A PROPOSED MULTIPOLE WIGGLER FOR CAMD

V.P. Suller[a] , M. Fedurin[b], P. Jines[a], D. Launey[a], T. Miller[a] and Y. Wang[a],
[a]CAMD/LSU, 6980 Jefferson Highway, Baton Rouge, LA 70806, USA
[b]NSLS, Brookhaven National Laboratory, Upton, NY 11973, USA

Abstract

New insertion devices, such as a multi-pole wiggler (MPW), are being considered for CAMD. This is a consequence of the growth of CAMD's research program over the last several years, in particular after the commissioning of a 7 T wiggler, which has produced a demand for both higher beam brightness and flux density. A proposal has been submitted to the National Science Foundation for funding for a MPW which would replace the existing 7 T wavelength shifter. The outline specification for this new device is presented and also results of tests of modified optics for the CAMD storage ring which will be needed to accommodate the MPW. The modified optics have a reduced vertical aperture requirement of 20 mm at the location of the MPW. It will also be necessary to up rate the RF system to cope with the increased radiation loss.

INTRODUCTION

Although the original application for the CAMD facility was expected to be mainly for microfabrication, in the period since its commissioning in 1992 a general research program has been developed which makes use of all regions of the synchrotron radiation spectrum. The spectrum was extended in 1999 by the addition of a 7 Tesla superconducting wavelength shifter which made photons available up to at least 30 keV [1]. The central pole of this device produces a horizontal fan of about 200 mrad which feeds 4 beamlines [2], namely; micro-fabrication; protein crystallography; x-ray tomography; and x-ray absorption spectroscopy, which is now being commissioned.

To increase the source flux density for the protein crystallography beamline and give a better match into its optics, the storage ring is operated in a mode which greatly reduces the vertical beta at the wiggler [3]. It would be beneficial to increase the source brightness but the storage ring is already operating with a reduced horizontal emittance of about 150 nm.rad and this cannot be significantly improved [4]. It has therefore been concluded that increasing the source flux is the only option and a MPW would be capable of giving almost an order of magnitude increase. An application for funds has recently been made to the National Science Foundation for a 7.5 Tesla MPW which would replace the existing wavelength shifter and supply the present, but up rated, beamlines.

MULTIPOLE WIGGLER PARAMETERS

There are at least 6 superconducting MPWs in operation at light sources worldwide and 2 of them operate at fields of 7.5 Tesla [5]. In CAMD 7.5 Tesla would give an x-ray spectrum useable up to 65 keV which would usefully improve the range of the XAS and tomography beamlines.

The maximum attainable peak field $\hat{B}$ on the beam axis of a MPW is determined by the ratio of the magnetic period λ to the vertical gap g by the relationship [6]

$$\hat{B} = \frac{B_0}{\cosh\left(\frac{\pi g}{\lambda}\right)} \tag{1}$$

where B_0 is the field at the pole tip. This relationship can be used to extrapolate from existing designs to a new MPW. In CAMD the vertical gap needs to be sufficient to contain the beam at injection where, because of the low injection energy 180 MeV, the beam size is large. The present day limiting vertical aperture is 31.5 mm, which is at the 7 Tesla wiggler, but this would be too large an aperture for an optimized MPW.

To reduce the required vertical aperture at injection, the storage ring has been tested successfully in a mode which produces a low vertical beta value symmetrically in two opposite straights. The storage ring lattice functions for this mode are shown in figure 1. An additional benefit of this mode is that it would permit a second small aperture insertion device to be installed at some later date.

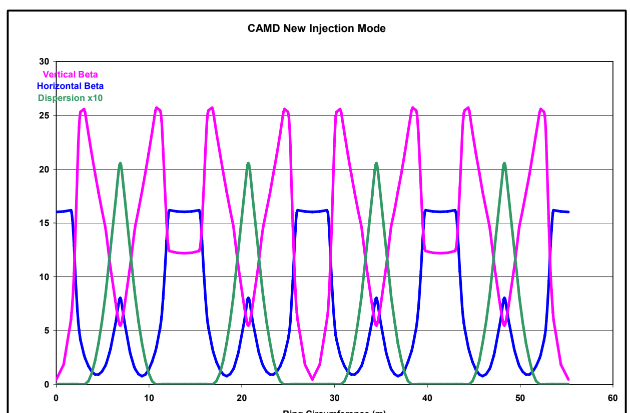

Figure 1: The lattice functions of the New Injection Mode.

