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IEEE Transactions on Nuclear Science, Vol. NS-26, No. 3, June 1979

SSRL: PAST EXPERIENCE, PRESENT DEVELOPMENT, FUTURE PLANS

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I - Introduction

The Stanford Synchrotron Radiation Laboratory (SSRL) has been in operation since May 1974 serving experimenters with intense synchrotron radiation in the visible, UV and x-ray regions of the spectrum.(1) Funded by the National Science Foundation and operated as a national facility serving many users, the SSRL program has grown rapidly in spite of the limitations of parasitic operation on the SPEAR colliding-beam program. In October 1978 there were 301 active proposals involving 409 scientists from 74 U.S. institutions and 19 foreign institutions. More details about the SSRL facility and experimental program is available from semi-annual Activity Reports which may be obtained on request from SSRL. Earlier reports describe the design of the facility.(2,3)

The first beam line, providing 11.5 mrad and now serving five simultaneous experiments, began operation in May 1974. The second beam line, providing 18 mrad and now serving 4 simultaneous experiments, began operation in May 1976. These beam lines, along with experimental support facilities and offices, are located in the North Arc Building (see figure 1). About 2 mrad of visible and near UV radiation is deflected vertically upwards into a "lifetimes port" garden shed building located above the storage ring shielding shielding. This port began operation in December 1977.

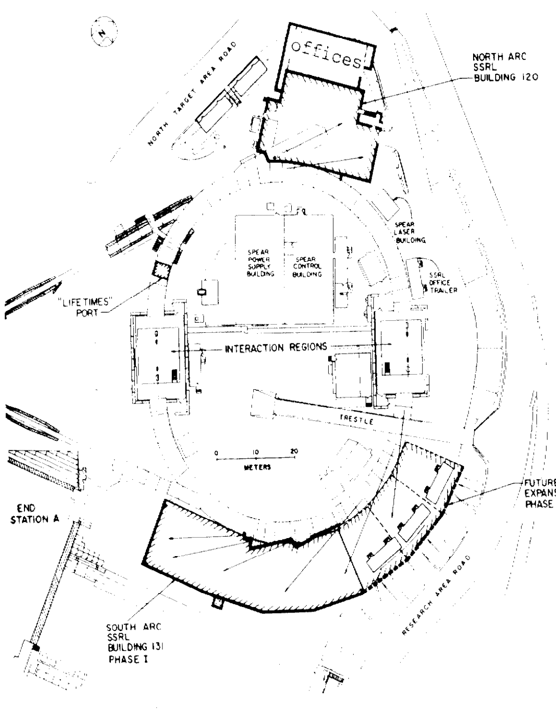

Figure 1. Layout of SPEAR & SSRL Facilities

Four new beam lines are now in construction in the recently completed South Arc Experimental Hall (Phase 1) and more beam lines are possible. Initially 12 experimental stations are planned. The first of these, utilizing radiation from an 18 KG, 7 pole wiggler(4) magnet, is now beginning to operate. Figure 2 gives the layout of the first 3 beam lines.

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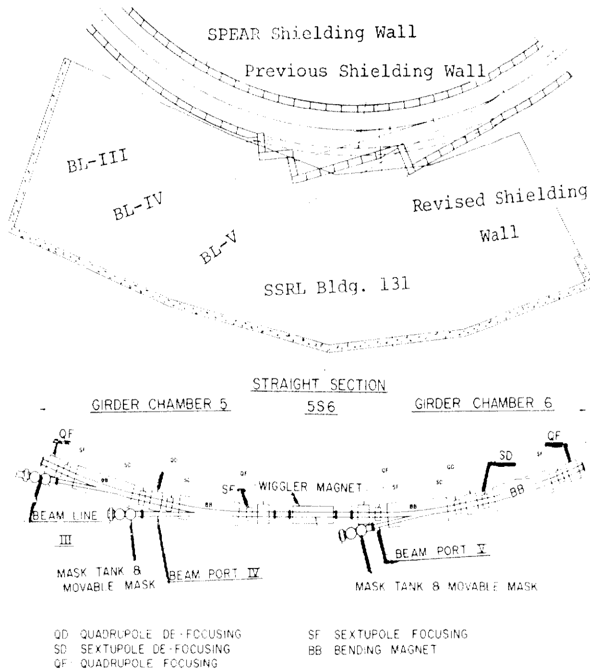

