): Tony Warwick, Piero Pianetta, Marjorie Olmstead, Jeffrey Bokor, Jim Tobin, Brian Tonner, and Harald Ade.

Fred Schlachter, ALS User Liaison Group Leader, described the efforts of the ALS to develop new research opportunities and to provide an efficient working environment for users. He noted that a procedure for processing proposals from independent investigators will be in place by next year and, in the meantime, anyone wishing to submit a Letter of Interest is encouraged to contact him. To complete the overview of user issues, Georgeanna Perdue, acting ALS EH&S Program Manager, gave a short talk describing her role in making the ALS a safety-conscious facility and outlining the training requirements for ALS users.

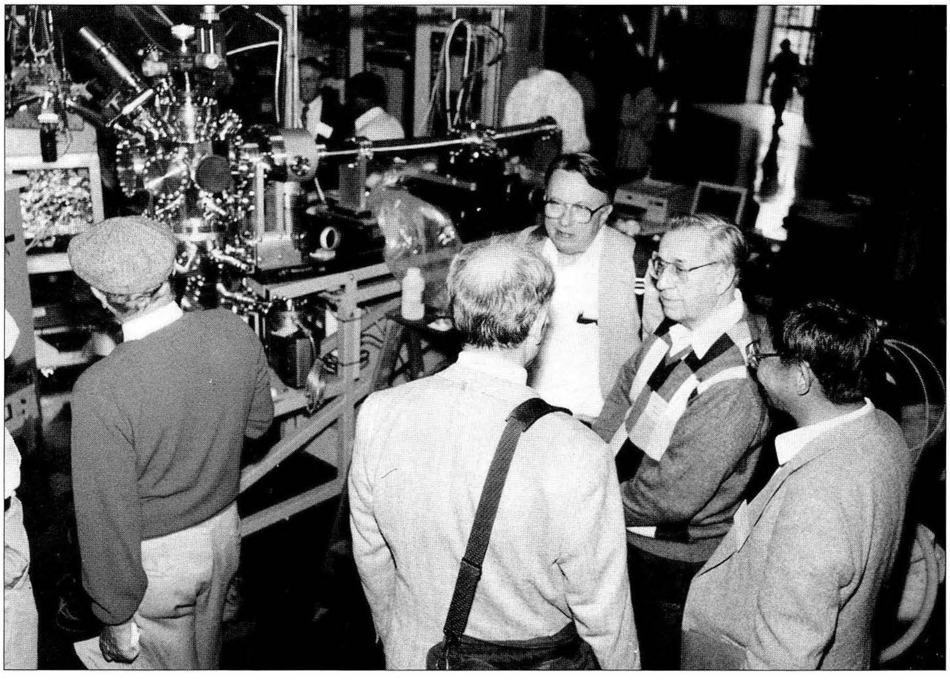
Richard White (University of California at Berkeley) spoke on the research being done by the Berkeley Sensor and Actuator Center (BSAC) to develop a science and engineering base for microsensors, microactuators, mechanical microstructures, and microdynamic systems. White pointed out that the ability to make much thicker micromachines by using the light of the ALS offers many advantages such as an increase in volume which provides more mass and strength, and the possibility of using alternative materials and fabrication methods, e.g., cast polymers for non-planar shapes.

Albert Thompson (LBL Center for X-Ray Optics) finished the day's program with an exciting report about the results from the x-ray fluorescence microprobe, the first beamline at the ALS. Thompson pointed out a few of the many advantages of the microprobe, such as small spot size (1 μm by 1 μm) and femtogram elemental sensitivity. The talk included several examples of how the microprobe will be used for research in materials sciences. Among these were investigating how trace elements are distributed in ceramics, mapping the composition of fluid inclusions in quartz samples for geological studies, and elemental analysis of ancient documents.

That evening, the conference banquet featured a special talk by Albert V. Baez on the early days of x-ray optics. In 1948, Kirkpatrick and Baez devised an imaging system to eliminate the astigmatism of a single mirror used at glancing incidence. The mirror scheme turned out to be very useful in many x-ray optics applications. In fact, many modern beamlines including the microprobe and diagnostic ALS beamlines employ configurations that are similar to the Kirkpatrick-Baez scheme.

