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THE SYNCHROTRON RADIATION ANGIOGRAPHY PROGRAM AT THE NATIONAL SYNCHROTRON LIGHT SOURCE

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ABSTRACT

The National Synchrotron Light Source (NSLS) angiography program is under development. The program is a collaboration between the Stanford University Angiography Project and the NSLS. A 180 m^2 clinical facility has been built. A beam line is being constructed to utilize a superconducting wiggler radiation source. Projected start-up date for the NSLS program is Summer, 1988.

I. Introduction

The angiography program at the National Synchrotron Light Source (NSLS) is a collaboration with the Stanford University Angiography Project. As long ago as 1981 it was clear to the project members that success in the early stages of the work would require the establishment of a clinical facility in the United States for long-term studies. Such a facility would need many weeks of synchrotron radiation beam each year, high energy photons to image at the iodine K-edge, a completely equipped angiography suite with full patient care facilities, local medical support, and the availability of a large patient pool. The Stanford Synchrotron Radiation Laboratory (SSRL) was not in a position to guarantee large blocks of operating time or to provide a full clinic for long-term studies involving hundreds of patients.

In 1982 the NSLS x-ray ring was nearing completion. Although the bending magnet spectrum with the ring at 2.5 GeV would not be able to supply the necessary high flux at 33 keV, a superconducting wiggler magnet was already being constructed. Such a device at the NSLS would produce a factor of 5 to 10 more photons than were available at SSRL. In addition, an NSLS construction program (Phase II) was approved by the U.S. Department of Energy to upgrade both the conventional facilities and the experimental capabilities by the installation of new wiggler and undulator radiation sources.

Thus, the situation was ideal for planning and implementing the long-term clinical phase of the angiography program. In 1982 the director of he NSLS agreed to guarantee 25% of the operational time of the superconducting wiggler beam line (X17) to the Stanford angiography program. With this guarantee of as many as three months a year of beam, the NSLS Phase II building program was modified to include a complete angiography clinic consisting of direct elevator access, patient reception, examination room, recovery areas, physician's station, computer room, monochromator cave, and toilet facilities. The NSLS agreed to complete the conventional construction of the facility, the patient safety interlock systems, and the x-ray beam transport to the angiography suite. On-site human studies support and protocol would be under the control of the Brookhaven National Laboratory Medical Department. The Stanford Angiography Program would supply the imaging system, computers, patient positioning chair, staff, and the medical research program.

Over the last several years, the above agreements have been implemented. The Phase II expansion of the NSLS facility will be ready for occupancy by the staff in July 1987. The x-ray ring is currently shut down (May 1987) for installation of the insertion device hardware. The clinic will be complete in the summer of 1987, ready for the imaging system to be moved from SSRL. Construction of the X17 beam line has started, with the first photons expected down the line from the superconducting wiggler in early 1988. Anticipated start-up of the angiography program for human studies is the summer of 1988.

Dr. E. Rubenstein, one of the principle investigators on the Stanford program, has been actively developing collaborations with medical research groups in the New York City metropolitan area. At present, collaborations have been established with staff from New York University and the North Shore University Hospital. Thus, coupled with the programs from the Stanford University Medical Center and the Palo Alto Veterans Administration Hospital, a full research program is assured from start-up.

In this paper, we will detail the characteristics of the photon source, the beam line design, and the clinical facility physical plans. The up-to-date reports on the instrumentation and medical progress of the Stanford Angiography Program can be found in the references [1], and in reports at this meeting by Dr. E. Rubenstein and Dr. H. Zeman.

II. Photon Source

Prior to the 1987 shutdown, the NSLS x-ray ring was operating at 2.5 GeV with current fills reaching over 200 mA. The lifetimes for these beams were in excess of 10 hours at 100 mA. Figure 1 shows a recent day of operation, displaying the current vs. time for the x-ray ring. When the ring is recommissioned in late 1987 and early 1988 similar operation is initially expected with ultimate currents in the 300 mA range within a year.

The angiography program will be carried out using the central 5 mradians from the NSLS superconducting wiggler (SUW). The 5 center poles of the magnet are at the full magnetic field, while the end poles are each one-half field. The SUW has undergone field measurements on and off the central axis. Field integral measurements with a long rotating coil and local field measurements with a Hall probe were made. The peak field in the SUW can be routinely taken to 5.4 Tesla (215 Amperes) without quenching. Higher fields (about 6 Tesla) are possible with increasing probability of a quench.

