STATUS OF THE CAMD LIGHT SOURCE

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Abstract

In parallel with the increasing diversity of its research program, the CAMD Light Source has improved its beam brightness and quality. Using a well calibrated model of the lattice, the ring optic has been refined to generate a lower beam emittance of 150 nm.rad and this has been confirmed by measuring the beta values with the modulated quadrupole shunt system. The beam sizes have also been measured with an X-ray pinhole camera and compared to the calculated emittance. The beam orbit is corrected to a standard position referenced to the quadrupole centers to a precision better than 0.5 mm, using a suite of well localized bumps which can also flexibly steer the user photon beams to their requirements. Beam reliability has been improved by bringing into use a VME control system for the energy ramp.

INTRODUCTION

The Center for Advanced Microstructures and Devices (CAMD) was originally conceived as a light source catering mainly for lithography and related applications. There was consequently little requirement for high beam brightness in the 4 cell Chasman-Green lattice, which was designed for an emittance of about 200 nm rad [1]. The main parameters are given in Table 1.

With the growth in the Facility's research program over the last several years, and in particular following the commissioning of a 7 T wiggler [2], a demand has arisen for both higher flux density and beam brightness. The flux density was increased by changing the optic to give a significantly reduced vertical beta value [3] at the wiggler source point. Only recently has the use of an active quadrupole shunt system allowed the lattice to be studied in enough detail to permit optimization of the brightness.

In conjunction with higher brightness it is obviously necessary to provide reliable beam orbit correction and beam intensity (current) and both of these issues have been addressed. The orbit is now corrected with reference to the beam based orbit via the quadrupole centers. The reliability of maintaining the beam current in the energy ramp has been improved by changing to a VME based control.

ACTIVE QUADRUPOLE SHUNTS

A system of active shunts for each storage ring quadrupole was installed on CAMD in 2004 [4]. Each shunt can bypass up to 10 Amps and either DC or AC with selectable frequency may be used. The AC mode permits the electron beam position monitors to have their centers calibrated with respect to the center of an adjacent shunted quadrupole. The DC mode is used to determine the betatron functions at each quadrupole by measuring the tune shift resulting from a given shunt current. This has been of great value in aiding an understanding of the lattice behavior.

LATTICE FUNCTIONS

An example of the betatron functions as measured with the quadrupole shunts is given in figure 1. The functions are measured to a precision of ±0.7 m, which is determined by the accuracy with which the tune shift can be measured, and is represented by the error bars on the data points. It is apparent that there is reasonably good agreement between the measured values and the model of the lattice which is based on calibrated data. However, for getting the best possible performance from the storage ring it would be beneficial to obtain better agreement and studies are continuing towards that goal.

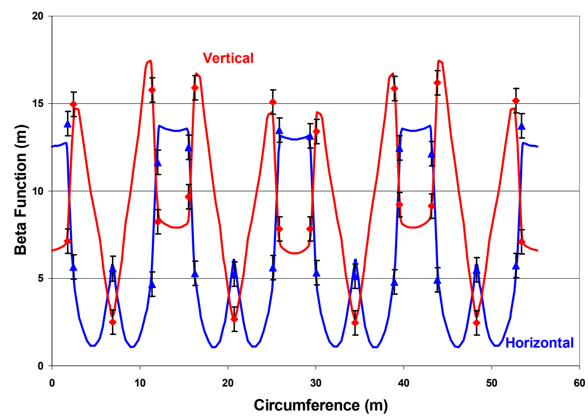

Figure 1: Measured beta functions, shown by the data points, for the basic lattice in its fully symmetric mode with the wiggler off. The solid lines are computed from the lattice model.

LATTICE MODEL

The model of the lattice has been developed to assist in understanding the measured behavior of the storage ring and to improve its performance. The model uses the best available calibration data for the storage ring magnets and aims to obtain agreement between the calculated and measured properties starting from the observed magnet currents set by the control system.

Important parameters which are imprecisely known are the effective gradient lengths of the quadrupoles and the effective lengths and poleface angles of the dipoles. Best agreement between the predicted and measured betatron tune values, for several different settings of the lattice, has been obtained by setting in the model an effective quadrupole length of 0.323 m (compared to 0.332 m which would be expected if the quadrupole steel had infinite permeability); and giving the dipoles fringe fields

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of half the central 1.48 T extending for a half gap at each end. The effective poleface angle of the fringe field is set at 20.5^{0} (compared to 22.5^{0} physical).

It is also necessary to include the 7 T wiggler in the model, and this is based on hard edged rectangular poles which have first and second field integrals in accordance with the values measured in the real wiggler. Figure 2 shows the measured and computed lattice functions for the lattice optic which gives a small vertical beta value at the wiggler with the wiggler operating at 7 T. It is seen that there is reasonable agreement in the horizontal between the measurements and predictions, but there are discrepancies in the vertical plane. These may be due to gradient components which the central pole is believed to contain at 7 T, although this has not yet been measured.

