

AN OPTIC WITH SMALL VERTICAL BETA FUNCTION FOR THE CAMD LIGHT SOURCE

VP Suller, P Jines, D Launey, T Miller, S Wang*, Y Wang
 LSU-CAMD, 6980 Jefferson Hwy, Baton Rouge, LA 70806, U.S.A.
 *IFP, China Academy of Engineering Physics, Mianyang, 621900 China

Abstract

At the CAMD Light Source a new optic has been developed for the lattice having small vertical beta function in each of the 4 long straight sections. This optic will be necessary to operate the multipole wigglers with small vertical apertures which are planned to be installed in the near future. Results are presented of the tests which have been made with this optic, particularly in the critical area of injection, which is made at low energy. The lattice functions have been characterized using LOCO software and the reduced vertical aperture confirmed with an adjustable scraper.

INTRODUCTION

The CAMD light source [1] is planning for new insertion devices (IDs) to facilitate its research program in a broad range of science. These IDs include Multi Pole Wigglers (MPWs) for the x-ray region [2] and an elliptical polarized undulator (EPU) for the Vacuum Ultra Violet (VUV). For optimum performance with any of these IDs it will be necessary to employ a relatively small vertical gap.

In its standard operating mode the storage ring has a vertical aperture of 32 mm in the long straight sections, which would be too large for the new IDs under consideration. For these an aperture of 20 or 10 mm will be needed and to permit this reduction to be made whilst still achieving high injected beam currents a new lattice optic has been developed.

LATTICE OPTIC

The CAMD storage ring is a 4 cell Chasman-Green lattice with nominally zero dispersion in the 4 straights which have approximately 2.8 m free space. The working energy of the ring is 1.3 GeV which is obtained by ramping the ring from the injection energy 180 MeV. A beam current of typically 250 mA is achieved. Although at injection the lattice is set for zero dispersion in the long straights, at the working energy finite dispersion is set, which reduces the horizontal beam emittance to 150 nm.rad from 300 nm.rad. The lattice functions of one cell are shown in figure 1.

A superconducting wavelength shifter with a field of 7 Tesla has been in regular use since 2002 [3] and to maximize the flux density from this source the lattice quadrupoles are adjusted to modulate the beta function after ramping the energy. The vertical beta function at the center of the long straight where the wiggler is located is thereby reduced to 0.6 m [4]. However, injection cannot be made into this lattice configuration.

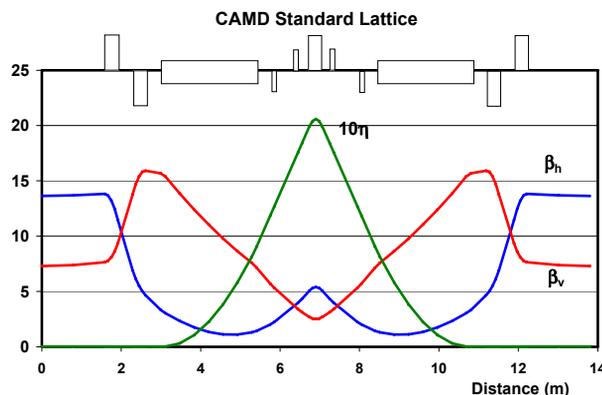


Figure 1. The lattice functions of the CAMD storage ring in standard operating mode.

INJECTION APERTURE

Injection into CAMD is made from a linac at an energy of 180 MeV and at such a low energy there are significant drawbacks. The beam lifetime is short unless the beam size is large and for this reason successful injection of beam currents of several hundred mA can only be achieved when the ring is tuned onto a coupling resonance. The betatron tunes used are approximately 3.23 horizontal and 1.23 vertical, which is on the coupling resonance $Q_h - Q_v = 2$. When this is done the transient kicks during the horizontal injection process are coupled into the vertical, which gives the required large beam size. The radiation damping time at injection is several seconds, compared with the injection repetition rate of 1 Hz.

The vertical beam aperture scales as the square root of the vertical beta function and the limiting locations in the CAMD ring are at the end of the dipoles (50 mm, betav 15.6) and the straight containing the wiggler (32.5 mm, betav 7.5). Since it is not possible to modify the aperture in the dipoles, to permit ID apertures of 20 mm and 10 mm the vertical beta must be reduced to 2.5 and 0.6 respectively. To achieve this, a new lattice optic is necessary.

NEW LATTICE OPTIC

The new configuration of the lattice is shown in figure 2. It can be seen that the vertical beta function is significantly reduced in the long straight, but otherwise the lattice functions are very similar to the normal lattice. The other difference is that the vertical betatron tune is increased to approximately 2.23. The horizontal tune remains at 3.23 so that the required coupling resonance for injection optimization is now $Q_h - Q_v = 1$.

