OPERATIONAL EXPERIENCE AT SRRC

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Abstract

The Taiwan Light Source (TLS) is a synchrotron radiation facility that has operated for the past four years at SRRC. At this time, the operating energy has been increased from 1.3 GeV to 1.5 GeV, and the beam lifetime is 9 hours at a current of 200 mA. The monthly uptime is normally more than 90%, and the orbit stability better than 5 micrometers. Both transverse and longitudinal instabilities have been observed, and the corresponding feedback systems have been constructed. The transverse feedback system is in routine operation. A fast orbit feedback system is capable of restricting orbit errors to within 10 micrometers, even in the presence of strong orbit perturbations such as insertion-device gap changes.

1 ACCELERATOR OPERATIONS

During 1996, the TLS operating energy was increased from 1.3 GeV to 1.5 GeV, thereby greatly increasing the flux of x-rays, especially for photon energies greater than 1 keV. The beam lifetime is now 9 hours or more at a current of 200 mA. During typical user operations, the vertical emittance coupling is increased to a few percent to increase the vertical beam size and the beam lifetime.

The light source is normally scheduled to operate 24 hours per day, five days per week, for synchrotron radiation users and for machine studies. The operation of the light source has been very reliable, and monthly beam availability has normally exceeded 90%. Long shutdowns are occasionally scheduled - for upgrades, maintenance, repairs, and holidays. For example, user operations were interrupted for 9 weeks in March and April of 1997, in order to install and to commission the U5 undulator and 18 new quadrupole power supplies (which provide independent control of pairs of quads in the storage ring). At the same time, the power-supply control system was upgraded, so that the storage-ring energy can now be ramped from 1.3 GeV (the injection energy) to 1.5GeV, in only a few seconds.

There are three insertion devices installed in the storage ring: W20, U10, and U5. The U9 undulator will be completed in 1998. Additional insertion devices are under development or are being considered, including an elliptically-polarizing undulator (EPU) and a superconducting magnet (wiggler or bend magnet) to address the needs of the x-ray user community.

Four photon beamlines are in routine operation for users, and a major beamline construction program is in progress. A total of 15 photon beamlines are expected to be operational by early 1998.

2 BEAM INSTABILITIES AND CURES

Coherent beam oscillations due to transverse coupled-bunch instabilities have been observed since the commissioning of the storage ring. Up until 1995, these instabilities were suppressed by increasing the sextupole-magnet strengths to provide large positive chromaticities. Unfortunately, this method of beam stabilization had two serious drawbacks. First, variations in the filling pattern required changes in the sextupole strengths and thereby led to orbit changes of up to 100 μm. Second, the high sextupole-magnet strengths reduced the dynamic aperture and the beam lifetime.

In October of 1995, a transverse feedback system was put into operation [1]. This broadband, bunch-by-bunch transverse feedback system consists of transverse-oscillation detectors, notch filters, baseband quadrature processing circuitry, power amplifiers, and kickers. It successfully controls a large number of transverse coupled-bunch modes, and the orbit stability and beam lifetime have been improved by operating at (constant) lower sextupole-magnet strengths.

The transverse beam instabilities can be observed using a synchrotron-radiation profile monitor. When the transverse feedback system is turned on, the beam is seen to be stabilized, and its effective vertical size is reduced to less than 100 μm. Reducing the beam size in this way results in a shorter beam lifetime, showing the importance of Touschek scattering in the TLS.

Longitudinal instabilities have also been observed. For now, the dangerous higher-order modes are reduced or shifted away from the beam modes by tuning each cavity using an additional tuner and by using precision control of the cavity temperature. Also, a longitudinal feedback system is under construction and will be completed in 1998.

3 ORBIT STABILITY AND FEEDBACK SYSTEMS

An extremely stable electron beam must be provided at any third-generation synchrotron-light source, because electron-beam motion degrades the effective brightness of the photon beams. Sources of beam perturbations have been identified and suppressed at the Taiwan Light Source, so that at this time the electron beam is intrinsically very stable. The short-term beam motions are less than 5 μm, and the long-term beam drift is less than 20 μm. However, a significant remaining source of beam perturbations are the insertion devices, which create orbit changes when their magnetic gaps are adjusted.

A digital global feedback system (DGFB) has been developed to suppress orbit changes caused by insertion-device adjustments and by other low-frequency beam motions.[2] The beam-response matrix is experimentally measured, and this matrix is then used in making orbit corrections by the singular-value decomposition method. Eddy currents in the vacuum chamber limit the field penetration, so that the correction bandwidth is now 20 Hz horizontally and 80 Hz vertically. Operational experience with the DGFB system shows that orbit motions can be kept within ±10 μm, even during insertion-device gap changes.

The intrinsic beam stability is so good that a global feedback system may not always be needed. Under some operating conditions, a local feedback system may be able to suppress beam perturbations at their very sources. Such a local system is currently under development, and its hardware will be integrated with that of the global feedback system.

4 STORAGE-RING PARAMETER OPTIMIZATION

A careful program to study the actual tuning of the storage ring, followed by the correction of any residual errors found, can improve the performance of high-precision synchrotron light sources. With the collaboration of James Safranek of NSLS, the machine-error-finding program LOCO [3] was used experimentally to measure the linear optics of the TLS - and the BPM gain errors, as well. The rms variations in the quadrupole-magnet strengths, within each family of quads, was found to be only a few tenths of a percent. This result is in general agreement with the results of earlier magnetic measurements.

Figure 1 shows the measured betatron functions during 1.3-GeV operation with the sextupole magnets on. Horizontal offsets of the beam in the sextupoles cause focusing errors and a small "beta beat," about 4.5 percent horizontally and 8 percent vertically, measured beta distortion. We anticipate that the recently-installed independent power supplies for quadrupole-magnet pairs can be used to correct these minor lattice errors.

