STANFORD SYNCHROTRON RADIATION LABORATORY

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II ACCELERATOR PHYSICS AND SPEAR IMPROVEMENTS

In 1986 the New Rings Group and the Machine Physics Group were combined into one Accelerator Physics Group. The new group is focusing mainly on the improvement of SPEAR's operating conditions and on plans to convert PEP into a next generation x-ray source. Being associated with Stanford University, the SSRL accelerator physics group has become a training center for accelerator physics graduate students. The construction and improvement projects for SPEAR, PEP and the SPRL (Stanford Photon Research Lab) storage rings provide valuable opportunities for students to gain practical experience with accelerator theory, design, construction and operations. This training, presently involves three PhD students. Two others will be supported by SSRL in the future.

During the spring run of SPEAR, a series of machine physics shifts were dedicated to improving the operation of SPEAR for the production of synchrotron light. Specifically, attention was given to significantly reducing the orbit distortion of the beam. This has resulted in much smoother and more reproducible ring operation. It was possible, for example, to fill SPEAR to 80 to 100 mA on demand during the critical period when the method of Digital Subtractive Angiography was applied for the first time to three human subjects.

The improved operating conditions in multibunch mode made the problems encountered during the timing mode with only four bunches all the more obvious. More machine physics is needed to determine the cause of this difference in the SPEAR performance.

Additional efforts have been dedicated to the investigation and cure of beam jitter and movement. To pursue this, new photon beam position monitors have been built.

Silicon Photo-Diode Position Monitors

- Experiments have been done with silicon photodiodes as x-ray position monitors.

Silicon diodes may offer some advantages over split ion chamber type position monitors. For example they do not require a high voltage bias supply, do not require a special gas control system because the detector sensitivity is not affected by gas composition and they can be made two dimensional. There may be other attributes such as spectral and intensity insensitivity.

Most testing has been done on a commercially made position sensitive PIN diode intended for use with visible light, but modified to allow x-rays to shine directly on the detector surface. It is a monolithic device with a 1 cm square active area. The resistive division of current flow to the edges of the detector are compared to derive the position of the beam on the photodiode.

The detector has been operated in the Beam Line II-4, white radiation beam for a period of two weeks under 3 GeV dedicated conditions. The beam was attenuated with 6.4 mm of aluminum and was collimated horizontally to a width of 3.2 mm. No vertical aperture was imposed. Under these conditions the detector electronics was operated at a factor of 3 to 10 below its maximum gain setting.

units. The new system will enable complete remote control of the steering system, either from the SPEAR control console or even from a remotely located SSRL console, and will provide the SPEAR control program with information from the SSRL position monitors and servo units. This information can then be used to augment and refine the level of automated orbit control in the future. These new systems will be installed in the SPEAR control room during 1987.

Also scheduled for completion in 1987 is the installation of another closed-loop vertical steering system for the new PEP Beam Line 1B, and the continuing development of the 2-loop servo system for PEP beam lines that will correct orbital position and angle independently at the source point (described in the 1985 Activity Report).

Angiography Personnel Protection Interlock System - For use as an angiography station for human subjects in May, 1986, the Beam Line IV-2 hutch was equipped with a personnel protection interlock that would permit a person to receive a controlled dose of synchrotron radiation. An Angiography Personnel Protection Interlock (APPI) was configured that would:

o permit safe access to the patient exposure area while the synchrotron radiation beam was illuminating the upstream dual-energy monochromator (to preserve thermal stability of the monochromator);

o allow a patient to be radiated by the monochromatized beam under the supervision of a radiologist, with scan chair motion and precision shutter actuation regulated by an angiography control computer, while providing a suitable number of safeguards against accidental radiation exposure;

o have different modes of operation to accommodate equipment set-up, test, and calibration and patient exposure;

o ensure the quick extinction of the beam in access areas if a potentially unsafe condition was detected.

The Beam Line IV-2 hutch was divided into two sections, front and rear, with a set of panels. The front hutch contained the dual-energy monochromator and other ancillary equipment, as well as a pair of redundant fast-acting beam shutters that controlled beam exposure to the rear hutch. The rear hutch served as the angiography exposure area and was equipped with the computer controlled scan chair.

Access to the front hutch was supervised by the standard SSRL hutch protection system (HPS): keyed interlock panel, lockable doors, and upstream redundant beam stoppers ("hutch stoppers"). The rear hutch was fitted with a pair of swinging doors with no locks, allowing quick access or egress in case of medical emergency; access was supervised by the new APPI system. Primary radiation protection for the rear hutch was provided by the fast-acting pair of "safety shutters".

