

Operational Experience of the CAMD Accelerators

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Abstract

The synchrotron light source at Louisiana State University has been operating as an x-ray producing facility for over a year. There are four active beamlines, five in various stages of installation, and at least two more committed. The synchrotron currently operates on two eight-hour shifts, five days per week. One shift per day is devoted to providing light to the beamlines. The other shift is being used for machine studies, maintenance, and upgrade work. The synchrotron operates at a nominal energy of 1.3 GeV, but is capable of up to 1.5 GeV. A 200 MeV linac serves as the injector for the storage ring. The maximum current stored has been 311 mA at 1.3 GeV. We will discuss the current operational status of the linac and storage ring and discuss our experiences with the machines during our first year of operations.

1. INTRODUCTION

The Louisiana State University's Center for Advanced Microstructures and Devices (CAMD) storage ring [1] has been routinely providing synchrotron light for one and one-half years now. The university took control of the accelerator from the Brobeck Division of Maxwell Laboratories, (the company that designed, built and performed the initial commissioning), almost two years ago. The synchrotron was designed to operate nominally at 1.2 GeV with 400 mA of beam current or at 1.4 GeV with 200 mA, using a 200 MeV linac as its injector. Presently, the synchrotron operates at a nominal voltage of 1.3 GeV with a typical current of 110 mA. The injector runs routinely at 180 MeV, and can put out in excess of 20 mA over a 200 ns pulse. The linac can also operate in a single bunch mode, filling a single bucket in the ring. Operating the linac at 1 Hz, the ring can be filled with 300 mA of beam current in less than 30 seconds. The electrons are ramped from 0.2 to 1.3 GeV in about 10 seconds. The maximum current achieved at 1.3 GeV has been 311 mA. This represents a synchrotron radiation output power in excess of the 25 kW design power. The maximum injected current is 330 mA. A present operational current limit of 120 mA is self-imposed due to a problem with the dipole chambers that will be discussed later along with other operational aspects. Operation of the storage ring at 1.5 GeV has been

tested and shown to be feasible. Much work has also been devoted to improving the resolution of the beam position monitor system and implementing improved orbit correction algorithms.

2. OPERATIONS

The storage ring is currently being run on a schedule of eight hours of user beam available per day, five days per week. From beginning of 1994 to end of May 1994, the ring has been up 96% of the scheduled 753 hours of user time. There are typically two injections per eight hour shift, although the lifetime of the beam (defined as the actual amount of time it takes 100 mA of beam current to decay to 50 mA) is about eight hours. A plot of the beam current and vacuum for a typical shift is shown in Figure 1.

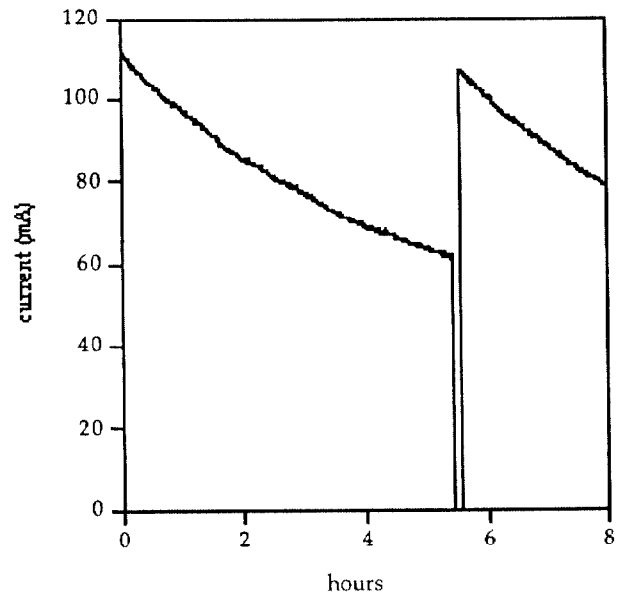


Figure 1. Typical shift of user beam.

