DESIGN AND PERFORMANCE OF THE STANFORD SYNCHROTRON RADIATION PROJECT (SSRP)†


Summary

The Stanford Synchrotron Radiation Project (SSRP) is now in full operation as a national facility utilizing the intense ultraviolet and x-radiation from the storage ring SPEAR at the Stanford Linear Accelerator Center (SLAC). The experimenter-operated facility is designed to maximize access to, and utilization of the radiation by 5 or more simultaneous users, within the limits of parasitic operation on a high energy colliding beam storage ring. A novel experimenter-controlled personnel protection system permits independent access to each of 5 experimental areas. A vacuum monitoring and control system protects the storage ring vacuum from contamination, rising pressure, or catastrophic failure. The design and operation characteristics of these control systems and of the beam position monitoring and control system, vacuum system and thin beryllium windows are presented.

Introduction

The SSRP has been in operation since May, 1974, as a national facility for UV and X-ray research using synchrotron radiation from the storage ring SPEAR at SLAC. SSRP has been funded since June, 1973, by the National Science Foundation and is administered by the W. W. Hansen Laboratories of Physics at Stanford University. Contributions to the facility have also been made by the U. S. Navy Michelson Laboratory at China Lake, California, the Xerox Corporation and the Bell Telephone Laboratories. SLAC exercises control over radiation safety and sets vacuum standards for experiments which connect on-line to the SPEAR vacuum system.

The research program includes studies of UV and X-ray photoemission, extended X-ray absorption edge fine structure, low angle X-ray diffraction, protein crystallography, UV reflectivity, and X-ray Raman scattering. Details are given in the 1974 SSRP Users Group Meeting, obtainable on request from R. Dannemiller at SSRP, and in the 1974 Hamburg Conference on VUV Radiation Physics. Professor S. Doniach of Stanford is the Project Director and Professor W. Spicer of Stanford is the Consulting Director.

The facility is built around a single beam port on the SPEAR vacuum system, accepting 11.5 mrad of synchrotron radiation which was initially split among 5 simultaneous users. As a secondary program on SPEAR, the facility was designed to permit operation of 5 or more simultaneous synchrotron radiation experiments during SPEAR colliding beam runs with maximum protection for the SPEAR vacuum system and minimum involvement of SPEAR and SLAC operations personnel. Particular attention to 3 elements proved vital in achieving this goal. These are:

1. Vacuum system and vacuum interlocks.
2. Radiation shielding and personnel protection system.
3. Orbit monitoring and control.

In this report we present a general description of the facility with particular emphasis on the above 3 areas.

Plan of the Synchrotron Radiation Facility

A prefabricated steel building 12 m wide, 24 m long and 7.5 m high has been constructed adjacent to SPEAR as shown in Fig. 1 and 2. The building is well insulated and temperature controlled and has a thick (30 cm) concrete floor for stability. Vibration sources (such as compressors) are located outside the building and decoupled from the building and floor. A 6 m extension of the building is planned to accommodate a second beam run.

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About 11.5 mrad of synchrotron radiation, corresponding to 15 cm of curved path in a SPEAR bending magnet, emerges tangentially into a high vacuum pipe. The spectrum of this radiation, corresponding to SPEAR stored beam energies of 1.5 to 4.5 GeV, is shown in Fig. 3. Single beam currents of 50 mA at 3 GeV and 100 mA at 4.5 GeV are anticipated during single bunch collisions. These currents are limited by beam-beam interactions. In single beam multi-bunch mode of operation, large currents (250 mA and 3 GeV and 500 mA at 2.5 GeV) should be possible. The SPEAR RF frequency is 358 MHz which is the 280th harmonic of the orbital frequency. In single beam runs ~ 1000 bunches have been filled. The one bunch mode offers unique timing capabilities since the pulse duration is 1.7 nsec and repeats at 1.25 MHz. Other reports give more information about SPEAR and the synchrotron radiation it produces.

![Spectral Distribution of Synchrotron Radiation from SPEAR (p=1.27 m)](image)

Fig. 3

The horizontal fan of radiation is split 3 ways by reflection at grazing incidence on 2 ultra smooth, platinum-plated copper blocks placed 6.5 m from the source point. These mirrors may be remotely inserted and adjusted by experimenters during operation. Five or more simultaneous experiments share the radiation as and adjusted by experimenters during operation. Fifteen or more simultaneous experiments may be conducted at the same time. The mirrors are cooled thermo-electrically to enable operation with up to 25% of synchrotron radiation per mrad.

A plane mirror with an rms surface roughness of λ/50 intercepts the inner 3 to 6 mrad at a vertical grazing angle of incidence of 1°. The resulting beam rises at 8° and contains photons up to ~ 300 eV. Custom built high vacuum gratings monochromators are connected to these lines. The mirrors are cooled thermo-electrically to enable operation with up to 25% of synchrotron radiation per mrad.

