OPERATIONS AND UPGRADES AT SRRC

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Abstract

The Synchrotron Radiation Research Center (SRRC) operates a third-generation synchrotron light source in Taiwan. Improvements in machine maintenance and operations over the past few years have greatly improved the reliability of the light source, from 89% in earlier years to 95% in the past two years. Accordingly, the focus of recent and planned machine upgrades is the improvement of beam stability for the benefit of the user community. The most troublesome beam instabilities arise from a number of sources, and they are being addressed in turn. Upgrades to the conventional utilities (cooling water, air conditioning, and electrical systems) and orbit feedback systems have already produced significant reductions in the orbit drift, and the implementation of full-energy (1.5 GeV) beam injection has improved the long-term stability. The remaining beam instabilities, over a wide range of frequencies, seem largely to be driven by the higher-order modes in the copper RF cavities. New machine upgrades, including a longitudinal feedback system and superconducting RF cavities, are intended to control and to cure these instabilities.

1 OPERATIONS

1.1 Reliability

Figure 1 shows the year-by-year operational reliability of the light source. The 95% reliability of the past two years represents a major improvement over that achieved in earlier years (around 89%). This improvement was achieved by implementing a general program of improved maintenance and by identifying and correcting unreliable subsystems. More specifically, in 1996 the injection system suffered many problems, so the technical staff was reorganized in order to make the entire accelerator team responsible for the injector, in contrast to the small, separate “Injection System Group,” that was formerly responsible. Radiofrequency system problems in 1997 were addressed by a number of equipment modifications, such as to the feedlines, that improved operational reliability.

1.2 Major Earthquake

On September 21, 1999, a major earthquake of magnitude 7.6 struck Central Taiwan. There was great loss of life and serious infrastructure damage near the epicenter in Nantou County; but SRRC, the institution and the staff, suffered minimal direct damage, in spite of the severe ground shaking in Hsinchu. That there was so little damage speaks very well of the reinforced-concrete building construction and the use of strong support stands for all accelerator components. It was also fortunate that the earthquake struck while the light source was in a shut-down mode.

For about a week after the earthquake, there was no electricity from the power grid and very little city water. However, the operation of the light source was restarted only a few days after all utilities were restored. When the storage ring was restarted, the peak changes in the closed orbit were found to be less than one millimeter horizontally and less than a few hundred micrometers vertically. After orbit correction, the residual rms orbit

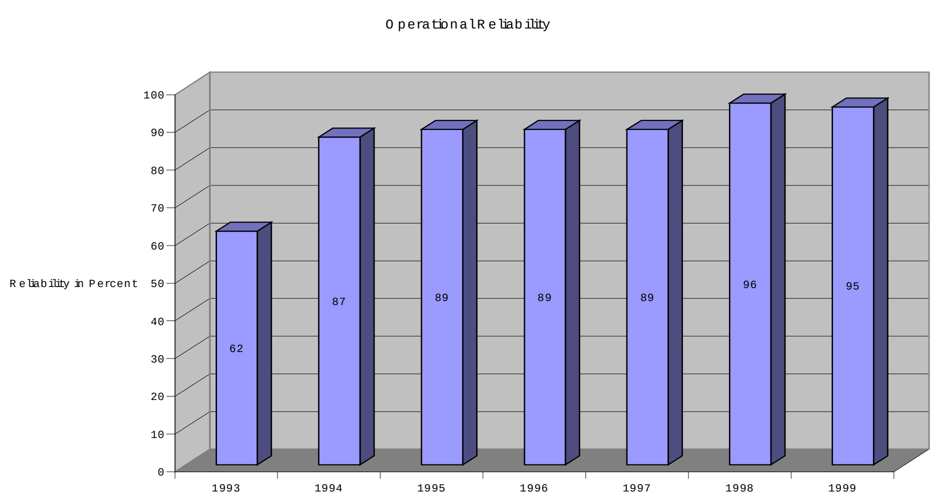

Figure 1: Operational Reliability.

distortions were 105 micrometers horizontally and 55 micrometers vertically. Consequently, the use of local orbit bumps was adequate to restore full operation to the light source.

2 MACHINE UPGRADES

2.1 Upgrade Priorities

The priorities for machine upgrades are the following:

- To improve machine reliability,
- To improve beam stability for the users, and
- To improve machine performance.

As the machine reliability has improved, more resources have been used to address beam stability and improved performance.

2.2 Utilities Upgrades and Orbit Feedback

Several years ago, it was observed that inadequate stability of the conventional utilities at SRRC caused uncontrollable drifts in the beam characteristics. In particular, changes of several degrees C in the temperatures of the cooling water and of the ambient air caused large drifts in the beam position. Over time, the utilities systems have been gradually upgraded, as budgets have permitted, so that the temperature drifts have been greatly reduced. At this time, water temperature is held constant to about $\pm$ 0.1 degrees; and air temperature, to about $\pm$ 0.2 degrees.

In addition, the implementation of orbit feedback systems has greatly reduced the orbit drift, as measured with the beam position monitors (BPMs). The remaining orbit drift is a few micrometers, to a few tens of micrometers, depending on whether the BPM reading is included in the orbit feedback loop.

2.3 1.5 GeV Injector Upgrade

Originally, the SRRC injection system was designed for full-energy injection into a 1.3-GeV storage ring. It consisted of a 50-MeV linac, a 1.3-GeV booster ring, and a 1.3-GeV beam transport line. For the past several years, since the upgrading of the storage ring for operation at 1.51 GeV, it has been necessary to ramp down the energy of the storage ring to 1.3 GeV during each beam-injection cycle. Unfortunately, these changes in storage-ring energy caused temperature changes, so that, after each injection cycle, about two hours were needed before the machine temperature entirely stabilized.

