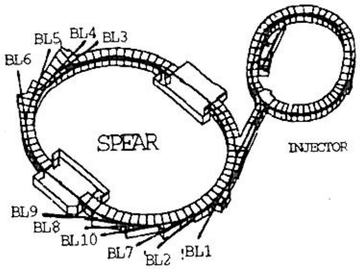
The Stanford Synchrotron Radiation Laboratory Users Newsletter



October 1993

SSRL AT 20 YEARS - SOME PERSONAL REMEMBRANCES OF THE EARLY DAYS

- H. Winick

For those who have only known SSRL for a few years it may be hard to believe that the lab began operating in 1974 in an uncertain parasitic mode, with about a dozen users, a full time staff of 4 people, and five experimental stations sharing a single bending magnet beam line. Here are some very selective, personal remembrances of those early days up to about 1980.

A RISKY VENTURE

At its inception in 1973, the Stanford Synchrotron Radiation Project (SSRP) was considered a risky venture. Some were optimistic. For example, Bill Spicer had communicated his enthusiasm about using "cyclotron radiation" from SPEAR to Pief Panofsky, the first Director of SLAC, in 1968, well before SPEAR was built. However, there was a residue of doubt that a parasitic program on a multi-GeV storage ring would be viable.

The initial funding by the NSF was therefore carefully limited to a two year program to try it out. If it didn't work, SSRP would cease to exist. When Seb Doniach, the first Director of SSRP, hired me in June 1973, he made it clear that there might be no future beyond two years. I may have neglected to mention this to my wife when we moved here. She became a bit suspicious when I insisted that we not sell our house in Massachusetts immediately.

But SSRP did work and it worked quickly and brilliantly. In May 1974, 11 months after funds were received, the first experiments began. SPEAR operated at 2.4 GeV, 10 mA in colliding beam mode. The five experimental stations shared a meager 11.5 milliradians of synchrotron radiation from a SPEAR bending magnet.

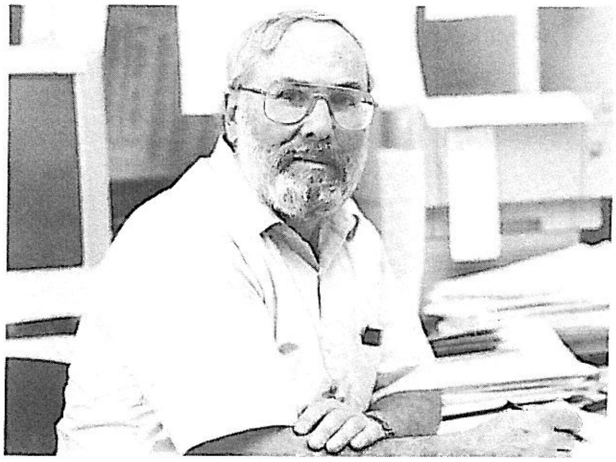
This success took me by surprise. I could hardly believe that all the control systems worked and that, with only a little tweaking, the photons made it through all the narrow apertures of masks and beryllium windows and found their way to the mirrors, gratings and crystals located as far as 20 meters away. Of course there were pressure bursts as the beam struck surfaces for the first time. Some of these resulted in a dump of the stored beam. But fortunately we quickly learned how to condition surfaces gradually so that we did not wear out our welcome as parasites.

Within weeks, previously unobtainable photoemission, EXAFS, and diffraction data were obtained using photon beams that were about 100,000 times more intense than from other sources. And to think, these photons all came from less than six inches of curved path in a SPEAR bending magnet, out of a total ring circumference of 770 feet. It was a heady time. Details are given in the first SSRP Activity Report, which is being reprinted as part of our 20th Anniversary celebration and will be available at the Users' meeting.

This stunning success was due to several factors:

1. Gerry Fischer and Ed Garwin convinced Burt Richter to include in the original construction of SPEAR a vacuum chamber with an exit spout to allow synchrotron radiation to leave a bend magnet. This minimized interference with SPEAR operation due to the construction of the first beam line and reduced the cost and time to construct this line.