When a human heart scan was to be performed, the APPI was operated in "patient" mode. A "diagnostic" mode was also provided to allow equipment set-up, alignment, calibration, etc., in the rear hutch to be quickly carried out without having to satisfy the complete patient mode interlock. In patient mode, the safety shutters could not be opened unless:

o both swinging doors were closed;

o a hand-held "scan switch" was depressed by the radiologist during a key-started timer interval, and was held depressed during the entire patient scan period;

o the scan chair was moving faster than a certain speed determined by a redundant set of motion detectors, so as to prevent patient overexposure during changes in direction as well as in the event of motion malfunction; and

o a redundant pair of "exposure timers", triggered by the initial computer-generated request to open the safety shutters and intended to limit the overall scan period to an interval determined by the radiologist, were active.

An APPI system fault would be generated if either safety shutter was not closed and one or more of the above conditions were not satisfied, or if either one of two "scan stop" buttons were pressed, or if the APPI detected an internal logic fault. An APPI fault would close both safety shutters and hutch stoppers, but would not cause the loss of stored beam in SPEAR.

The APPI system was subjected to hundreds of operational tests before being used for the human scan experiments. During the human patient experimental run, extensive system check-outs were carried out each morning before patient exposure was allowed. The successful functioning of the APPI system during these tests enabled the human angiography experiment to be performed at SSRL. By the same token, the barrage of tests and "hands on" experience has led to the identification of a number of items in the system, prototypical in nature, that could be improved or refined for future regular use. Among these are more polished designs for the safety shutters and chair motion detectors, and a more convenient means for converting the Beam Line IV-2 hutch from its normal operational mode to the angiography mode. Implementation of these changes is planned before the next human angiography experiment at SSRL.

MECHANICAL ENGINEERING

New Beam Lines Including Monochromators and Insertion Devices - The ME group has a major involvement in the design, construction and installation of the many components of a beam line. This activity ranges from full responsibility for the design and construction of beam lines that are fully funded by DOE through SSRL to varying lesser degrees of involvement in beam lines funded in other ways by Participating Research Teams (PRT's). Assembly, test and installation of beam line components is often carried out primarily by others (e.g. SSRL vacuum and operations groups) with advice, assistance and supervision by the ME group.

In 1986 the ME group, in cooperation with other groups worked on the following new beam lines and monochromator systems: PEP Beam Line 5B, PEP Beam Line 1B, SPEAR Beam Line III-2, SPEAR Beam Line VIII, SPEAR Beam Line X, Beam Line V monochromator, plus 24 and 30 period undulator installation in Beam Line V.

Booster Synchrotron Injector for SPEAR - Design studies were begun for components of a proposed new injector for SPEAR, in cooperation with the SSRL Accelerator Physics Group. Layouts have been made for the bend, quadrupole, and sextupole magnets, magnet assembly fixturing and alignment devices, and the vacuum system.

SYNCHROTRON RADIATION BASED TRANSVENOUS CORONARY ANGIOGRAPHY

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Substantive improvements were made in the imaging system that has been under development on beam line IV-2. The X-ray fluence was increased by the use of asymmetrically cut monochromator crystals; a new dual-drum X-ray beam chopper was constructed which allows scanning speeds at the rate of 12 cm/sec and decreases the line exposure time; a new subject support system was built and installed; and a personnel protection system was developed and implemented to insure the safe exposure of human subjects in the synchrotron X-ray beam. The enhancements in the X-ray optics resulted in striking improvement in the quality of transvenous canine angiograms compared with those recorded previously.

These results led to the use of this imaging system in May 1986 on three human subjects, each of whom was under treatment for coronary artery disease at the Palo Alto Veterans Administration Hospital at the Stanford University Medical Center 1 .

The operating parameters for these studies were: electron beam energy 3.0 GeV; electron beam current 51.5 to 80.4 mA; scanning speed 6 or 12 cm per sec; line exposure time 1.7 or 3.3 msec; interval between exposures 0.4 or 0.8 msec; total time to record one frame (256 lines) 2 sec or 3 sec (including starting and stopping time). The contrast agent (Renografin-76) was injected at rates of 12-15 ml per sec and in volumes of 36 to 50 ml (0.41 to 0.67 ml per kg) by means of a 6.7 French pig-tail catheter, inserted into the internal jugular vein and positioned so that its tip was in the distal superior vena cava or right atrium. The X-ray dose per frame varied from 0.10 to 0.29 rads.

Images were recorded of the left anterior descending coronary artery, the right coronary artery, and of saphenous vein and internal mammary artery grafts. Greater X-ray fluence is needed to provide images of clinical quality. Improvements in the imaging system are now being made to achieve the needed fluence.

Figure 1. A synchrotron transvenous coronary angiogram done during May 1986 on a 48-year-old man who had undergone coronary artery surgery for diffuse coronary atherosclerosis. The image shows the left internal mammary artery (LIMA) anastamosed to the left anterior descending coronary artery (LAD), and vein bypass grafts (VBG), one of which is anastamosed to the right coronary artery (RCA). Poor postoperative perfusion of the LAD and the RCA are revealed. These findings were corroborated at the time of repeat surgery.

References.

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