LATTICE DESIGN FOR FUTURE PLAN OF UVSOR

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Abstract

We have designed a storage ring of 1 GeV electron energy, for the future plan of UVSOR. The magnetic lattice is based on a compact double bend achromat cell, which consists of two bending magnets and four focusing magnets, all of which are of combined function. The circumference is around 80 m. The emittance is 4.2 nm in the achromatic condition, which becomes smaller in the non-achromatic condition. The lattice of 6-fold symmetry has six straight sections of 4 m long and six of 1.5 m long. We are now working on optimizing the dynamic aperture of the storage ring using Bayesian method. In this report, some preliminary results are presented.

INTRODUCTION

UVSOR is a low energy synchrotron light source, which had been operated since 1983. After two major upgrades [1-4], now it is called UVSOR-III. The circumference of the storage ring is 53 m and the electron beam energy 750 MeV. It has 8 straight sections and six of them are occupied with undulators of various kinds. It has a moderately small emittance of about 17 nm and provides vacuum ultraviolet light of high brightness.

Nowadays, to meet the demand of diffraction limited light beam in the vacuum ultraviolet and x-ray range from scientific community, several synchrotron light sources, which have exceedingly small emittance less than 1nm, are under consideration, construction, or in operation [5-7]. In such a situation, we have started considering a future plan for UVSOR with an emittance smaller than at least a few nm to provide diffraction-limited light in the vacuum ultraviolet range. As the first step of the investigation, we have analyzed the present magnetic lattice of UVSOR and found that a few optics with emittance around 10 nm may be realized [8]. To reach the lower emittance around a few nm, we have started designing a totally new storage ring. The storage ring has a higher electron energy, 1 GeV and a larger circumference, 82.5m. The lattice consists of twelve double bend cells. Among twelve straight sections, two sections will be used for the injection and RF cavity, and ten sections will be used for insertion devices.

In this paper, we will describe the design of the new lattice for UVSOR-IV and the related beam dynamics studies.

LATTICE DESIGN

The lattice has been designed based on a compact double bend achromat cell (DBA), which consists of two bending magnets and four focusing magnets, all of which are combined function magnets. Two sextupole families are located in between two combined dipoles for the chromaticity correction and two harmonic sextupole families are also employed to correct the high order geometric aberrations. This lattice has twelve DBA cells with six long straight sections about 4 m and six short straight sections around 1.5 m long. These lengths are same as those of UVSOR-III. This may enable us to use the undulators at UVSOR_III in the new ring.

It is noted that this lattice has a flexibility on the dispersion function at the straight sections, which enables to realize various operation modes such as of achromatic, lower emittance, or isochronous.

A tune survey was performed to find the linear optics with a low emittance and appropriate optical functions. ELEGANT [9] was used for the calculations. The emittance is around 4 nm in the achromatic condition, which becomes lower in the non-achromatic condition. Figure 1 shows the lattice functions in the achromatic condition. The major parameters are listed in Table 1 and are compared with those of UVSOR-III.

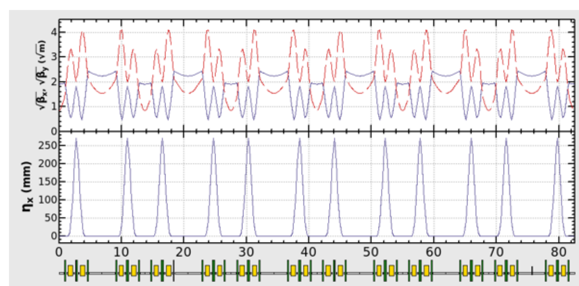

Figure 1: Lattice function of 1 GeV storage ring for UVSOR-IV. The blue and red lines show the horizontal and vertical betatron tune, respectively.

Table 1: Lattice Parameters

	UVSOR-III	UVSOR-IV
Electron energy	750 MeV	1 GeV
Stored current	300 mA	300 mA
Circumference	53.2 m	82.5 m
RF frequency	90.1 MHz	89.4 MHz
Harmonic num.	16	26
RF voltage	120 kV	100 kV
Coupling ratio	0.01	0.01
Energy spread	0.000526	0.000576
Emittance	16.9 nm	4.3 nm
Betatron tunes	(3.75, 3.20)	(10.4, 4.2)

It is noticeable that if we occupy three of short straight sections with 2T multipole wigglers in symmetry, the

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energy loss due to the radiation in the wigglers enhances the damping effect and the emittance reduces to 3.7 nm. These wigglers can provides tender X-ray, which are hardly accessible at the present UVSOR-III.