2. A pilot project started in 1972 by Seb Doniach, Ingolf Lindau, Piero Pianetta, and Bill Spicer, produced a beryllium window assembly and some X-ray instru-



Herman Winick in 1993

mentation. (This pilot project began to use radiation within the SPEAR shielding in July, 1973, continuing in a small box outside the alcove as the SSRP building was constructed around it. The first XPS spectra on the gold 4f levels were obtained in November 1973.)

3. Major help in designing and constructing 5 monochromator systems and end stations on the first beam line was provided by scientists from Xerox (Bob Bachrach, Fred Brown), China Lake (Vic Rehn, Jim Stanford), Cal Tech (Nick Webb), Bell Labs (Peter Eisenberger), the University of Washington (Dale Sayers, Ed Stern), Boeing (Farrel Lytle), and Stanford University (Sally Hunter, Brian Kincaid, Ingolf Lindau, Piero Pianetta). The salaries and equipment cost for this came from sources other than the NSF grant. In return these first "Participating Research Teams" (PRTs) received priority time on the stations to which they contributed.

4. Many people worked furiously to compress an originally planned 18 month construction period into 10 months. In addition to those mentioned above, this included the SSRP full time staff (Priss Dannemiller, Axel Golde, Ben Salsburg, Herman Winick), together with Don Baer and Ron Gould on loan from Hansen Labs on the Stanford campus and many from SLAC (Mark Baldwin, Norm Dean, Bob Filippi, Gerry Fischer, Ralph Gaxiola, John Harris, Earl Hoyt, Bruce Humphrey, Fred Johnson, Joe Jurow, Bob Melen, Jack Miljan, Bill Savage, Gary Warren).

The accelerated construction schedule was decided upon in order to use the beam before a planned SPEAR shutdown from July to October, 1974 to upgrade the energy capability from 2.4 GeV to 4 GeV. SSRP was to come into full flower with increased flux of hard X-rays that would be produced at these higher electron energies. In addition to this extended spectral range, much higher currents (30-50 mA compared with about 5 mA at 1.5 GeV) and longer beam lifetimes would be available at the higher SPEAR energy.

The first SSRP Users' Meeting took place on October 24-25, 1974 with about 100 attendees including the core Stanford group (Bienenstock, Doniach, Hodgson, Lindau, Pianetta, Spicer, Winick) and other luminaries of synchrotron radiation science including Bob Bachrach, Bob Batterman, Bernd Crasemann, Dick Deslattes, Dean Eastman, Peter Eisenberger, Brian Kincaid, Mel Klein, Christof Kunz, Pierre Lagarde, Farrel Lytle, Ian Munro, Vic Rehn, Ed Rowe, Stan Ruby, Jim Samson, Dale Sayers, David Shirley, Ed Stern, Georg Zimmerer.

THE FIRST X-RAY DROUGHT

However, shortly after SPEAR began operation in October 1974, the Psi particle was discovered on November 8th in a brief run at 1.55 GeV to check some inconsistencies in old data. At such a low SPEAR energy only long wavelength, vacuum ultraviolet or VUV, photons were produced by SPEAR in useful quantities. Three of our five stations sat idle because they needed higher energy photons, hard X-rays. These stations needed SPEAR to operate at higher energy, at least 2 GeV. Our frustration was compounded when a second new particle, the Psi Prime, was discovered a few weeks later at a SPEAR energy of 1.86 GeV, leading to more operation below 2 GeV.

This period, called the November Revolution by high energy physicists, was one of the most exciting in the history of high energy physics. It resulted in a Nobel prize for Burt Richter. However it was a disaster for SSRP. Except for occasional surveys for (mostly nonexistent) new particles at higher SPEAR energy (up to 3.7 GeV), for the next few years SPEAR ran mostly below 2 GeV; our first X-ray drought.

THE BRIGHT SIDE

In spite of difficult parasitic conditions (mostly low current, low energy runs, and schedules which changed on short notice) SSRP was "the only show in town" (*i.e.* the only source of soft and hard X-rays in the U.S.). Some very brave and excellent scientists were attracted here by the new opportunities made possible by the very high intensity beams that were at least occasionally available, and the fine instruments we had built in collaboration with our PRTs. Outstanding scientific results began to be published, and some graduate student theses were completed. Among the first students to do their thesis work at SSRP were Brian Kincaid, working with Seb Doniach and Peter Eisenberger, and Piero Pianetta, working with Ingolf Lindau and Bill Spicer. Our NSF program manager, Bill Oosterhuis, managed to get funding for a second beam line in 1975. Axel Golde supervised the first of many extensions to building 120 to make space for it. John Cerino came to SSRP to join Al Thompson of LBL and others on the SSRP staff in designing and constructing it.

