PRELIMINARY STUDY OF THE WAVELENGTH SHIFTER EFFECT IN SRRC STORAGE RING

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Abstract

The possibility of installing a superconducting wavelength shifter was discussed in SRRC. After surveying and comparing, magnet of one full strength pole and two half strength poles, with peak field of 7.5 tesla, was chosen for the feasibility study. Due to the space constraint, the wavelength shifter will not installed in the straight section middle. This paper reports the perturbation on lattice of the chosen wavelength shifter and the restoring from its perturbation. Effect on the ring is also investigated form the dynamic aperture point of view.

1 INTRODUCTION

The SRRC storage ring is dedicated for the VUV and soft X-ray research. It was operated at 1.3Gev while it is upgraded to 1.5 GeV for the routine operation. For higher photon energy applications, a wavelength shifter (WLS) was proposed to install in the ring. Under the constraint of available space, parameters for WLS were discussed. This paper reports the feasibility of the discussed situation in 1996. In this study, one full strength pole and two half strength poles with the maximum field of 7.5 tesla are assumed for the WLS. That means the WLS is a superconducting wiggler. Table 1 summarized the WLS parameters used in the study.

Table 1: The assumed WLS parameters

Maximum field strength	7.5 T
Number of poles	1 full strength
	2 half strength
Pole length	0.244 m
Location:	
(from Q1 edge to WLS center)	0.87 m

Figure 1 illustrates the relative location and spacing of quadrupoles and WLS in the section in which the WLS installed. The quadrupoles are used to match the beta-function to the desired values at the matching points. From figure 1 the WLS is not installed at the middle of straight section, i.e doesn't locate at the symmetry point. Hence the beta-function will be strongly disturbed and would not be symmetry w.r.t. WLS center. The photon flux from WLS and from 1.24 tesla bending magnet at 1.3 GeV are compared and shown in figure 2. The increasing of photon energy by WLS is clearly illustrated in the figure. The critical energy is governed by

$$\varepsilon_c(KeV) = 0.665 * E^2(GeV) * B(T) \tag{1}$$

Therefore the critical energy will be increased from 1.394 KeV, emitted from 1.24T bending magnet(1.3GeV), to 8.429 KeV at 1.3 GeV and to 11.222 KeV at 1.5 GeV as WLS is installed in the ring.

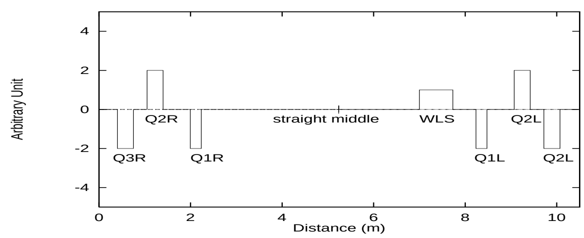

Figure 1: Schematic layout of quadrupoles and WLS in the straight section.

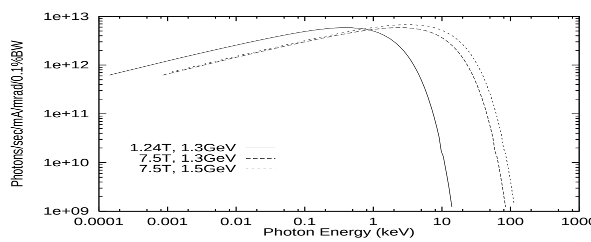

Figure 2: Comparison of photon flux between different magnetic field.

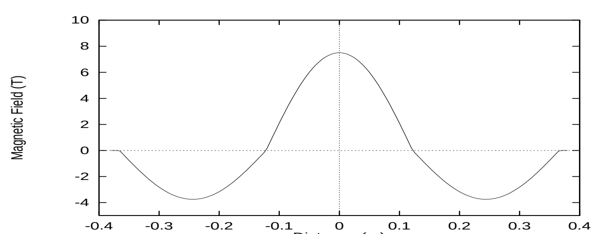

Figure 3: Magnetic field profile of WLS along the ideal trajectory.

2 FIELD INTERPRETATION

The WLS field in the ideal beam trajectory is represented by half sinusoidal function for each pole. Figure 3 shows the field profile along the WLS axis for the study. The field profile is symmetrical and has a zero field integral such that the exit angle equals the entrance angle. The second integral is also zero for this profile arrangement. Form of the WLS field is that of K. Halbach expression. Following the same trick of reference 1, the WLS field is approximately written by

$$B_y = B(m)sin(K_p(z-(m-1)A_p/2))(1+ \{(K_p y)^2/2! + (K_p y)^4/4!\}) \quad (2)$$

where B(m) is the peak field for each pole with B(1)=B(3)=-B_0/2, B(2)=B_0 and B_0=7.5 tesla.