Figure 2. Schematic of Beam Lines III, IV & V

SPEAR will be utilized as a dedicated source of synchrotron radiation for 50% of its operations time by the beginning of 1980. During dedicated operation higher stored beam energy and current, reduced emittance and improved overall duty cycle (due to shorter fill times and reduced ring access needs) result in a factor of 40 more average flux for VUV experiments and a factor of 100 more for x-ray experiments compared to usual colliding-beam conditions. Coupled with the new beam lines now in construction this will provide a very large increase in experimental capability.

There has been only brief experience with dedicated operation to date, primarily one week in July, 1978. During this time SPEAR was operated under a variety of conditions including 60 mA in one bunch at 3.7 GeV and 100 mA in 4 bunches at 3.0 GeV. The maximum radiated power was 78 KW. At this power level thermal effects are observed, particularly on monochromator crystals that are located in the direct beam. Provisions for cooling these elements will be required for routine dedicated operation at the highest power levels. SPEAR has operated briefly at radiated power levels of about 100 KW and is expected to reach 150-200 KW. However, at these higher levels there may also be thermal problems in exit chambers, beryllium windows and beam line mirrors and improvements in design or cooling capacity may be required.

II - Past Experience

From the experience at SSRL, it is clear that certain design features of synchrotron radiation beam lines play an important role in maximizing the utilization of the radiation. In this section we discuss some of these features. We will not discuss specialized instruments such as monochromators and detectors. These are well covered in other journals and particularly in the proceedings of synchrotron radiation instrumentation workshops and conferences.(5,6,7) In other contributions to this conference more detailed descriptions are given of vacuum control systems,(8) beryllium windows(9) and thermal design considerations for beam lines(10) at SSRL.

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A. Vertical Beam Position Control

In storage rings such as SPEAR, the actual electron orbit can vary by several millimeters from the design equilibrium orbit. These variations, and the angles associated with them, result in variations in position of synchrotron radiation beams at the location of the experiment. This is particularly serious in the vertical direction for x-ray beams from multi-GeV machines because the opening angle ($\theta_v \simeq mc^2/E$) is very small and experiments are located 10-40 m from the source.

Rather than move the experiment to follow these changes, a system was devised for SPEAR to control the vertical location of the electron beam at the synchrotron radiation source point. A local vertical orbit distortion (beam bump) is made in the vicinity of the synchrotron radiation source point using a pair of horizontal steering coils (actually trim coils on quadrupole magnets) which are approximately 180° apart in vertical betatron phase and approximately equidistant from the synchrotron radiation source point. A vertical position monitor (see next section) installed in the synchrotron radiation beam line produces a signal proportional to vertical displacement of the synchrotron radiation beam. This error signal is used in a feedback system to control the current in the steering coils. In this way, the vertical position of the synchrotron radiation beam can be automatically stabilized to ± 0.25 mm at a location 20 m from the source point in SPEAR.

The above described system has been implemented for beam lines I and II at SSRL and works satisfactorily. Similar systems will be used initially for new beam lines but some difficulties are anticipated because on the the new beam lines the source points are closer together and independent control of each beam line is more difficult. Also, with many beam lines on a single ring, the small residual displacements from each local beam bump will be more troublesome. It is likely that a more complex system, with more steering coils and possibly computer control, will be necessary.