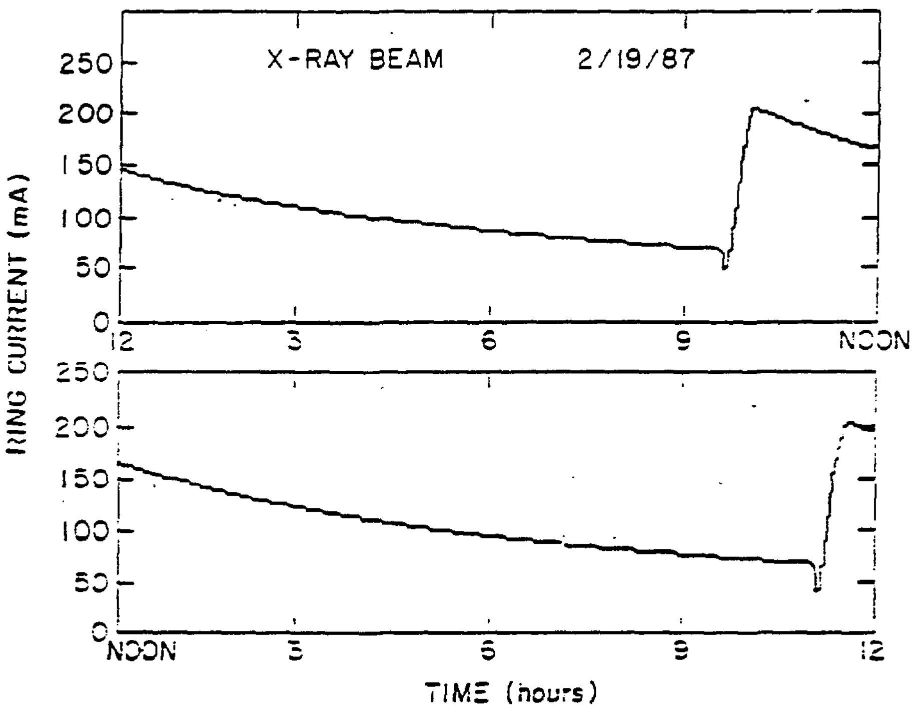

Figure 1. Current vs. time for the NSLS x-ray ring.

The white beam flux from the SUW will be filtered by pyrolytic graphite filters before passing through Be windows. The anticipated flux for the ring at 2.5 GeV and 300 mA current is shown in Fig. 2. The calculations [2] were carried out for the beam passing through 0.391 mm of graphite and 0.508 mm of Be. The limiting vertical aperture was 1.5 mradians.

One of the problems facing all optical systems, especially the SUW beam line, is the high power density in the beam. For the X17 beam line, a Xenon gas filter has been designed and constructed [3]. Xenon gas has its K-absorption edge at 34.6 keV. For a Xenon filter 180 mm long at 1 atmosphere of pressure, the total power on the first monochromator crystal will be decreased by a factor of 5, while the flux at 33 keV will only decrease by a factor of 2. The Xenon filtered spectrum is also shown in Fig. 2.

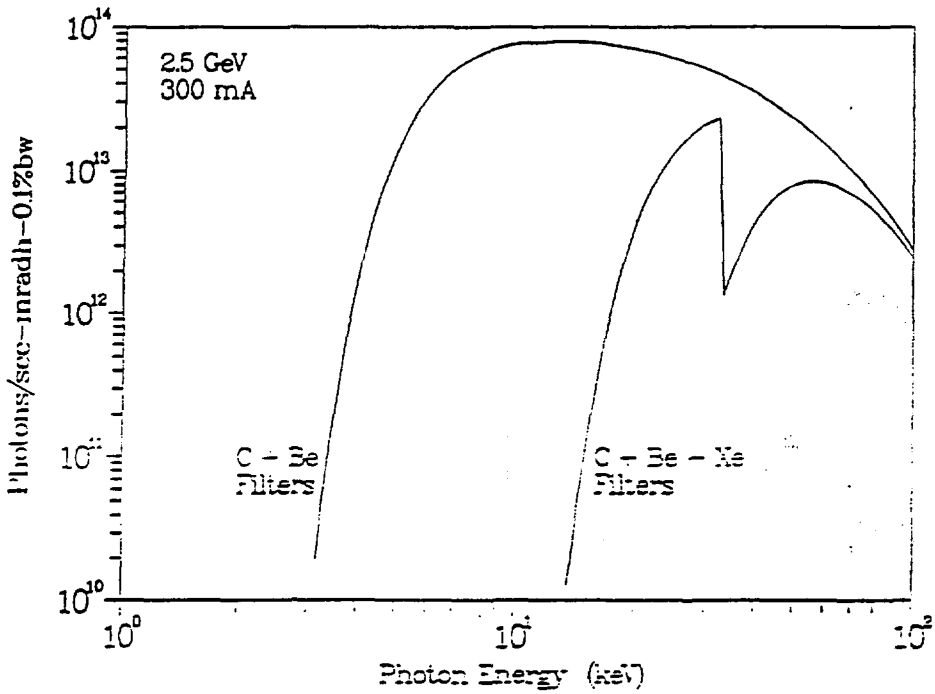

Fig. 2. Calculated flux for the SUW at 5 Tesla and the NSLS x-ray ring at 2.5 GeV and 300 mA. Curves for two different sets of filters are shown.