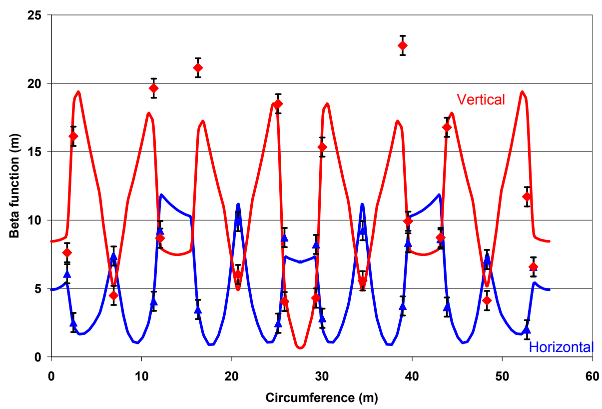

Figure 2: Measured beta functions for the small beta optic with the wiggler at 7 T. The wiggler location is at the center of the diagram.

An unexpected result of working with the lattice model was that the predicted horizontal beam emittance for the small beta optic was found to be larger than expected at 450 nm rad. This was due to a mismatched dispersion function, which was larger than desired. A study was then made to derive an optic which would have a significantly lower emittance, but retain the small beta at the wiggler.

A new low emittance optic was found which retained the required beta functions and tune values with a significantly improved emittance of 150 nm rad. This optic was tested and measured and has been the standard operating mode for CAMD since November 2004. The measured and predicted lattice functions are shown in figure 3.

Figure 3 shows again quite good agreement between prediction and measurement in the horizontal plane, but discrepancies in the vertical similar in size to figure 2 probably due to errors in the wiggler model. Therefore, to confirm that the model was correctly predicting a reduced emittance, it was felt that measurements of the beam size were highly desirable.

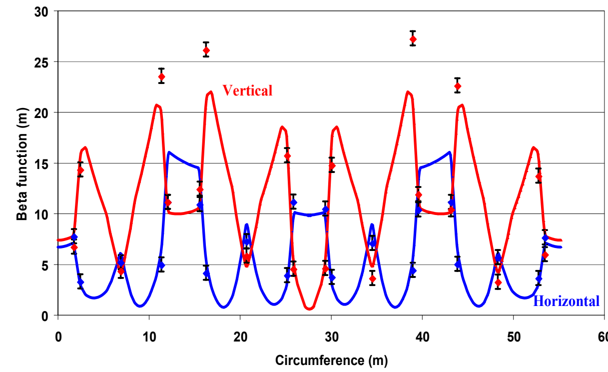

Figure 3: Measured and predicted beta functions for the new low emittance optic, including the 7 T wiggler.

BEAM SIZE MEASUREMENT

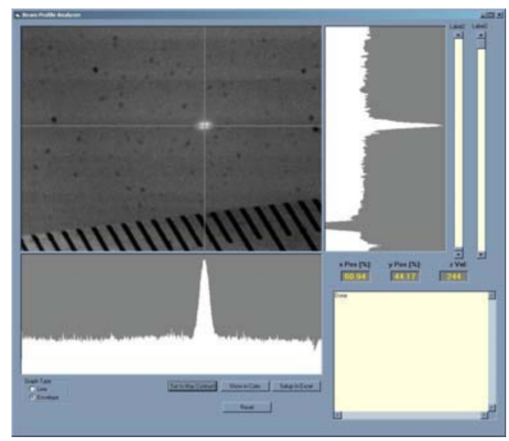

Figure 4: X-ray pinhole image with small beta optic and wiggler at 7 T.

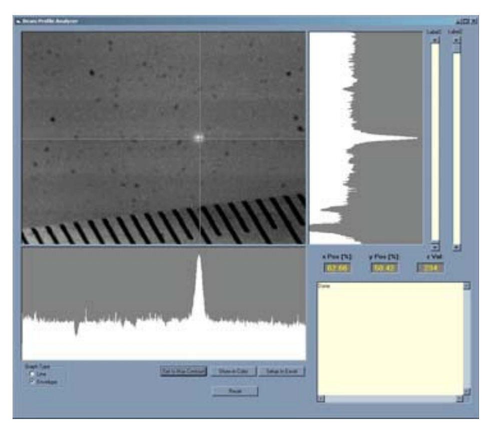

Figure 5: X-ray pinhole image with new optic and wiggler at 7 T.