The present day wiggler is the limiting vertical aperture during standard injection. The aperture there is 31.5 mm and the vertical beta function value is 7.3 m. The aperture at one end of the dipole chambers is 50 mm with a vertical beta function of 16 m, and is consequently quite close to being limiting also. With injection into the lattice shown in figure 1 the vertical beta function at the dipoles is 22 m and at the location of the MPW 3.5 m. Therefore the MPW aperture can be scaled from the dipole chamber by the square root of the vertical beta ratio to give a

1-4244-0917-9/07/$25.00

vertical aperture of 20 mm. The magnetic gap within the MPW will be larger than 20 mm due to the thickness of the vacuum chamber walls and the insulation between it and the cryostat. Conservatively the magnetic gap has been assumed to be 40 mm and applying this to equation (1) results in a period length of 270 mm, or pole length 135 mm.

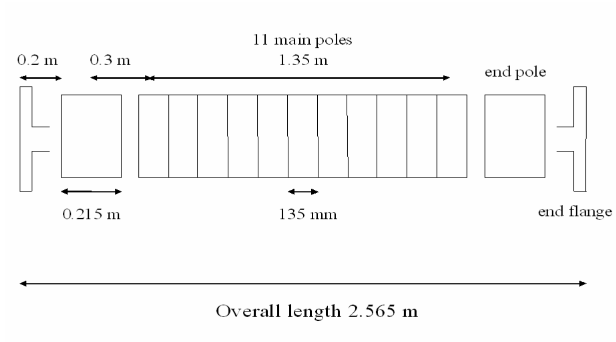

Figure 2: Schematic diagram of the MPW.

The length of the straight section over which the vertical aperture can be 20 mm is determined by the variation of the vertical beta function, which has a minimum of 0.5 at the straight center and rises to 3.5 at +/-1.25 m. The overall length of the MPW can therefore be about 2.5 m. With appropriate allowances for end poles and insulation 11 poles can be accommodated, as shown in figure 2.

Table 1: Main parameters of the proposed MPW

Peak field on axis (Tesla)	7.5
Number of full poles	11
Pole length (mm)	135
Overall MPW length (m)	2.565
Beam vertical aperture (mm)	20
Magnetic gap (mm)	40
Beam power at 200 mA (kW)	18

IMPACT ON THE STORAGE RING

Beam Dynamics

The operation of the MPW in the storage ring will cause a vertical tune shift due to the edge focusing of the magnetic poles. Modeling shows that the uncorrected tune shift would be 0.15, but this can easily be adjusted to zero with the lattice quadrupoles. Beta modulation due to the limped nature of the MPW can also be accommodated by differentially energizing the four quadrupoles families.

Of greater concern will be the tune shift with amplitude, which together with any high order field components present in the MPW could severely restrict the dynamic aperture. These factors are currently still being evaluated.

The storage ring horizontal emittance has been reduced from the original design value of 250 nm.rad to 150 (with the wavelength shifter operating) by configuring the lattice with finite dispersion. This will also apply to the new injection mode and it is calculated that the MPW will operate with a negligible increase in emittance to 155 nm.rad.

Radio Frequency

The MPW will significantly increase the radiation losses in the storage ring. The loss per turn in the dipoles is 86 keV and 15 keV in the existing wavelength shifter. The losses in the MPW will be 92 keV. To maintain the overvoltage at 3.7 is beyond the capability of the single cell DORIS cavity with which the ring is equipped and so the intention would be also to install the spare cavity complete with its 60 kW power source. This arrangement will be able to provide the necessary overvoltage and sufficient power to maintain a beam current of 400 mA.

At 200 mA the power radiated by the MPW will be 18.2 kW compared to 3 kW from the wavelength shifter. Such a powerful beam will need to be carefully steered within the ring vacuum chamber and a fast interlock system must be provided to protect it in the event of uncontrolled correction magnet excursion.

To allow the possibility of a 2nd ID for CAMD, which was mentioned earlier, the RF system must be relocated into the straight section which is presently unused. This would put the 2nd ID diametrically opposite the MPW. The beamline from the ID would not be in a favorable area within the hall. By using a lattice optic which has 4 vertical minibetas instead of 2, it would be possible to retain the RF in its present position and locate the 2nd ID into the empty straight.