The term outside the braces contributes to the linear perturbation due to the WLS and the terms within the braces are the intrinsic non-linear field of WLS which contribute to the non-linear perturbation. In order to perform the beam dynamics calculation the linear part of WLS field, as defined in equation (2), is cut into a series hard edged rectangular dipole magnets to model the additional vertical focusing. Before the study, method of the series dipole approach was verified first. The code MAD8[2] was used to do this checking by comparing the theoretical vertical tune shift[3,4] due to one assumed wiggler field with the simulated results of which the wiggler field is approximated by a series dipoles. Results of these two approaches are consistent within the acceptable level.

3 BETA FUNCTION MATCHING AND TUNE COMPENSATION

Before the matching, the perturbation of WLS on linear optics was first investigated. Compared with the original ones, as shown in figure 4, the perturbated optical function is illustrated in figure 5. It is obvious that the vertical beta function was strongly distorted and enhanced to big values at some locations and the symmetry of the vertical beta function is also broken. Vertical tune is shifted from the design one of 4.13 to 4.277. As expected, the horizontal beta function and eta function are not affected by the WLS field.

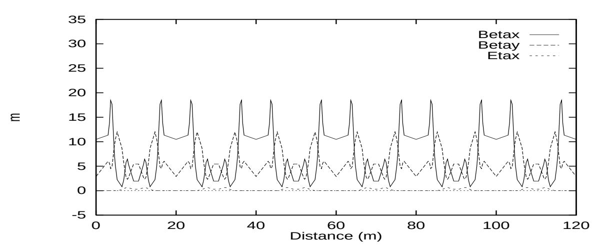

Figure 4: Unperturbated optics functions.

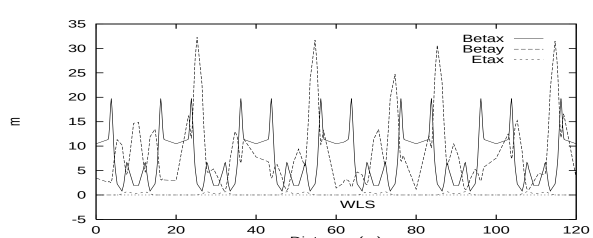

Figure 5: Perturbated optics functions by WLS.

By using the dipole model approximation and chosing the proper cutting[1], the beta matching and retunning from the WLS perturbation was performed by using MAD8. The quadrupoles within the WLS section are used to match the beta functions to the design ones at the matching points. Since the WLS doesn't insert at the middle of straight section, the symmetry point, the matched optics would not be symmetrical w.r.t. the symmetry point. This indicates the matched quadrupoles within the WLS section need to be tunned independently. Figure 6 shows the matched optics. It is clear that the optics is almost restored to the original ones outside the WLS section except those within the WLS section. The vertical beta function is also reduced to the acceptable value. With this matching the optics conditions will almost keep at design sets outside the WLS section and the perturbation on optics is mainly localized within the WLS section. The setting of quadrupoles within the WLS section for the cases with and without matching are listed in table 2.

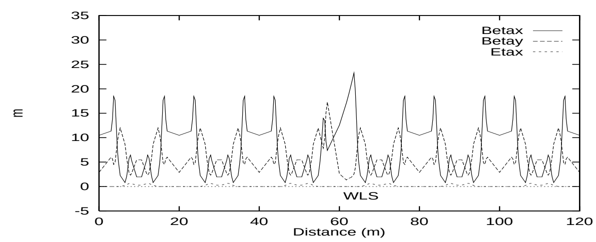

Figure 6: Matched optics functions from the WLS perturbation.

Table 2: Quadrupole settings in the WLS section with and without matching

Quadrupole	Design (m^{-2})	Matched (m^{-2})
Q1R	-1.50815	-2.34859
Q2R	2.87048	2.93744
Q3R	-1.15592	-0.05415
Q1L	-1.50815	-0.000189
Q2L	2.87048	1.88955
Q3L	-1.15592	-1.61765

As beta functions are matched, the tune shifts a little bit from the design one. Two quadrupole families, Q2 and Q3, outside the WLS section are chosen to restore the tune. After retunning, setting of Q2 family changes from 2.87048 m^{-2} to 2.850635 m^{-2} and Q3 family shifts from 1.15592 m^{-2} to -1.061488 m^{-2}. The Twiss functions slightly shifts from the matched optics and would not give big effect.