During 1999, the injection system was upgraded to provide full-energy injection, at 1.51 GeV. Many subsystem upgrades were required, including the upgrade of the booster-ring White circuit inductors, new booster magnet power supplies, replacement of transport-line quadrupole magnet coils, upgraded booster controls, and increased electrical power for the injector. The component installation was completed during the 1999-2000 winter shutdown, and the 1.5-GeV Injector Upgrade was successfully commissioned early this year.

2.4 Longitudinal Coupled-Bunch Instabilities

The most troublesome beam instabilities at SRRC are the longitudinal coupled-bunch instabilities. The higher-order modes (HOMs) of the radiofrequency cavities couple to beam modes to drive these instabilities at frequencies of many hundreds of MHz. Unfortunately, at SRRC this problem cannot be solved entirely by adjusting the cavity-tuner positions and cavity cooling-water temperatures. The light-source users are normally unable to detect the presence of these instabilities at hundreds of MHz. However, fluctuations or changes in these instabilities, at frequencies of a few Hz to 100 Hz, cause photon-beam instabilities that are a serious problem for the users. The next three sections all discuss methods to address these instabilities.

During 1999, some very slow, very annoying beam fluctuations – with periods of up to five minutes – were observed. It seems that these particular beam instabilities were associated with the presence in the ring of the prototype third-harmonic (Landau) cavity, which was removed during the last winter shutdown.

2.5 RF Modulation

Voltage modulation of the 500-MHz RF signal, at about twice the synchrotron frequency, can be used to control the longitudinal coupled-bunch instabilities. The beam bunch splits into three beamlets that move independently in longitudinal phase space, and the increased synchrotron tune spread and the enhanced Landau damping can suppress these longitudinal coupled-bunch instabilities.

At this time, voltage modulation of the RF is used on a routine basis to control these beam instabilities.

2.6 Longitudinal Feedback System

A bunch-by-bunch longitudinal feedback system has been under construction. Some innovative solutions incorporated in the design include the following:

- 500 Mbytes/sec fast digital signal processing electronics (commercially available signal processing chips, specially designed ADC/DEMUX and DAC/MUX circuits),
- 1.0 – 1.25 GHz broadband RF system that kicks individual bunches every 2 nanoseconds, and
- A longitudinal kicker that is fast and efficient.

The fast DAC/MUX circuit has required a redesign and has been delayed, but it has recently been completed and installed in the machine. Earlier tests of the feedback system in the single-bunch mode have clearly demonstrated successful damping of longitudinal oscillations of single bunches. Multi-bunch tests of the longitudinal feedback system are now under way.

2.7 500 mA Upgrade Project (SRF)

The "500 mA Upgrade Project" is an ambitious machine-upgrade project with the following goals:

- To provide photon beams with significantly better stability, and
- To store up to 500 mA of electron beam, while maintaining the current beam lifetime.

The major components of this upgrade include new RF cavities with reduced HOMs to provide improved beam stability and with the capability to store 500 mA of beam current, increased RF power to accommodate high beam current, and third-harmonic (Landau) cavities to increase bunch lengths. Early in 1999, SRRC selected a RF cavity design, namely the Cornell superconducting RF (SRF) cavity designed for use at CESR.[1] The pure niobium material for two cavities (including one spare) has been purchased, and this year a purchase contract was signed for two crymodules (i.e., SRF cavities plus cryostats) and associated equipment and services. Work on the procurement of the cryogenics plant is proceeding.

Figure 2 shows a cryomodule of the Cornell design.

REFERENCES

[1] S. Belomestnykh, et. al., "Development of Superconducting RF for CESR", PAC'97, Vancouver, May 1997, p.3075.

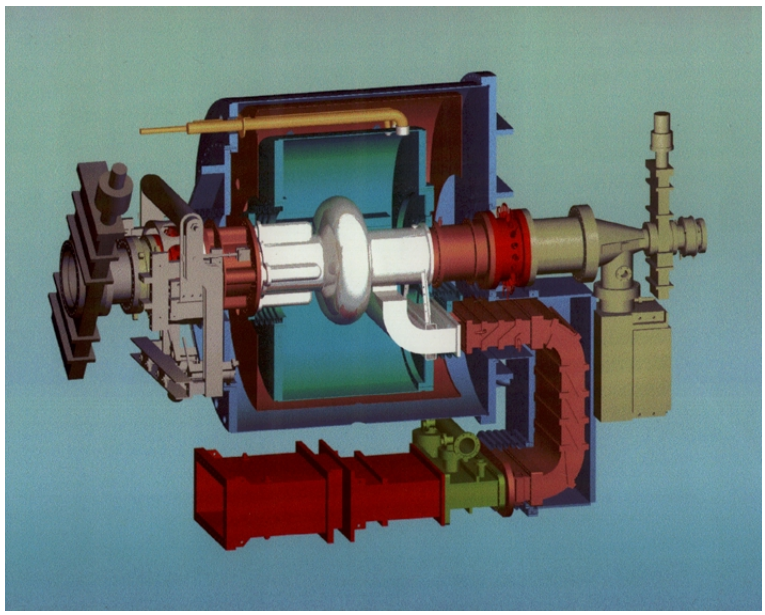

Figure 2: Cryomodule