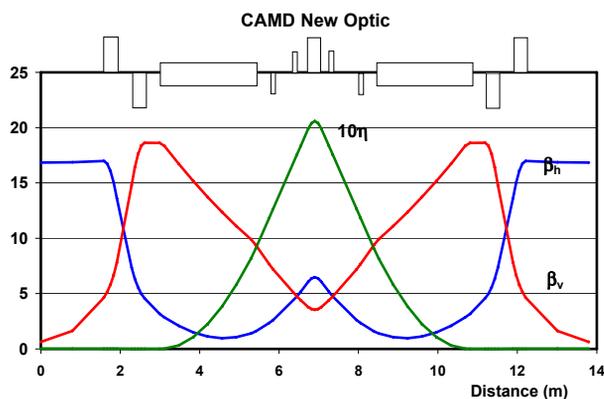


Figure 2. Lattice functions of the new optic giving small vertical beta function in the long straight section.

The other lattice parameters such as emittance, momentum compaction, damping times, etc, are very similar to the standard optic but the negative natural chromaticity is about 35% increased and needs higher sextupole currents to correct. This is well within the rating of the magnets and power supplies.

TESTS WITH THE NEW OPTIC

Injection

The new optic has been extensively tested during accelerator studies time over the last 18 months. Although the ring parameters have not been highly optimized it has been demonstrated that over 200 mA can be injected, which is very comparable with standard operations. If injection settings are kept identical to those for standard operation a decrease in injection rate of about 15% is observed, but the rate can be restored by adjusting the match of the injection transport line into the ring.

Due to the increased vertical betatron tune there is an increased current required for some of the quadrupole power supplies, which exceeds their ratings. For this reason the maximum energy to which the beam can be ramped is presently limited to 1.0 GeV. Ramped beam current is in the range 100 – 200 mA. Once new power supplies have been installed it is confidently expected that the energy will be able to be ramped with the new optic without problem to 1.3 GeV.

The tune space in the range Q_h 3.0–3.5 and Q_v 2.0–2.5 has been explored and many locations have been identified where it is possible to inject high currents, but as expected all are on some form of coupling resonance (for example $2Q_h - Q_v = 4$). The most consistent performance is obtained by locating the tunes near the main coupling resonance $Q_h - Q_v = 1$.

Evaluation of Lattice Functions

The lattice functions have been evaluated using the LOCO [5] software. At 1.0 GeV the sextupoles can be switched off and over 100 mA beam retained, and with the beam orbit corrected to better than 0.5 mm rms in both

planes the software collects the necessary data in less than 10 minutes. The lattice functions calculated from the LOCO data for the complete ring are shown in figure 3 and show some slight non-uniformity in the beta functions, probably due to errors in the calibration of the quadrupole power supplies. LOCO also provides calibrations of the different quadrupole power supply families and these have been found to agree with the calibrations obtained by other techniques to a few parts in 10^3 .

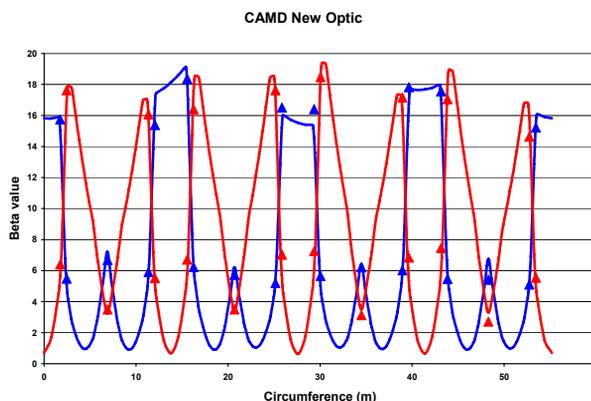


Figure 3. Solid lines show beta values for the New Optic as measured by LOCO at 1.0 GeV; blue is horizontal, red is vertical. The points show the betas measured by current shunts on each individual quadrupole.

Figure 3 also shows the beta values measured at the location of each of the ring quadrupoles by using the current shunt circuits [6] which are fitted to each individual quadrupole. It is seen that there is excellent agreement between the beta values provided by LOCO and those measured with the shunts. There is also excellent agreement in the horizontal dispersion function between LOCO measurement and that calculated using the quadrupole calibration factors.

Vertical Aperture

The vertical aperture required for injection in the long straight sections has been measured using a pair of individually controlled scraper blades. An initial measurement was made with the scraper located near one end of straight section number 4 at 1.16 m from the center, and at a later date a second measurement was made with the scraper centrally placed in straight section number 2. The tests were made by measuring the injection rate as a function of scraper position for both the standard and the new optic. The results are shown in figures 4 and 5.

It can be seen in figures 4 & 5 that the injection vertical aperture is, as expected, much less for the new optic. For the case of figure 5, where the scraper was at the straight center (which is where the vertical beta is minimum), the new optic requires 9 mm full vertical aperture compared with 22 mm for the standard lattice.