DYNAMIC APERTURE

We use ELEGANT [9] to optimize the dynamic aperture

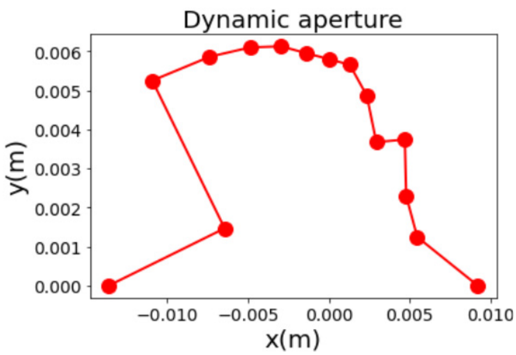

Figure 2: Dynamic aperture for on momentum particles with two family sextupoles. The particle tracking has been run for 1024 turns passing through the storage ring.

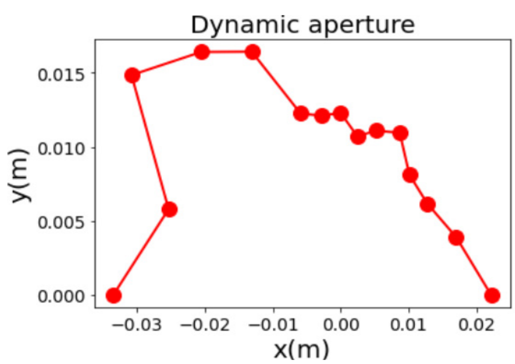

Figure 3: Dynamic aperture of the optics with thin harmonic sextupole families (top) and thick ones (bottom) for on momentum particles.

without considering multipole errors and misalignment errors. Figure 2 shows the dynamic aperture for on-energy particles at the straight section with two family sextupoles whose strengths are determined so as to make the linear chromaticity zero. The horizontal aperture for the on-momentum electron is about -19 to 10 mm and vertical aperture is about 6 mm. To realize a larger dynamic aperture, two harmonic sextuple families have been added to the lattice and their strengths are optimized using Bayesian method for maximizing the dynamic aperture. The details of the calculation will be described in a future paper. Figure 3 shows an example of the dynamic aperture of an optimized optic.

CONCLUSION

A new 1 GeV storage ring lattice with a circumference of 82.5 m has been proposed to upgrade the UVSOR synchrotron facility. The lattice has been designed based on DBA cell to have a low emittance. Optimising the magnet arrangement and the working point, a small natural emittance 4.2 nm is obtained in the achromatic condition. The lattice has twelve straight sections, ten of them are available for insertion devices. Occupying 3 short straight sections with 2T multipole wigglers can reduce the natural emittance to 3.6 nm-rad. Moreover, these wigglers provide intense tender X-rays.

Dynamic aperture was studied without machine errors. We used Bayesian method to optimize the strength of the harmonic sextupole families for maximizing the dynamic aperture. Our simulations show that the optics has sufficiently large dynamic aperture.

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REFERENCES

[1] M. Katoh, K. Hayashi, T. Honda, Y. Hori, M. Hosaka, T. Kinoshita, S. Kouda, Y. Takashima, J. Yamazaki, Nucl. Instr. Meth. A 467, 2001, pp.68.
[2] M. Katoh, M. Hosaka, A. Mochihashi, J. Yamazaki, K. Hayashi, Y. Hori, T. Honda, K. Haga, Y. Takashi, T. Koseki, S. Koda, H. Kitamura, T. Hara, T. Tanaka, in *AIP Conf. Proc. 705*, 2004, pp.49.
[3] M. Adachi, H. Zen, T. Konomi, J. Yamazaki, K. Hayashi, M. Katoh, J. Phys. Conf. Ser. 425, 2013, pp. 042013.
[4] M. Katoh, M. Adachi, H. Zen *et al.*, in *AIP Conf. Proc*. 1234, 531 (2010).
[5] M. Eriksson *et al.*, "Commissioning of the MAX IV light source," in *Proc. IPAC 2016* , Busan, Korea, 2016.
[6] R. Wanzenberg, I. Agapov, W. Brefeld, R. Brinkmann *et al.*, in *AIP Con. Proc*. 2054, 030002 (2019).
[7] T. Hara, T. Aoki, H. Dewa, T. Fujita *et al.*, PRAB24, 110702 (2021).
[8] E. Salehi and M. Katoh, "Lattice Design for a Future Plan of UVSOR Synchrotron" in Proc. *12th Int. Particle Accelerator Conf. (IPAC'21)*, Campinas, SP, Brazil, May. 2021, pp. 3970-3972.;doi:10.18429/JACoW-IPAC2021-THPAB089
[9] M. Borland, APS LS-287 (2000).