The number of users and proposals at SSRP grew rapidly, approximately doubling each year during the first three years. An extrapolation of this data lead to the prediction that by the end of this century every man, woman and child in the U.S. would be involved with synchrotron radiation research. It became clear that synchrotron radiation from storage rings was revolutionizing many areas of scientific research and that the U.S. needed a major increase in capacity, particularly in the spectral region beyond about 100 eV.

THE FIRST NATIONAL ACADEMY PANEL; NEW FACILITIES

In 1976, in response to the increasing demands of those who could not get enough running time at SSRP, a panel (the Morse Panel) of the National Academy of Sciences met to survey U.S. national needs. This panel recommended a major expansion of U.S. facilities for synchrotron radiation research. In very short order the Energy Research and Development Administration [ERDA the successor to the Atomic Energy Commission (AEC) and the predecessor to the present Department of Energy (DOE)] and the National Science Foundation (NSF) provided funding for new facilities. ERDA funded the 0.75 GeV and 2.5 GeV NSLS rings at Brookhaven National Laboratory. The NSF funded a $6.7M major expansion of facilities (Phase II) at SSRP, plus the 0.8 GeV Aladdin ring at the University of Wisconsin, to replace the 240 MeV Tantalus ring whose spectral range was limited to about 100 eV.

As backup to the SSRP proposal, a 300 page book en-

Ground Breaking for the 1977 SSRL Expansion Program
(L to R) S. Doniach, R. Gould, W. Spicer, S. Hagström, W. Oosterhuis, A. Bienenstock, A. Sessler, W. Miller, H. Winick, W.K.H. Panofsky, S. Stamp and G. Pimentel

At the time of the 1st Protein X-ray Crystallography Experiments on Beam Line 1-4 at SSRL
M. Bernheim, K. Hodgson, A. Wlodawer, J. Phillips

titled "Synchrotron Radiation Research and the Stanford Synchrotron Radiation Project", was produced. This document, SSRP Report 76/100, edited by Keith Hodgson, Herman Winick and Gil Chu, summarized what had been done at SSRP by mid 1976 as well as our proposal for Phase II.

PHASE II AT SSRP; MORE BEAM LINES, DEDICATED TIME, WIGGLERS

The 1976 Phase II SSRP proposal called for additional beam lines, a major new building (131) to house these lines, plus 50% dedicated operation. The strong interest in dedicated time for synchrotron radiation research created a major problem for SLAC because it came at a time when SPEAR was the most productive and exciting high energy physics facility in the world and also at a time when SLAC was planning to operate PEP in a few years.

In a January 30, 1976 letter, which is included in SSRP 76/100, Pief Panofsky wrote "Our problem is essentially one of 'embarrassment of riches' in respect to <u>both</u> elementary particle physics and synchrotron radiation use of SPEAR". In this same letter Pief went on to make the following proposal: "SPEAR will be available at a time when PEP has reached an operational stage at which half of PEP operating time is dedicated to high energy physics such that one-half of SPEAR's operating time can be dedicated to synchrotron radiation running." This Solomon-like solution was what we needed to make a strong Phase II proposal, which was funded by the NSF in July, 1977. At this time SSRP, a project within the Hansen Labs became SSRL, an independent lab within Stanford University. 50% dedicated time began in fiscal year 1979.

SSRP had some earlier experience with dedicated operation of SPEAR. On November 11, 1974, there was one 8-hour dedicated shift during which SPEAR was operated at 2.8 GeV and 80 mA. In December 1975 there were eight dedicated shifts, and 21 shifts in July 1978. In the latter run SPEAR was operated at 3.7 GeV with 60 mA in single bunch mode and at 3.0 GeV, 100 mA in 4 bunch mode. The time from the end of one fill to the delivery of beams on a new fill was less than 30 minutes. Compared to colliding beam operation, dedicated single beam runs offered higher energy, higher current, longer lifetime, greater stability and lower vertical emittance. These were very exciting runs in which orders of magnitude more hard X-rays were produced than in parasitic runs at 1.5-2 GeV with currents below about 10 mA. Activity reports for these periods give details of the results obtained.