To confirm that the expected reduction in horizontal emittance had been achieved, a temporary X-ray pinhole camera was set up using a beam line normally dedicated to lithography. The positions available for locating the pinhole and the fluorescent screen were unfortunately not very favorable for an accurate measurement. The source point to pinhole distance was 7.9 m and the pinhole to screen distance 1.3 m, giving a demagnification ratio of 6. The pinhole system images obtained with the original and new optics are seen in figures 4 & 5.

The horizontal beam sizes (sigma value) for the small beta and new optics are calculated to be 0.91 and 0.49 mm respectively. The image sizes (± 2 sigma) calculated for the pinhole camera set up as described, taking account of the blurring due to the 0.1 mm pinhole diameter, are 0.61 and 0.34 mm. Diffraction by this size pinhole is negligible. From figures 4&5 it is seen that the observed images are in reasonable agreement with the predictions and suggest that the expected reduction in beam emittance has been achieved. A dedicated X-ray pinhole camera with optimized geometry has been designed and will be installed later in 2005.

ORBIT CORRECTION

The active quadrupole shunts can be excited with a time varying current at a selectable frequency which is typically a few Hertz. By using localized orbit bumps [4] to position the beam at the shunted quadrupole for minimum perturbation of the beam orbit, the center of an electron beam position monitor adjacent to the quadrupole can be referenced to its centre. The measured orbit can be quickly adjusted to the calibrated EBPM centers using the local bumps, after which an SVD algorithm makes the final improvement and minimizes the corrector strengths. Figure 6 shows a corrected orbit for the new low emittance optic produced using this technique. The residual distortions seen in figure 6 are due to relative misalignments between closely located quadrupoles and to EBPM faults.

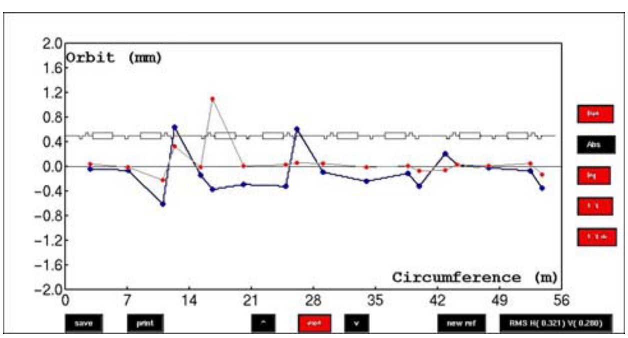

Figure 6: Corrected orbit referenced to the quadrupole centers for the low emittance optic. The horizontal (blue) rms is 0.32 mm, the vertical (red) rms is 0.28 mm.

ENERGY RAMPING

The beam injection energy at CAMD is nominally 200 MeV but in practice is operated at 180 MeV to reduce the stress on the linac modulators. At this low energy the beam is relatively unstable and has short lifetime, so it is important to ramp the energy quickly and accurately to avoid loss of beam current.

The original system for ramping the storage ring was based on CAMAC. Much of the data needed to control the ring systems during the ramp, magnets, RF, etc., was generated by the control computers before being sent to the LIST processor which directed the CAMAC interface to the power supplies. Whilst this was reasonably effective, the number of intermediate points in the ramp was limited and there was minimum capability for control feedback or diagnostics. The basic energy ramp was accomplished in 45 sec, with an additional 90 sec for energizing the wiggler to 7 T.

The ramp, power supply control and associated applications and diagnostics have now been converted to VME using RTEMS under EPICS. For flexibility the ramp tables are still generated by the control computers. The ramp is executed by VME, but now has greatly enhanced flexibility in ramp table size, software selectable speed and during-ramp diagnostics. Power supply diagnostic information is available in real time and is archived. Comprehensive post ramp analysis utilities are also now available. This system has been used to detect deficiencies in two quadrupole power supplies and justify their replacement. Planned enhancements are real time orbit and tune measurements during the ramp, and adaptive ramp control based on power supply response, tune and orbit. A similar VME setup is being used for RF diagnostics and control at CAMD [5].

Table 1. The main parameters of CAMD

Energy (GeV)	1.3 (1.5)
Beam Current (mA)	250
Circumference (m)	55.2
Horizontal emittance (nm.rad)	175
Number of cells	4
Betatron tune (horiz; vert)	3.23; 1.16
Natural chromaticity (horiz; vert)	-3.7; -6.3
Length of straights (m)	3.2
Dipole field (T)	1.48 (1.71)
Radio frequency (MHz)	499.67

REFERENCES

[1] BC Craft et al., NIM B-40/41, p373, (1989).
[2] VM Borovikov et al., J Synch Rad, vol.5, p440(1989).
[3] M Fedurin et al., Proc PAC2003, pp1053-1055.
[4] VP Suller et al., Proc EPAC04, pp2427-2429.
[5] D Launey et al, Poster FPAT056, these proceedings.

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