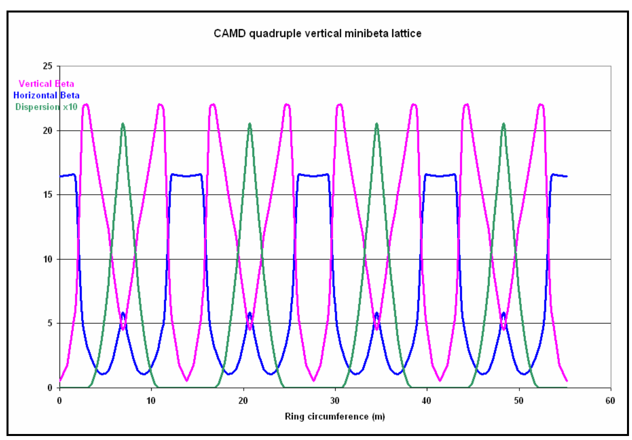

Figure 3: Lattice functions of an optic with a vertical minibeta in each of the 4 long straights.

A lattice optic with a vertical minibeta in each of the long straights is shown in figure 3. This lattice has been briefly tested, and there is an expectation that with further development it will be used in preference to that shown in figure 1.

1-4244-0917-9/07/$25.00 ©2007 IEEE

MPW SPECTRUM

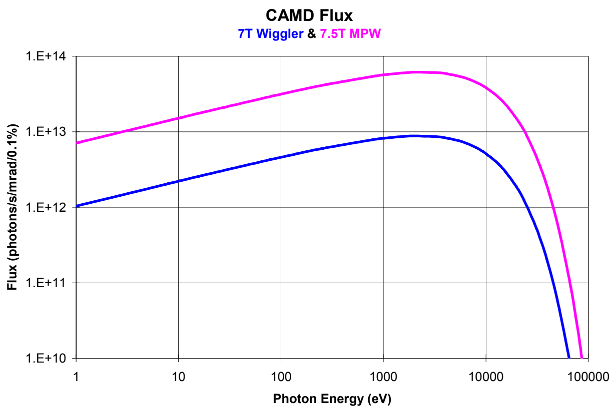

Figure 4: Flux spectrum from the 7.5 Tesla 11 pole MPW compared with the 7 Tesla wavelength shifter.

The flux spectrum produced by the MPW for a beam current in CAMD of 200 mA is shown in figure 4 in comparison with that produced by the present 7 Tesla wavelength shifter. The MPW flux will exceed the wavelength shifter by over a factor of 10 and extend to at least 65 keV. Each pole of the MPW will deflect the electron beam by 149 mrad which is sufficient to supply the existing 4 wavelength shifter beamlines which are spread over 80 mrad, however only the center lines will accept the full length of the extended source and receive the full flux increase.

CONCLUSION

The proposed 11 pole 7.5 Tesla MPW will greatly enhance the capability of CAMD to undertake research in the hard x-ray region. The specification of the MPW is conservatively rated and is based on the performance achieved with similar devices at other Light Sources. A new injection mode is required for the storage ring which reduces the vertical aperture where the MPW will be located, and this has been tested successfully.

REFERENCES

[1] V.M. Borovikov et al., "Superconducting 7 Tesla Wiggler for LSU CAMD", Journal of Synchrotron Radiation, Vol. 5, part 3, p. 440 (1998).
[2] H. Bellamy et al., "The Center for Advanced Microstructures and Devices (CAMD): New Opportunities and New Facilities", 9th International Conf. on Synchrotron Radiation Instrumentation, AIP Conference Proceedings 879, p. 163 (2006).
[3] M. Fedurin et al., "CAMD Low Beta Configuration for the 7 Tesla Wiggler", Proc. PAC 2003, Portland, OR, p. 1053, http://www.jacow.org.
[4] V.P. Suller et al., "Status of the CAMD Light Source", Proc. PAC2005, Knoxville, TN, p. 3103, http://www.jacow.org.
[5] N.A. Mezentsev, "Survey of Superconducting Insertion Devices for Light Sources", Proc. PAC2005, Knoxville, TN, p. 256, http://www.jacow.org.
[6] G. Brown et al., "Wiggler and Undulator Magnets-a Review", Nucl. Instrum. Methods 208, 65 (1983).