Although we were excited about the prospects of months of dedicated operation of SPEAR each year, in 1976, when we proposed the Phase II expansion, dedicated running was still several years away. Partly to maximize the utility of parasitic operation, I urged that the SSRP Phase II proposal should include a beam line using a high field, multi-pole wiggler magnet as a source, as well as several bending magnet based beam lines. This would shift the spectrum to hard X-rays even when SPEAR ran at energies below 2 GeV as well as increasing the flux at all photon energies.

However, there had been mixed experience with wiggler magnets. Although wigglers were successfully implemented at the Cambridge Electron Accelerator (CEA) for high energy physics purposes, there were problems when a wiggler was tried on the Tantalus ring at the University of Wisconsin. As parasites, we understood that we could only implement a wiggler at our own risk; *i.e.*; we would not be able to turn on the wiggler during colliding beam runs if it caused problems with the high energy physics program. We evaluated the potential problems of wigglers at the Wiggler Workshop held at SLAC in March 1977. With the help of Don Stevens, funding for this workshop was provided by ERDA, our first from this agency. No showstoppers were identified at the workshop by 67 accelerator experts from around the world.

The results of this workshop and the prospects for continued colliding beam operation of SPEAR mostly below 2 GeV led to a conservative plan to build and install the wiggler, but not commit to the experimental stations until it was proven to be compatible with the operation of the ring.

The wiggler, a 6 pole, 1.8 Tesla electromagnet, was designed in late 1977 by Jim Spencer, on sabbatical from Los Alamos. It was installed in SPEAR in the summer of 1978 and turned on when SPEAR started up in October 1978. It was quickly shown to be compatible with colliding beam operation. In fact it improved the luminosity by enlarging the transverse beam size, allowing more current to be stored before reaching the so-called "beam-beam limit". Although this effect was anticipated, it caused much excitement when it was observed to be real and somewhat larger than expected. SSRL was delighted to have the harder spectrum for the wiggler stations, plus more current, and hence more flux for the bending magnet and wiggler stations as well.

But, in fact, there were no wiggler stations in October of 1978. We intensified efforts to move a two-crystal

1st Light on Beam Line 2 in 1976
(Seated) D. Jackson, R. Gamble, B. Filippi, R. Gaxiola, (standing L to R) A. Bianconi, J. Hastings, H. Stephens, H. Winick, A. Bienenstock, P. Dannemiller, P. Eisenberger, C. Wilson, W. Basinger, Johnson, P. Fuoss, J. Cerino, J. Phillips and two unidentified persons

X-ray monochromator and associated equipment from Beam Line 2 (the so-called EXAFS II station) to the wiggler beam line (Beam Line 4) and complete the control systems. The first beam from the wiggler was observed in the newly completed building 131 on February 28, 1979 and the first EXAFS spectrum (from a copper foil) was taken in a few minutes on March 7, 1979 with SPEAR running at 1.55 GeV and 4 mA. It would have taken several days to acquire comparable statistics from a bending magnet line under these SPEAR operating conditions. The wiggler effectively boosted the SPEAR energy by 1 GeV. It met all expectations.

The impressive performance of the wiggler prompted a reconsideration of the plans for Phase II and a tough decision by Art Bienenstock, the new Director of SSRL, to trade two planned bending magnet lines (one bending magnet line, Beam Line 3, was already in construction) for a second wiggler. The second wiggler would be located in an extension of the north arc building (120) rather than the newly constructed south arc building (131) in which alcoves for all the originally proposed Phase II lines were already built.