To obtain a high injected current the ring must be operated close to the main betatron difference resonance to achieve a large horizontal to vertical coupling and therefore a larger vertical beam size. This contrasts with previous operational experience, where the vertical blowup occurred away from the main difference resonance and was attributed to the

presence of ions [2]. That effect seems to have disappeared following some planned vacuum work, and the previous operating point, which had been very stable and easy to ramp from, proved to be very temperamental. The present injection operating point is near 1.224 vertical and 3.248 horizontal but is very difficult to measure due to the presence of synchrotron sidebands on the betatron sidebands which overlap each other. After finding the new working point we were once again able to inject in excess of 300 mA.

In the process of increasing the stored current, an accident happened in which an RF shield bar in one of the bending magnet chambers got too hot and bent partially into the slot allowed for the synchrotron light to pass through. The major external symptom was a sudden large increase in the vacuum pressure due to the RF bar outgassing after it bent into the direct path of the synchrotron radiation and heated up significantly. The chamber did get warm to the touch, but by the time the heat reaches the outside of the chamber the damage has already occurred. There do not seem to be any direct warning signs before the RF bar bends. This was the second incident in which this happened. The first time an RF bar bent, the cause was misdiagnosed as mechanical stress being relieved. It was going to be repaired at our leisure since we could steer the beam around the shield through the gap that was left. The second bent bar could also be steered around, but has since been replaced with a test chamber that has no synchrotron light ports. To avoid a third failure, the beam current is being limited to around 110 mA. Meanwhile we have started an effort to design a retrofit for the existing dipole chambers that will enable the RF shields to absorb the full synchrotron power. Simulations show that as little as 200 W along the entire bar can cause significant bending. The solutions being looked into include water cooling and various schemes that will let the bar get hot, but will avoid having it bend down into the light gap.

3. IMPROVEMENTS

With our extremely small staff, all work on upgrades must be very carefully considered and takes a back seat to keeping the accelerator running (the operations group of five people is also the controls group, the linac group, the RF group, and the electronics group). Several things have been accomplished or are being worked on however. Among these are an improved BPM system, orbit correction algorithms, improved vacuum pressure monitoring, control system enhancements, and operation at 1.5 GeV.

Operating the storage ring at as high an energy as possible is desirable for the micromachining research being pursued at CAMD and for some of the other applications being pursued here. The primary energy limitation is the dipole magnet power supply, which can provide enough current to push the magnets

to allow a maximum energy of 1.55 GeV. This corresponds to 1.8 Tesla in the magnets, 1.5 GeV corresponds to a field strength of 1.75 T. The main obstacles to achieving 1.5 GeV were the cooling for the coil packs and voltage limitations on the defocussing quadrupole power supply, both of which were fairly easy to overcome. To overcome the heating problem, we increased the cooling capacity of the heat exchanger. Because of the quadrupole limitation, the vertical tune at 1.5 GeV is much lower at 1.07. The lifetime at 55 mA was around 3 hrs. No efforts were made to improve this.

Much effort has been devoted to the BPM systems, resulting in much improved performance. The system consists of 16 stations of four buttons each. Each button is multiplexed into the processing electronics whose output is directed to a 16-bit analog-digital converter. The processing electronics consists of a 500 MHz bandpass filter, an input amplifier, a variable attenuator, more amplification, a diode detector, and a little DC amplification. The resolution is limited by the noise level which has been reduced to a typical maximum value of $\pm 30 \mu\text{m}$ and an rms value of less than $20 \mu\text{m}$. We believe these numbers can be improved even a little bit more. The reduction in the noise has enabled us to begin orbit studies, where as previously much of the beam motion was masked by the noise.

We can presently correct the orbit to $150 \mu\text{m}$ horizontally and $100 \mu\text{m}$ vertically from store to store. The limitations on the correction have not been studied yet, but the potential for BPM motion relative to the magnets does exist. The absolute orbit in the ring has no meaning since the button station positions are unknown and the buttons are not calibrated. A calibration of the stations was done by finding the center of the quadrupoles. The algorithm used to do this entailed iteratively correcting the orbit as the tune was moved toward the integer resonance. This worked quite well in decoupling the orbit from changes made in the quadrupole currents, indicating the orbit is close to the magnetic centers of the focussing and defocussing quadrupoles. Figures 2 and 3 show the effect on the orbit of changing the quadrupole strengths both before and after centering the orbit. Figure 2 shows the horizontal orbit differences that occur when the focussing quadrupoles are increased by 0.5 A. Figure 3 shows the vertical orbit differences present when the defocussing quads are decreased by 0.5 A. The horizontal correction proved more difficult to achieve and is not quite as good as the vertical. The reasons for this are that the horizontal tune must cross more resonances, resulting in beam loss, and the horizontal orbit became impossible to correct with our present orbit correction program so that the resonance could not be approached as closely as the vertical one could.