4 DYNAMIC APERTURE TRACKING

The dynamic aperture tracking study was performed 1000 turns at the WLS center by running RACETRACK[5]. Matched lattice with the linear WLS field, which is treated by a series rectangular dipole as described in section II, was tracked first. Figure 7 shows the tracking results compared with the aperture of the bare lattice. From figure 7, the vertical aperture is reduced about 42% and no reduction in the horizontal as the linear WLS field included only. For the non-linear WLS field, as shown within the brace of equation (2), it is integrated for each cutting and is taken as ordinary multipole field. The tracking study was then performed with the matched and retunned lattice by including the non-linear WLS field and the measured (or the specified) multipole errors of dipole, quadrupole and sextupole magnets, as listed in table 3. Since the sextupole multipole errors will effect as quadrupole components and give tune shift as there is a closed orbit distortion, setting of Q2 and Q3 families are tunned a little bit to restore tune again. No significant strength changing of Q2 and Q3 family was found. The chromaticity is also corrected to zero in the study. Figure 8 shows the tracking results with the considered conditions. From figure 8, the horizontal aperture is reduced about 43% to 20.5mm (averaged). Compared with the original physical aperture of 20mm in horizontal, it is also big enough. The vertical aperture is reduced further only by 5%.

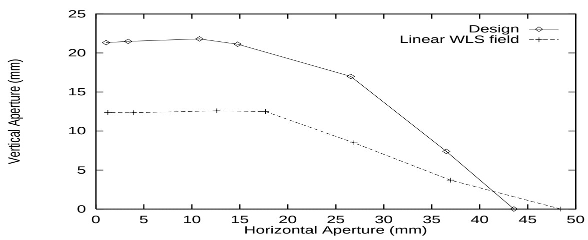

Figure 7: Comparison of dynamic aperture at the WLS center with the linear lattice considered only.

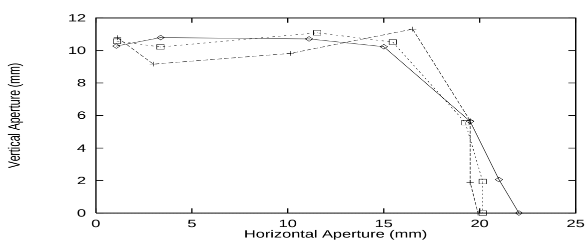

Figure 8: Dynamic aperture tracking of three random runs at the WLS center with the matched and retunned lattice and with multipoles in magnets considered.

From above study, it indicates the vertical aperture reduction is mainly coming from the linear WLS field but not from its non-linear parts. Above tracking study also indicates the WLS do have impact on the dynamic aperture.

5 DISCUSSION

Due to the space consideration the WLS won't be installed at the middle of straight section. For this arrangement the perturbation from WLS will become bigger than that the WLS inserted at the straight section middle. Compared with other rings, the maximum WLS field to the beam energy ratio for the proposed WLS in SRRC is quite large.

Table 3: Integrated multipoles in magnets used in the study

Magnet Type	order	systematic	random
Dipole			
	$4(m^{-1})$	0.0	0.00122
	$6(m^{-2})$	0.0657	0.033
	$8(m^{-3})$	3.06	1.1
	$10(m^{-4})$	-72.4	36.2
Quadrupole:			
	$4(m^{-1})$	0.0	0.0013
	$6(m^{-2})$	0.005	0.01
	$8(m^{-3})$	0.277	0.05
	$10(m^{-4})$	0.0	17.71
	$12(m^{-5})$	1307	265
Sextupole:			
	$18(m^{-8})$	3005617(SF)	
	$18(m^{-8})$	-13836572(SD)	

Hence the impact of WLS on the beam will be more serious than other rings. Nevertheless, the WLS effect is reduced by matching beta-function and restoring the tune. From above dynamic aperture tracking results , it is found the vertical aperture is mainly reduced by the linear WLS field. As the non-linear field of the WLS and of the ring magnets included, the dynamic aperture at the WLS center is reduced further to 10.5mm(V)x20.5mm(H) (averaged). For the original chamber in the straight section, it is elliptical shape with inner cross section of 38mm(V)x40mm(H). This indicates the tracked vertical aperture is smaller than the original physical aperture. Hence a reduction of beam lifetime would be expected from the aperture limitation point of view.

6 REFERENCES

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[5] A. Wrulich, RACETRACK version ssc/AUG 86.