B. Position Monitor

The position monitor used to sense vertical displacement of the synchrotron radiation beam consists of a pair of copper photo-emitting surfaces located in the beam line vacuum system several millimeters above and below the median plane of the storage ring. The gap between the plates is sufficient to pass the x-ray beam. However, UV radiation, which has a larger vertical opening angle, strikes these plates, causing electron emission. The emitted current is differentially amplified to provide an error signal proportional to the displacement of the synchrotron radiation beam from the median plane. Typically several microamperes are emitted from each plate.

The copper photo-emitting surfaces are water cooled to accept the full thermal loading of a misaligned beam. Provision is made in the electronics for compensation of small variations in sensitivity between the two plates. The system is calibrated by using a scintillation screen, accurately aligned to the median plane.

A similar position monitor has been used in the beam line helium system. In this case, in addition to the photo-emission there is also a contribution to the signal from photo-ionization of the helium gas. Plans are being made at SSRL to use a position monitor consisting of a pair of horizontal strips or wires, one located above and one below the median plane. Because they are narrow these emitters will always be fully illuminated whereas larger emitter plates can have unequal illumination due to upstream masking misalignments. A design that eliminates water cooling is being studied.

C. Radiation Shielding

The approach adopted at SSRL is to provide free access close to experiments during all phases of operation of the storage ring; e.g. during injection, storage and dumping of a beam. Experiments are located in an experimental hall which is isolated from the ring by shielding.

For the first two beam lines implemented at SSRL a permanent magnet was installed along the beam close to SPEAR (about 5.5 m from the source point in orbit). This significantly reduces possible radiation hazards from charged particles by deflecting them vertically so that they do not pass through small vertical apertures (about 2 cm high) located in transverse shield walls 4-5 m downstream of the permanent magnet.

For subsequent beam lines larger apertures were required in transverse walls (to transmit VUV beams with larger vertical opening angles and for beams deflected from mirrors). For these beams it is difficult to use magnets to provide the larger deflections required. Instead, shutters which block the apertures in transverse walls are closed automatically during injection so that personnel need not be evacuated from the experimental hall during injection.

D. Experimental Enclosures (Hutches) & Interlock Systems

At SSRL x-ray experiments are generally performed inside interlocked steel enclosures called hutches. Upstream of the hutch and separate from it are beam shutters, which block the beam to that hutch only, and other specialized equipment such as a monochromator or a mirror. The basic idea is to design the hutch in such a way that it is difficult or impossible for a person to be inside it when there is a beam in the hutch. Initially this was accomplished with small hutches or small doors. The door must be closed to satisfy an interlock system(2) before beam shutters may be opened. In addition to microswitches, which sense the position of the door, the hutch is provided with a key which can only be removed when the hutch door is closed. Removing the key inserts a bolt which mechanically locks the hutch door closed. The key is then inserted into a control panel which permits the beam shutters to be opened.

Once an experiment is installed in a hutch and the control system is put "On-Line" (via a key switch) by an operations technician, access to the hutch is under the control of the experimenter who can close the shutters, remove the key from the control panel and unlock the hutch door at any time. He can also reverse the procedure to put beam back into the hutch. The "On-Line, Off-Line" key is available only to operators and is different from the hutch door key.

For flexibility in setting up new experiments the hutch sidewalls are usually removable. These panels are padlocked in place during normal operation. When it is necessary to remove a panel the system is put "Off-Line" by an operator. In this condition, the beam shutters cannot be opened. Then a special key, not available to experimenters is used by an operator to permit removal of a hutch panel. Alternatively, in the "Off-Line" condition the entire hutch can be removed and a new one can be installed. In this way, prealigned and tested experiments can be installed in separate hutches and quickly changed.