A slow orbit drift with time was also observed.

The measurements showed that like most other rings a thermal drift is present when the machine is started cold. The orbit drifts by 0.3 to 0.4 mm over the course of about two hours when started up after a long period off. Even the small amount of time between consecutive stores is enough to allow the ring to cool slightly. A new fill after the ring has already been running approaches equilibrium in about one-half hour after a noticeable drift. After the initial drift the orbit appears relatively stable, although no longer term (> 3 hrs) studies have been performed yet.

4. SUMMARY

The CAMD synchrotron light source has been providing light for 1.5 years. Its maximum current to date is 311 mA at 1.3 GeV. Its operating voltage has been extended to 1.5 GeV. The BPM system has been improved, with a typical noise level of $\pm 30 \mu\text{m}$. A major problem has arisen with the dipole vacuum chambers, in which one of the RF shield bars in two of the chambers has deformed into the gap allowed for the passage of the synchrotron light. Due to this we are limiting the current to around 110 mA to avoid a third occurrence while a solution is being developed.

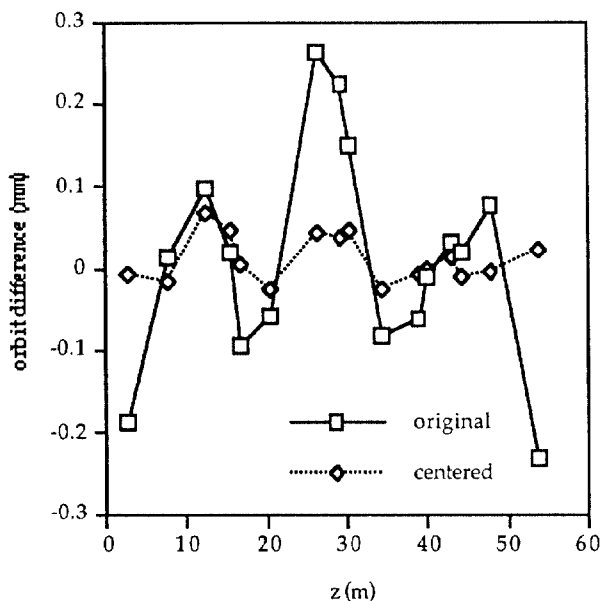


Figure 2. Horizontal orbit difference from the reference when the focussing quads are increased by 0.5 A for both the original orbit and the centered orbit.

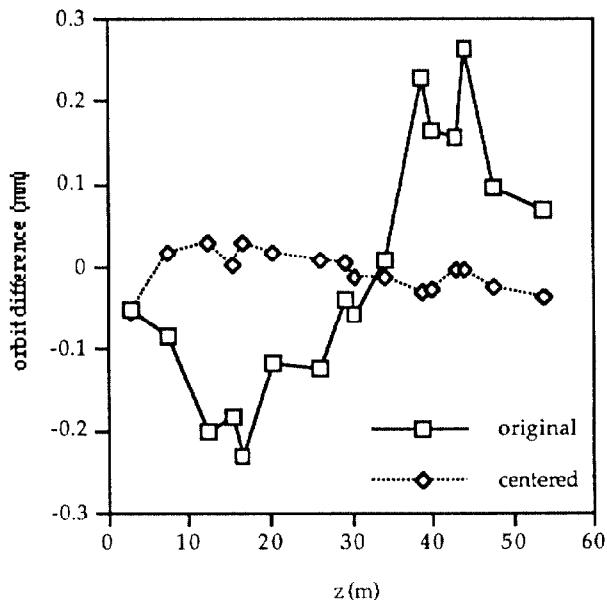


Figure 3. Vertical orbit difference from the reference when the defocussing quads are increased by 0.5 A for both the original orbit and the centered orbit.

5. REFERENCES

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