Spotlight on Spectroscopy

The second day began with a session devoted to spectroscopy in the soft x-ray spectral region served by the ALS. Gerhard Materlik (HASYLAB) described experiments using x-ray standing waves in the soft x-ray region. In the experiments, one can map the locations of surface species from the probe response as the positions of the standing-wave maxima and minima are



This year's meeting included the opportunity to view the initial set of beamlines on the ALS experimental floor.

varied. Materlik noted several advantages of using soft x rays, including accessibility of atoms with low atomic numbers and the possibility of using several probes in addition to the conventional fluorescence.

Günter Kaindl (Freie Universität Berlin) presented an overview of high-resolution spectroscopy experiments using the SX-700 II plane-grating monochromator, which has demonstrated a resolving power of up to 16,000 at a photon energy of 65 eV. Joseph Nordgren (Uppsala University) ended the morning session with a discussion of soft x-ray emission spectroscopy. In providing information about unfilled states, soft x-ray emission provides information complementary to that from photoabsorption and photoemission.

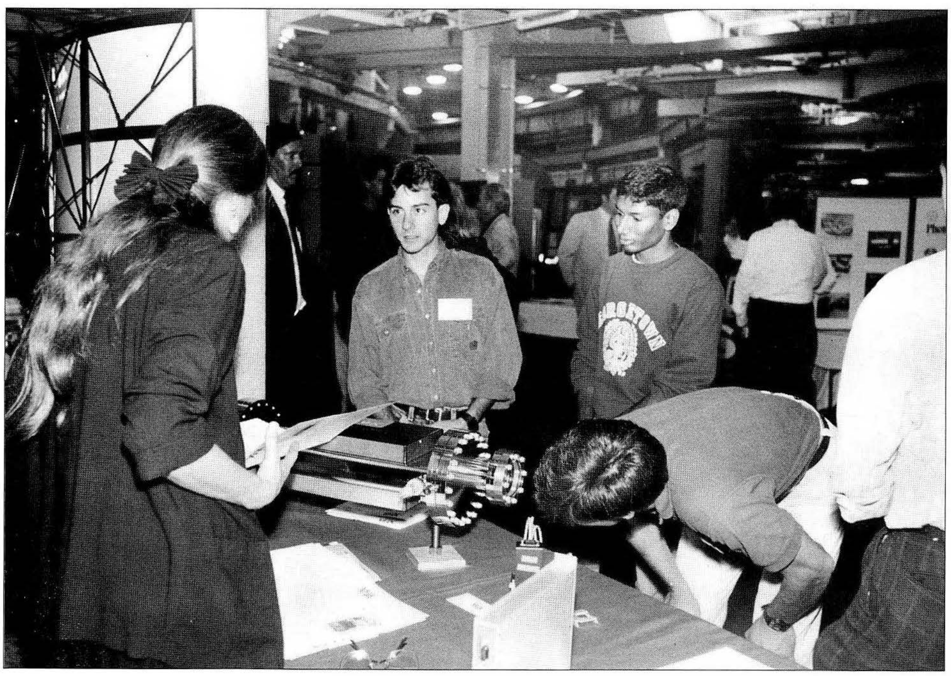
The morning session ended early so that the attendees could join LBL employees and guests at the ALS Dedication Ceremony outside the ALS building. Key speakers at the festive event included Charles V. Shank, director of LBL; David Shirley, senior vice president for research and dean of the graduate school at Penn State; Gayle Wilson, wife of California Governor Pete Wilson; Martha Krebs, associate director of LBL; Hermann Grunder, director of the Continuous Electron Beam Accelerator Facility; Donald Pearman, Jr., manager of DOE's San Francisco Operations Office, and Brian M. Kincaid, ALS director. (See front page article, *ALS Grand Opening.*)

Members of the Beamline 9.3.1 Participating Research Team take time out from the ALS tour to visit the site of their beamline scheduled for operation in mid-1994. From left: Dennis Lindle, Dave Shirley, Rupert Perera, Charles Fadley, and Zahid Hussain.