Thus the era of insertion devices started. SSRL continued with the permanent magnet undulator, conceived by Klaus Halbach of LBL and first tested in December 1980. The success of these devices was a primary impetus to the proposals for the third generation sources, such as the Advanced Light Source (ALS) now starting operation at LBL, and the Advanced Photon Source (APS) now in construction at Argonne, as well as similar facilities around the world. It also led SSRL to construct two beam lines on SLAC's 15 GeV storage ring PEP in the mid

Part of the SSRL Staff in 1978

S. Hunter, B. Salsburg, P. Dannemiller, A. Golde, J. Yang, D. Kubrin, G. Hamaker, R. Boyce, V. Rehn, K. Cantwell, H. Przybylski, G. Kerr, H. Winick, M. Adams, J. Cerino, R. Gould, B. Filippi, P. Pianetta, N. Hower, D. Brockhurst, J. Marchetti, U. Businger, J. Sullivan, L. Johansson, P. Phizackerley, E. Moss, J. Spencer, G. Brown, C. Jako, G. Brogren

1980's. George Brown and Richard Boyce led the team that built these first high brightness, undulator-based, hard X-ray beam lines.

The first wiggler was replaced by an 8-pole wiggler in 1980 and was later loaned to Cornell where it was the most intense hard X-ray source in the world for several years. The first undulator was replaced by the beam line 5 multi-undulator and was later loaned to Wisconsin, where it now serves as the source for MAXIMUM, their highest brightness beam line.

From 1980 to the present SSRL's fortunes have oscillated. Much good science was done on an expanding number of beam lines and experimental stations; but there were also periods with poor running conditions due to limited injection availability to SPEAR when the SLAC Linear Collider (SLC) was being commissioned.

However, now SSRL has come into its own. At present, SPEAR operates for many months per year in a low emittance mode (130 nm-radians at 3 GeV) providing intense radiation to 25 experimental stations on 9 main beam lines, five of which are illuminated by insertion devices. With the termination of the colliding beam program and with our own injector, SPEAR is now a fully dedicated source that operates independently of the SLAC linac. The parasites have truly consumed the host! The newest wiggler line, Beam Line 9, is now under construction, primarily for structural molecular biology applications. Plans are being developed for additional lines (for environmental studies and materials processing) since SPEAR has space for about 8 more insertion devices. Two of these could use insertion device sources up to about 10 m long in the straight sections formerly used for colliding beam detectors. Also, a study is being carried out of a possible change to the SPEAR lattice to further reduce the emittance by a factor of six.

In addition to continuing to exploit the rather large untapped potential of SPEAR, exciting new ideas for future, fourth generation light sources are now being developed at SSRL. Helmut Wiedemann is leading an effort to develop a source of ultrashort electron pulses (less than 100 femtoseconds). First measurements of coherent infra-red radiation indicate that an electron bunch length of about 45 microns or 150 femtoseconds (rms) has been achieved. Also, I am coordinating a group from LBL, LLNL, SLAC, and UCLA in a study of the use of the SLAC linac to drive free electron lasers at wavelengths down to about 3 nm initially and possibly even shorter wavelengths later on. Such sources would deliver photon beam brightness, coherence and peak power several orders of magnitude higher than third generation rings, offering major extensions in experimental capability.

The next 20 years at SSRL are likely to be as bright and exciting as the first!!

SSRL Workshops on X-ray Absorption Spectroscopy Are A Success

- Ingrid Pickering

In a new endeavor during the 1993 run, SSRL hosted two workshops on X-ray Absorption Spectroscopy. The workshops were aimed at introducing the concepts and techniques of XAS assuming no prior knowledge of the subject, with a strong emphasis directed toward "hands on" experience with experimental techniques and data analysis. It was hoped to encourage scientists who had not previously used XAS in their research, as well as providing more general background information to an audience of wider experience.

The first workshop, on the "Application of X-ray Absorption Spectroscopy to Environmental Sciences" was held on 24-25 May, 1993. The workshop was coordinated by Dr. Ingrid Pickering of SSRL and Prof. Gordon Brown of Stanford University. The workshop was organized in conjunction with the North Central Research Group Meeting "Synchrotron X-ray Sources in Soil Science Research", and was attended by some 37 participants from 21 institutions around the U.S. The workshop commenced with an afternoon of background talks which outlined the theory, experimental techniques and applications of XAS in the area of environmental science. The activities then continued with a day of practical sessions, including aspects of sample preparation, hands-on XAS data collection using beamlines 4-3 and 2-3, and EXAFS data analysis. The samples for XAS data col-