III. Instrumentation

The imaging system and beam line from the monochromator through to the detector system will be directly transferred to the NSLS from the program at SSRL. Details of the monochromator, shutters, beam monitors and apertures, patient mover, detector, and image analysis are to be found in the references relating to the Stanford University program [1]. It is very reasonable to anticipate that the availability of a dedicated laboratory for angiography will lead to rapid advances in various techniques. Detector development will continue for higher resolution imaging, various new monochromator optics will be tried to improve the quality and quantity of the imaging signal, and beam filtering will be studied to decrease thermal problems with the monochromator.

In order to deliver the white beam from the SUW to the angiography monochromator, the beam line design has had to deal with the extreme 1.2 kW/mrad of power in the central beam. In addition, beam must be provided 75% of the time to the material sciences program which resides upstream (toward the SUW). A schematic plan view of the X17 facility is shown in Fig. 3. The beam is collimated in both the front end and just before the material sciences monochromator by water cooled apertures. When the angiography area is using the beam, the material sciences monochromator is moved out of the beam line (remote controlled) and a beam transport pipe inserted through the material sciences hutch, X17B1.

In the present design there is also a side station, X17C, which will use the inner three mradians of the SUW beam. That program will be independent of the operation of the angiography studies, and is dedicated to high pressure physics.

The first optical element of the angiography beam line is the monochromator at 33.9 m from the SUW. A maximum of 5 mradians of horizontal beam is transmitted by the apertures, so a maximum of 17 cm is incident on the monochromator. Since the patient is located at 36.9 m from the source, an image field 18.5 cm wide is possible.

IV. Angiography Suite

The Phase II expansion of the NSLS provided the perfect opportunity for the installation of the angiography suite. Located just outside of the old perimeter wall of the building (see Fig. 3), it encompasses about 180 m^2 of floor area. The desire to have a private patient entry to the suite from the outside of the facility led to the present location of the elevator. Patients will enter the reception area without seeing the experimental hall of the x-ray facility. The details of the clinic are shown on Fig. 3. A toilet facility is available in the reception area for the convenience of the patients. Patients can be examined and rest in the examination area. This area can also be a future catheterization lab.

The radiology room has been designed rather large to accommodate the beam defining slits, position monitors and dose measuring detectors, as well as the patient chair and the detector system. Medical emergency equipment such as a crash cart will be in this room.

The attending physician will control the imaging scans from the physician's room (PHY) adjacent to the radiology room. From here, the physician can communicate with the patient and the staff in the computer room. The data acquisition and image processing systems will be located in the computer room. The physician will be the final safety officer in charge of determining the patient dose limits and having immediate access to the patient. It is anticipated that the human studies safety system will closely parallel the system used at SSRL. Details of that system are available [4].

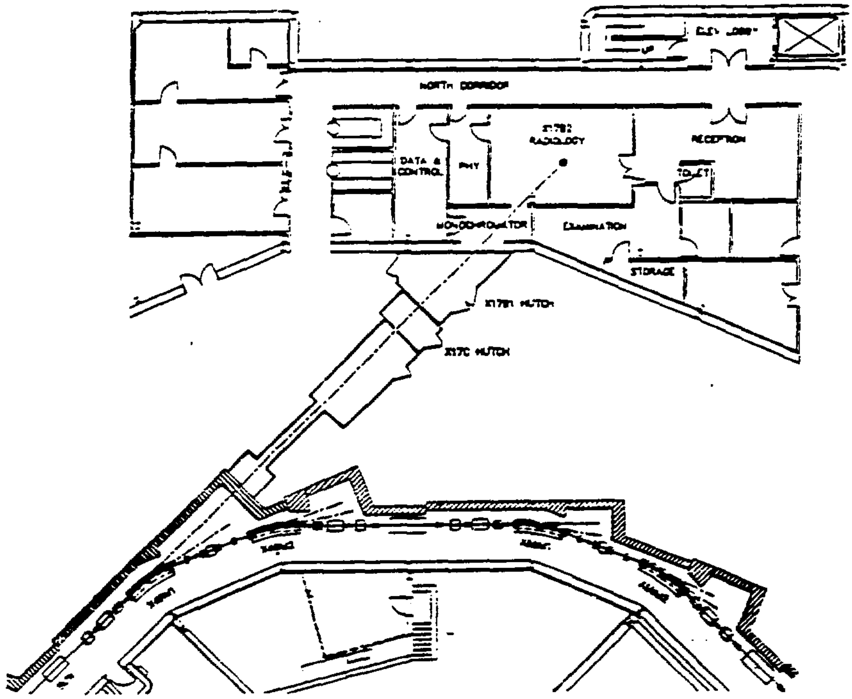

Figure 3. Plan view of the X17 beam port and medical research facility at the NSLS.

V. Summary

The Stanford/NSLS Angiography Program will be ready for the start of clinical evaluation studies in 1988. The human studies committees at Brookhaven National Laboratory are reviewing the imaging protocol, the physical facilities are nearing completion, success has been accomplished in imaging human coronary arteries at SSRL, the New York metropolitan research community is becoming active in the program, and staffing at the NSLS for these major programs has commenced. The staff of the National Synchrotron Light Source is looking forward to many years of progressive medical research on the X17 SUW beam lines.

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