The conference resumed as Paolo Carra (ESRF) began the afternoon talks with a discussion of the theoretical aspects of magnetic circular dichroism (MCD) and linear dichroism. Steven Cramer (University of California at Davis) described biological applications of soft x-ray and MCD spectroscopy. He noted the elliptical wiggler being designed and constructed by the ALS could increase by a few orders of magnitude the flux of polarized light relative to that from bend-magnet beamlines.

The final speaker, Yuan T. Lee (University of California at Berkeley), discussed plans for a chemical dynamics 8-cm-period undulator branchline for research on primary photodissociation and photoionization processes. The branchline has two primary end stations, one using white undulator light and the other using monochromatized radiation. The experimental end stations will be a complex system using pump-and-probe techniques with high power lasers and crossed molecular beams. Lee described the project as a national user facility for the study of fundamental chemical processes— especially combustion, radicals, and excited states.

Dave Ederer, chair of the Users' Executive Committee, ended the meeting by thanking everyone for their participation and encouraging the users to take an active role in creating an exciting and innovative scientific program at the ALS.



Participants show an interest in learning more about new products and technology related to synchrotrons and beamlines at the commercial vendor exhibit held on Thursday.

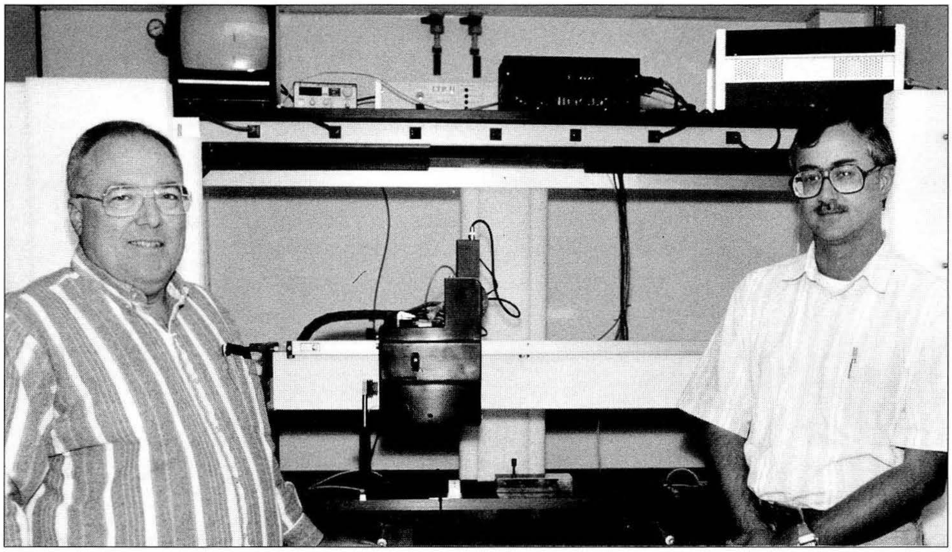
Long-Trace Profiler II Receives R&D Award

The success of the ALS in providing optics with near-perfect microroughness and figure is largely due to the decision early in the project that providing an accurate means of testing the surface of a mirror—both during and after the fabrication process—was of critical importance. With conventional metrology, an optician was limited by the length of a mirror that could be measured at one time and the radii of curvature that were measurable. Over short distances the profile often looked quite good, but the figure or accuracy over longer distances turned out to be poor.

To provide the much-needed ability to measure the integrity of a mirror along its entire length, Wayne McKinney of the Experimental Systems Group launched a collaborative effort to build two improved long-trace profilers (LTPs) based on an earlier one developed at Brookhaven National Laboratory. Long-trace profilers are designed to distinguish irregular spots on the surface of a mirror by detecting any slope errors that occur from one end to the other.

The design team organized by McKinney included scientists and engineers from LBL, Brookhaven National Laboratory, Continental Optical Corporation, Baker Engineering, and Tucson Optical Research Corporation. They made several improvements to the LTP design; the most important one being the addition of a reference beam that compensates for the pitching of the air-bearing stage as the optic is scanned. The new improved LTP-II can measure slope error to better than 1 μrad rms. A key member of the LTP-II project was ALS scientist Steve Irick who wrote the control software for the profiler and has made several important improvements to the LTP-II's original configuration. These include a new mounting system for the optic under test, and an improved way to remove errors generated by small pointing instabilities in the laser diode. The profiler received an R&D-100 Award from *R&D Magazine* as one of the most technologically important new products of 1992.