The central part of the beam contains 1/mrad of radiation (depending on insertion of mirrors) which is not deflected by mirrors. This radiation proceeds down the high vacuum beam pipe and passes through a pair of 75 µm thick water-cooled carbon foils which absorb the UV and soft x-ray part of the spectrum. The radiation then leaves the vacuum system at 10.5 m from the source point, extending through a pair of 250 µm water-cooled beryllium windows. This foil and window system begins to transmit at about 2.5 keV and reaches 50% transmission at ~ 4.5 keV. It is planned to improve this transmission by replacing the 75 µm foils with 5 µm pyrolitic graphite foils. A pair of such foils is now undergoing test in the beam run. In addition, a new beryllium window is planned with a total thickness of ~ 100 µm. In combination with the pyrolitic graphite foils, this window should provide significant transmission down to 2 keV.

After emerging from the SPEAR vacuum system the x-rays travel in a helium atmosphere into a shielded area in which several crystal monochromators are installed. The helium system is carefully sealed and monitored to keep a high concentration of helium. If the helium system is divided into several sections by 5 µ thick kapton windows. Each section has an independent helium input flow meter and output bubbler.

An elevated concrete slab, 5 m wide, 12 m long and 2.5 m above the floor serves as a second level for installing experimental apparatus. The thickness (20 cm) is adequate to provide shielding from the main beam line. Monochromatic x-ray beams and the rising 3° beam line vacuum system penetrate this slab as shown in Fig. 2 and 4. Electrical services, compressed air, and helium and water services are installed at several locations along the perimeter of the slab serving experimenters on both levels. A jib crane is used to bring heavy equipment to the upper level. Vacuum controls, radiation protection controls and signals to and from the SPEAR and SLAC control rooms are centralized in an adjacent control room.

Vacuum Systems and Vacuum Interlocks

The vacuum system is built to SLAC specifications and is all metal and bakeable. The central beam pipe extends to 10.5 m from the source, terminating at the beryllium window assembly within the SPEAR tunnel. The 1° and 3° beam runs continue in vacuum in the synchrotron radiation building and extend to 15 m and 25 m from the source point.

Four all-metal, high vacuum gate valves isolate the beam runs from each other and from the SPEAR vacuum system. Water-cooled masks assure that synchrotron radiation strikes only water-cooled surfaces and movable water-cooled absorbers may be remotely inserted to block the radiation. Four 150 l/sec triode ion pumps are used on the main beam line with additional pumps on the 1° and 3° beam lines.

All components of the vacuum system were chemically cleaned and baked to ~ 200° C prior to installation. Careful backfilling and purging with dry nitrogen is used during the assembly and servicing of the vacuum system. The system has not been baked since installation, but
The philosophy of design of the Hutch Panel embodies safety through redundancy. Relay logic \( \Sigma \bar{V} \) has been used throughout. Fail-safety has been achieved by creating interlock violations from any of the following: loss of power, unblocking of fuses, malfunctioning of single switches e.g., Hutch Door switches. Also, connectors are recessed so that electrical bypassing "boggling" of interlocks is difficult.

The accompanying figures portray the system.
Orbit Monitoring and Control

The SPEAR beam is normally maintained within $\pm 3$ mm of the nominal central orbit. In the radial direction this has been found to be adequate for position tolerance of the synchrotron radiation beam. In the vertical direction, however, only a small fraction of this is tolerable. The vertical opening angle of the synchrotron radiation ($\sim \frac{mc^2}{E}$) is $\sim 0.2$ mrad. Some experiments collimate to 1 mm at 20 m from the source point. A vertical orbit distortion of a fraction of 1 mm can result in a displacement of several mm at the location of an experiment because of the angles associated with orbit motion. Thus it has been found necessary to reproduce the position of the synchrotron radiation source point to a fraction of 1 mm.

This is accomplished by powering a pair of trim coils which provide equal horizontal dipole fields. These coils are located in quadrupole magnets which are 6.55 m upstream and 6.75 m downstream of the synchrotron radiation source point. Since they are approximately 150° apart in the phase of the vertical betatron oscillation these coils produce a local beam bump with only a small residual ($\sim 5\%$ of the peak local distortion) around the rest of the ring.

At present the SPEAR operator centers the synchrotron radiation beam by TV observation of its location on an aligned screen located 21 m from the source point. Position monitors are now under development which will produce an electrical signal proportional to the vertical beam displacement. A feedback system on the power supply controlling the beam bump will then keep the beam centered automatically.

Since the synchrotron radiation beam is simply and accurately positioned, all experiments merely align their equipment to accept a beam at the height of the SPEAR median plane. No further adjustments are necessary.

Acknowledgments

The successful operation of SSRP and the speed with which it was designed and constructed is attributable in large measure to the excellent cooperation and support services provided by SLAC.

References

6. E. Hoyt, W. Pierce (to be published).
8. This fast closing vane is of the type used in the ISR at CERN and was kindly supplied to us by CERN.