For the standard lattice the expected aperture at the long straight center is 34 mm, assuming that the aperture is filled at the main limitation point at the end of the dipoles. The measured 22 mm shows either that the beam does not fill the vertical aperture or that at some point around the circumference there is a vertical closed orbit error which effectively reduces the available aperture.

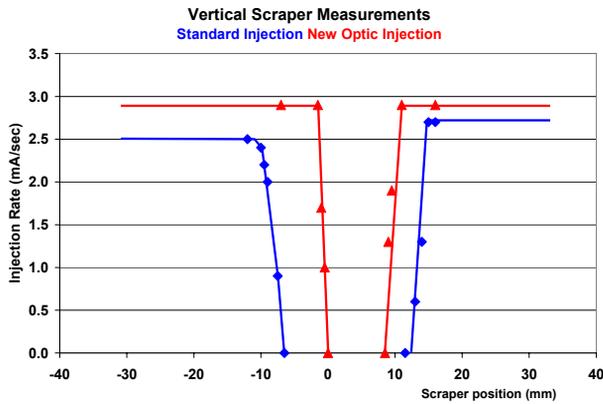


Figure 4. Scrapper results with the scrapper 1.16 m from the center of straight number 4.

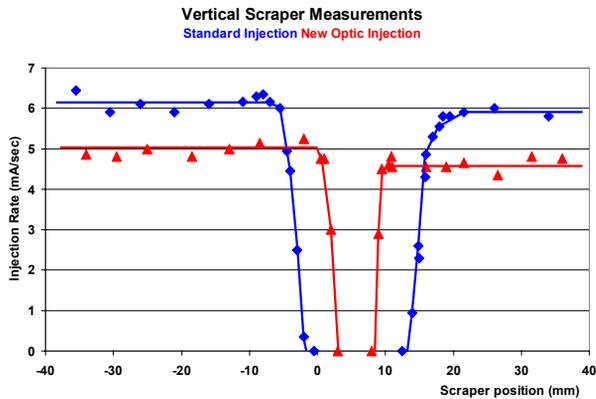


Figure 5. Scrapper results with the scrapper at the center of long straight number 2.

The vertical injection apertures for the new optic were measured as 9 mm at the straight center and 12.5 mm 1.6 m from the center. The straight center result is as expected from the beta value scaling, but again the result near the straight end would indicate that the aperture is smaller than expected.

The survey reference position of the scrapper at the straight center was checked by closing the jaws with a stored beam at 1.0 GeV and with the vertical orbit precisely aligned with respect to the magnetic centers of the straight quadrupoles. The jaws could be closed to a gap smaller than +/- 1 mm before the beam was lost and that was at a position of 6.5 mm. This probably indicates an imprecise alignment of the scrapper and vacuum chamber by that amount.

DISCUSSION

The new optic with reduced vertical beta function in the long straights has been successfully demonstrated. Injection of 200 mA has been achieved and the match of the injection transport line into the ring does not appear to be critical. A suitable betatron tune point has been established on or close to the main coupling resonance so that the beam size at low energy is enhanced.

The LOCO software has been very useful in confirming that the new optic lattice functions are as predicted and further confirmation has been obtained by the technique of current shunts on the ring quadrupoles. The lattice functions of the new optic are well behaved and the beam dynamic behavior of the ring appears to be the same as the standard optic.

Measurements of the required vertical aperture for injection in the long straights using an adjustable beam scrapper have shown that the aperture used is somewhat less than would be expected if the maximum available was being filled. This is the case for both the standard and the new optic. Therefore new IDs with vertical apertures of 10 mm for a 1.0 m long device or 20 mm for a 2.3 m long device can be confidently planned.

REFERENCES

- [1] VP Suller et al; "Status of the CAMD Light Source", Proceedings of the 2005 US Particle Accelerator Conference, pp3103-3105(2005).
- [2] VP Suller et al; "A Proposed Multipole Wiggler for CAMD", Proceedings of the 2007 US Particle Accelerator Conference, pp1161-1163(2007).
- [3] VM Borovikov et al; "Superconducting 7 Tesla Wiggler for LSU CAMD", Journal of Synchrotron Radiation, vol 5, part 3, pp440-442(1998).
- [4] M Fedurin et al; "CAMD Low Beta Configuration for the 7 Tesla Wiggler", Proceedings of the 2003 US Particle Accelerator Conference, pp1053-1055(2003)
- [5] J Safranek et al; "MATLAB-BASED LOCO", Proceedings of the 2002 European Particle Accelerator Conference, pp1184-1186(2002).
- [6] VP Suller et al; "A Beam Based Alignment System at the CAMD Light Source", Proceedings of the 2004 European Particle Accelerator Conference, pp2427-2429(2004).