Two LTP-II profilers were constructed so the optical components could be measured during and after the fabrication process: one for the ALS optical metrology group and one for the vendor. The second copy is now at Rocketdyne Corporation who has become the main supplier of large optics to the ALS and many other laboratories worldwide. Using the LTP-II, Rocketdyne can find out if a modification in the polishing process causes any changes to an optic's figure at the time the modification is made. This on-the-spot testing of figure allows the fabrication of optics that are qualified before installation in the beamline.



ALS scientists Wayne McKinney and Steve Irick with the Long Trace Profiler-II they helped design.

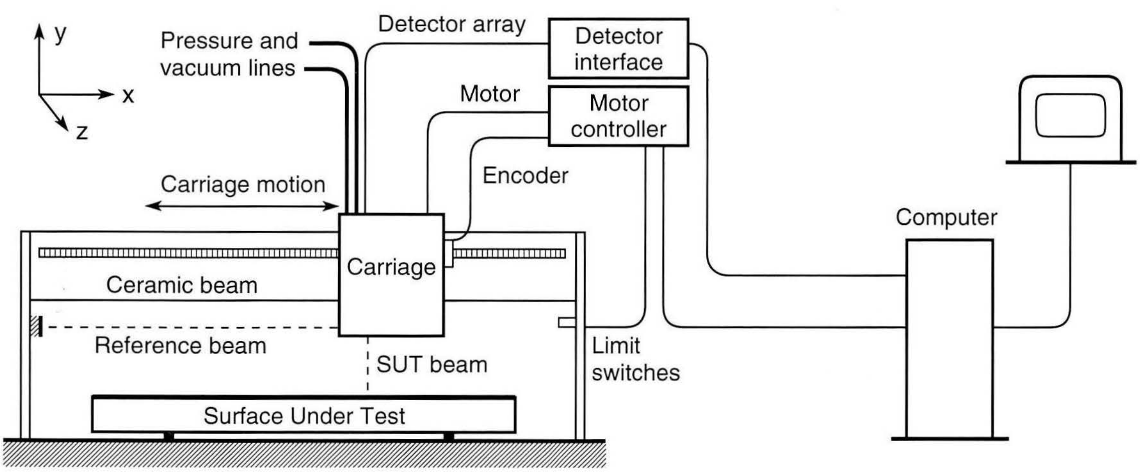


Diagram of the LTP-II illustrating how its custom air-bearing stage moves along the ceramic beam. The laser diode and optical components on the carriage relay a pair of laser beams to the surface-under-test (SUT) and the reference mirror. By analyzing the changes in phase of the laser reflections, the LTP-II measures any slope changes that occur along the mirror's length.

Please copy this card for your colleagues

ADVANCED LIGHT SOURCE INFORMATION

To receive information about the ALS, complete this form, clip, fold, and mail (postage-paid).

- ❑ I did not receive a copy of the *Advanced Light Source Report* addressed to me; please add my name to the ALS mailing list.
- ❑ Please send me LBL PUB-703, "Advanced Light Source: Ultraviolet and Soft X-Ray Beams for Research."
- ❑ Please send me LBL PUB-680, "Putting Synchrotron Radiation to Work: New Opportunities for Industrial R&D."
- ❑ Please send me the report of the workshop "Soft X-Ray Interferometry."
- ❑ Please send me the report of the workshop "Working Group on Elliptical Wiggler."

NAME ______________________________

INSTITUTION ______________________________

MAILING ADDRESS ______________________________

____

____

TELEPHONE ______________________ FAX ______________________

COMPUTER-MAIL ADDRESS ______________________________

My major scientific interests are in the fields of

- ❑ Materials Science
- ❑ Chemical Science
- ❑ Life Science
- ❑ Surface Science
- ❑ Atomic and Molecular Science
- ❑ Geosciences
- ❑ Accelerator Science
- ❑ Other ______________________________

NO POSTAGE
NECESSARY
IF MAILED
IN THE
UNITED STATES

Business Reply Mail

First Class Permit No. 1121 Berkeley, Ca.