The basic hutch and interlock system concept has worked well since 1974. It permits rapid, independent and convenient access to each of several simultaneous experiments. Hutches have grown in size to accommodate larger experiments and hutch doors have also grown in size to permit better access by the experimenter. For such larger hutches a sliding gate is installed parallel to the door which prevents a person from entering the hutch when the door is opened. The gate is padlocked shut whenever the system is "On-Line," i.e. whenever the shutters can be opened if the hutch door is closed. The gate has openings large enough for small pieces of equipment and also for hands to reach through (see figure 3) but too small to permit a person to enter the hutch.

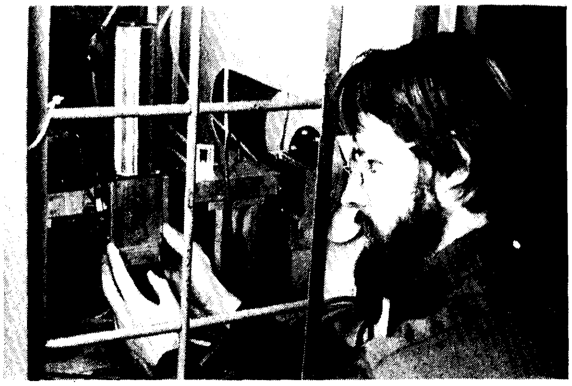

Figure 3. Experimental Hutch

Hutches that can receive white radiation are lined with 3 mm of lead in addition to the 3 mm of steel that make up the hutch walls. This provides adequate shielding to protect against the highest energy photons (up to about 100 kev) that are present in significant quantities when SPEAR operates at 3.5-4.0 GeV.

III - Development Programs

In addition to the new beam lines mentioned earlier, several other development programs are now underway. These include the following:

1. Two Dimensional X-ray Detector

A multi-wire proportional chamber with associated readout and storage system under computer control is now in design and construction in collaboration with detector groups at the University of California at San Diego and Berkeley. The initial chamber will be 28 cm x 28 cm and contain 150 anode wires, and 300 cathode wires. The energy resolution is expected to be about 20%, the counting rate capability will be about 100 khz and the quantum detection efficiency at 8 KeV will be about 60%.

2. X-ray Lithography and Microscopy Facilities

A special beam line and experimental end station is now in design optimized for soft x-ray lithography and microscopy studies. The beam will be split off from the main tangential beam by a mirror that deflects about 1.5 mrad of radiation by 3° providing photons with energy up to about 3 KeV. Isolation from the high vacuum system of the main beam line and the storage ring will be provided by differential pumping systems and/or ultra thin windows so that experiments can be done in poor vacuum and with potentially contaminating samples.

3. Gas Phase Studies (UV & Soft X-ray)

A special purpose beam line for gas phase studies is now in design in collaboration with a group from the Lawrence Berkeley Laboratory. Up to 5 milliradians of radiation will be deflected upwards at about 18° to a second level experimental floor in the South Arc building where it will enter a monochromator designed for operation up to about 150 eV. Gas phase samples will be isolated from the monochromator and high vacuum beam line by a differential pumping system consisting of refocussing mirrors and capillaries.

IV Plans for the Future

The development of SPEAR as a dedicated synchrotron radiation source[11] will be a major activity once 50% dedicated operation starts. Studies are planned aimed at achieving high stored beam current in multibunch mode (the SPEAR harmonic number is 280), reduced electron beam emittance[11] and variable bunch length. Additional wigglers and also undulators, including permanent magnet undulators, are planned. An undulator in SPEAR could produce quasi-monochromatic radiation of extremely high brightness at photon energies up to 1-2 KeV, which would open up new experimental possibilities including soft x-ray lithography and high resolution x-ray microscopy. Such an undulator could also be a prototype for a PEP undulator where the photon energy would reach the very important range of 5-25 KeV.

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Acknowledgment

This status report summarizes the work of the entire SSRL staff with much assistance from SLAC and the SSRL User Community. The materials incorporated in this work were developed with the financial support of the National Science Foundation (under Contract DMR 77 27489) and the Basic Energy Science Division of the Department of Energy.