5 UPGRADE PLANS

The operation of the Taiwan Light Source has matured over the past few years. Accordingly, an increasing focus is being placed on machine upgrades and improvements, in contrast to routine operations. That is, more effort is being expended to improve the performance of the machine and to increase its reliability for user operations.

Planning for light-source upgrades is an ongoing process, involving physics studies, workshops, and engineering designs. By its very nature, it will evolve and be clarified over a period of time. Nevertheless, considerable effort has been expended in planning for machine and building upgrades, primarily for the next two or three years. A summary of this plan is as follows:

1997 plans:

- Digital global feedback loops.
- Noise suppression and upgrade of the "core" area.
- Design studies of a superconducting wiggler and a superconducting bend magnet.
- Upgrade of the RF laboratory.

1998 plans:

- Passive Landau cavity to increase bunch length and beam lifetime.
- Longitudinal feedback system.
- Local orbit feedback loops.
- Integration of injector controls with storage-ring controls.
- Start replacement of storage-ring gate valves with all-metal-seal gate valves.
- Utilities upgrades.

1999 plans:

- Increased laboratory and office space.
- A third RF system for the storage ring, to permit operation at up to 450 mA.
- Dedicated diagnostic photon beamline.
- Control system upgrades.

Other efforts to improve machine reliability include a program of failure analysis and a related spare-parts program. Furthermore, planned reorganizations will streamline the operation and maintenance of the TLS, in order to increase the overall efficiency of the accelerator effort.

6 CONCLUSIONS

During the past four years, the operation of the Taiwan Light Source has been significantly improved, in terms of beam energy, beam lifetime, and beam stability. Also, plans have been developed to further enhance the performance and reliability of this light source. These plans are designed to carry SRRC forward to significantly improved accelerator performance in support of an aggressive research program at the beginning of the next millennium.

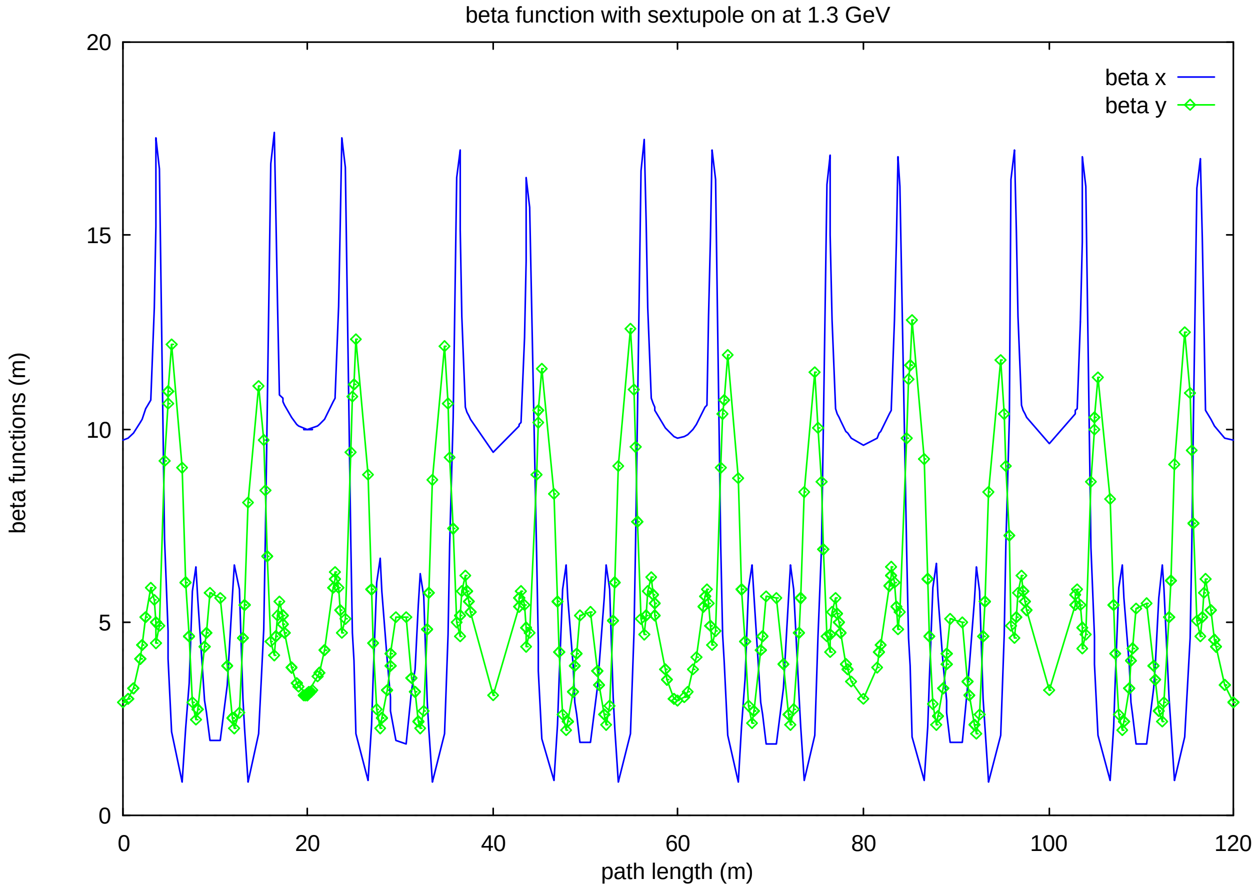

Figure 1: Measured betatron functions with sextupoles on at 1.3 GeV.

7 REFERENCES

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