Postage will be paid by addressee

Lawrence Berkeley Laboratory
1 Cyclotron Road
Berkeley, CA 94720

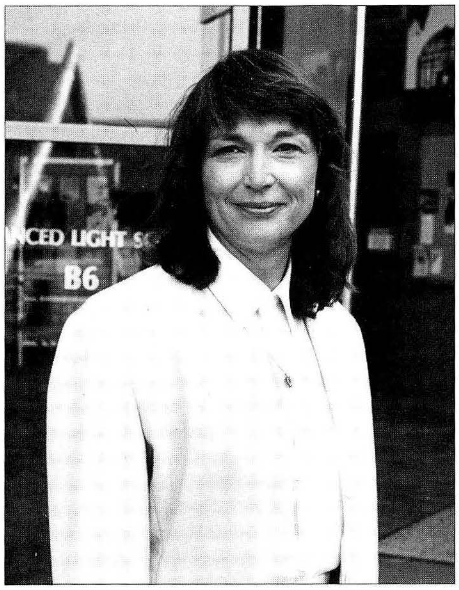
Attn: Jane Cross
Advanced Light Source
MS 2-400

Spotlight on Safety

Ensuring a safe and healthy working environment for ALS users and staff members is a big job. Georgeanna Perdue, acting ALS EH&S Program Manager, carries much of the responsibility for this critical task. She applies her knowledge and skills to making the ALS a safety-conscious facility.

Perdue joined the ALS in June of 1992 after working more than nine years in Navy nuclear shipyards at Charleston, S.C., and Mare Island in Vallejo, Calif. At the shipyards, she gained first-hand knowledge about the impact of a wide variety of chemicals and hazards on health and the environment. This experience has proved invaluable for her duties at the ALS which include recognizing potential health hazards, evaluating problems caused by hazards, and recommending corrective action. Potential hazards that are most apt to be encountered at the ALS include electrical; chemical, such as toxic fumes or gases; physical, such as excessive noise; and biological. Perdue must evaluate hazards for their short- and long-range effects on the working environment and coordinate measures to minimize the hazards to acceptable levels.

Part of Perdue's job is making sure the ALS keeps in compliance with the myriad of environmental, health, and safety regulations required by the federal, state, and local governments. She informs staff members of the ones they should be aware of and assists them in complying with the regulations related to their work. Perdue makes it clear, however, that merely complying with regulations is not enough to ensure a safe working environment. Even more important is teaching people to have an honest concern for their own safety. For this reason, she devotes considerable time to promoting safety awareness among ALS personnel and helping them to recognize the types of hazards present in their work and how they can be minimized.



Georgeanna Perdue coordinated the production of the ALS safety video.

Perdue's ability to recognize potential hazards also comes in handy in her role as coordinator of the ALS Experiment Forms. Once an experiment proposal has been approved by the ALS, the spokesperson for the experiment fills out an Experiment Form listing all chemicals and equipment involved so their potential hazards may be identified. When the form is received by the ALS, it is thoroughly reviewed by the beamline operations staff, the experimental systems group, and health and safety professionals to ensure the experiment meets ALS safety requirements. Perdue coordinates this review process, and, after the experiment is approved, ensures the Experiment Summary Sheet posted at the beamline includes the correct information for the approved chemicals and equipment.

Perdue is a key player in the ALS' commitment to provide a safe and efficient working environment and she encourages users to ask questions about safety issues and hazards. She, with the help of other ALS staff members, recently completed a safety video and *ALS Safety Handbook* that will make up part of the ALS user training program, designed to give an overview of safety policies and procedures at the ALS.

Soft X-Ray Interferometry Workshop

An informal workshop on soft x-ray interferometry was held on June 25 at the ALS to discuss the proposed technical design for a Fourier-transform spectrometer (FTS) being developed by ALS scientists Malcolm Howells and Zahid Hussain. The participants shared ideas on different design strategies for the instrument's components, detection methods, signal processing issues, and ways of meeting the manufacturing tolerances that are necessary for the instrument to achieve the desired levels of performance.

There are a number of problems in the physics of atoms and small molecules that challenge the resolution of the diffraction grating spectrometers that are traditionally used for vacuum-ultraviolet and soft x-ray experiments at synchrotron radiation facilities. The limit of current technology is a resolution of about 0.003–0.01 Å which is easier to get with a spectrograph, harder with a scanning monochromator. This translates into a resolving power of 20,000–60,000 at 60 eV for example.

In a attempt to obtain higher resolution in the range of 60–80 eV, the ALS is designing a soft x-ray FTS with a resolving power target of 500,000 at 60 eV. Fourier-transform spectrometers, successfully used in the infrared and the ultraviolet regions, utilize a two-beam interferometer to measure the Fourier transform of the desired spectrum. The ALS is proposing to extend the FTS technology to the soft x-ray region up to 100 eV. This will allow the principle of FTS to be applied to soft x-ray photoabsorption experiments with the goal of obtaining higher resolution than is possible with a grating. For example, the ALS soft x-ray FTS system should provide the opportunity to discover many new and extremely narrow resonances, now accessible only by theory, and to measure true line-shape parameters. Applications include the important case of helium as well as other atomic and small molecular systems.

Presentations by ALS staff members concentrated on the technical issues involved in implementing the spectrometer. A report of the workshop is available from the ALS upon request.

The *Advanced Light Source Report* is published periodically at Lawrence Berkeley Laboratory for members of the Advanced Light Source Users' Association and other interested persons.

Editor: Jane Cross

1994 Users' Executive Committee*

Michael G. White, Chair
Brookhaven National Laboratory
Department of Chemistry
Upton, NY 11973
Email: WHITE@BNLCHM

David L. Ederer
Tulane University
Department of Physics
6823 St. Charles Ave.
New Orleans, LA 70118

C. Denise Caldwell
University of Central Florida
Department of Physics
Orlando, FL 32816

Thomas A. Callcott
University of Tennessee
Department of Physics
401 Nielsen Physics Bldg.
Knoxville, TN 37996

George Castro
IBM Almaden Research Center
San Jose, CA 95120

Norman Edelstein
Lawrence Berkeley Laboratory
Chemical Sciences Division
1 Cyclotron Road
Berkeley, CA 94720

Linda S. Powers
Utah State University
Center for Biocatalysis Science and Technology
Logan, UT 84322

James G. Tobin
Lawrence Livermore National Laboratory
Chemical and Materials Science Division
Livermore, CA 94550

Brian P. Tonner
University of Wisconsin, Milwaukee
Department of Physics
Milwaukee, WI 53211

* The results of the election of three new UEC members for 1994 were not available at press time.

User Liaison:
Alfred S. Schlachter
Lawrence Berkeley Laboratory
Advanced Light Source
Berkeley, CA 94720
E-mail: FRED@LBL
Tel: (510) 486-4892
Fax: (510) 486-7696

ALS Director
Brian M. Kincaid
Lawrence Berkeley Laboratory
Advanced Light Source
Berkeley, CA 94720
E-mail: BMKINCAID@LBL
Tel: (510) 486-4810
Fax: (510) 486-4960

Laboratory Director:
Charles V. Shank
Lawrence Berkeley Laboratory
Berkeley, CA 94720

DISCLAIMER

This document was prepared as an account of work sponsored by the United States Government. Neither the United States Government nor any agency thereof, nor The Regents of the University of California, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by its trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or The Regents of the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof or The Regents of the University of California and shall not be used for advertising or product endorsement purposes.

PUB-6Ø1 Copy 1
REFERENCE COPY | Does Not | Circulate | Bldg. 5Ø Library.

IMPORTANT

You must return the enclosed postage-paid card to continue to receive the *Advanced Light Source Report* newsletter or call ALS Administration (510) 486-4257

Lawrence Berkeley Laboratory is an equal opportunity employer
PUB–601 Advanced Light Source Report prepared for the U.S. Department of Energy under Contract No. DE–AC03–76SF00098