Lattice Design for 8 GeV Synchrotron Radiation Source

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ABSTRACT

We present preliminary results of a design study on a storage ring lattice intended to be the next generation synchrotron radiation source as one of the possible future projects at KEK. The nominal beam energy is 8 GeV. The circumference of the ring is 1160 m. The lattice consists of FODO cells and 24 dispersion-free long straight sections. The emittance is 7 nm·rad. The dynamic aperture is sufficiently large for the injection and the stable storage of the beam.

(1) INTRODUCTION

In Japan, a demand for a next generation synchrotron source becomes stronger as well as in Europe and in USA. At KEK, a basic design concept of the new ring was presented by a working group[1]. It can be summarized as follows;

(1) The main light sources are undulators.
(2) The beam energy is 8 GeV.
(3) The number of long straight sections for undulators is more than 20.
(4) The emittance is around 10 nm·rad at the first stage. The lattice should be flexible for challenging lower emittance step by step.

In this paper, we present a lattice, which is designed tentatively as a basis for the further discussions in the working group.

(2) LINEAR LATTICE

The ring consists of 8 superperiods. The optical functions and the configuration of the lattice are shown in Fig. 1 for one superperiod. The parameters of the ring are summarized in Table 1. The lattice consists of FODO normal cells and two types of dispersion-free long straight sections; one is for undulators and for injection with high β and another is for RF systems and for others with relatively low

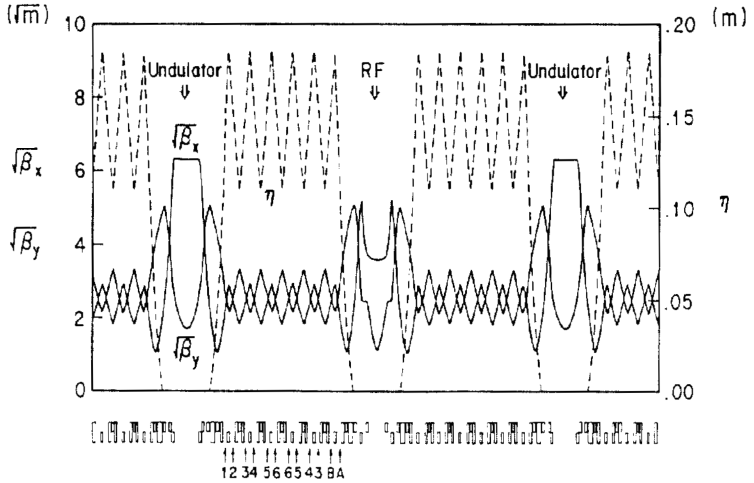

Fig. 1 The optical functions for one superperiod. The locations of the sextupole families are indicated by arrows with their names.

TABLE 1. RING PARAMETERS

BEAM ENERGY	8 (GeV)
NUMBER OF SUPERPERIODS	8
NUMBER OF INSERTIONS	24
FOR UNDULATORS	6 m × 15
FOR RF AND OTHERS	4.4 m × 8
FOR INJECTION	6 m × 1
CIRCUMFERENCE	1161.6 (m)
NATURAL BEAM EMITTANCE	7.3 (nm·rad)
MOMENTUM COMPACTION FACTOR	4.6×10^{-4}
HORIZONTAL BETATRON TUNE	39.23
VERTICAL BETATRON TUNE	27.18
HORIZONTAL NATURAL CHROMATICITY	-64.2
VERTICAL NATURAL CHROMATICITY	-46.7
ENERGY LOSS/TURN	9.5 (MeV)
ENERGY SPREAD	1.1×10^{-3}
DUMPING TIMES τ_x	6.5 (msec)
τ_y	6.5 (msec)
τ_ε	3.3 (msec)
BENDING RADIUS	38.197 (m)

TABLE 2. PARAMETERS OF BENDING MAGNETS

	L(m)	θ (deg)	B(kG)
BM	0.6	0.9	7.0
BM2	1.4	2.1	7.0

TABLE 3. PARAMETERS OF QUADRUPOLE MAGNETS

	L(m)	B L/Bρ (m^{-1})
QF	0.6	0.3734216
QD	0.4	-0.3325326
Q1	0.6	0.5026816
Q2	0.6	-0.0944004
QS1	0.6	-0.3163294
QS2	0.6	-0.0387847
QS3	0.6	0.3098740
QRF1	0.6	-0.4361547
QRF2	0.6	0.6490778
QRF3	0.6	-0.3606910

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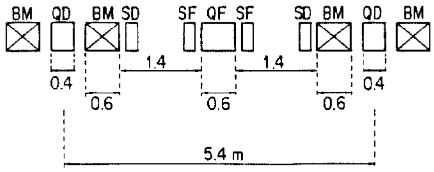

Fig. 2a The configuration of a FODO cell.

β. The lengths of the free spaces in the straight sections are 6 m and 4.4 m respectively. The details of the configurations of the FODO sections and of the matching sections, which are located between the FODO sections and the long straight sections, are shown in Fig. 2a and Fig. 2b. The parameters of the bending magnets (BM) and the quadrupole magnets (QM) are listed in Table 2 and Table 3. The phase advances per unit FODO cell are 60 deg. in the horizontal direction and 45 deg. in the vertical direction. To reduce the emittance, BM's are placed very close to the defocussing QM's (QD). As a result, the emittance of 7 nm·rad is achieved. There are many short free spaces in the FODO cells, which can be used for steering magnets, monitor systems and vacuum systems.

(3) CHROMATICITY CORRECTION

In this preliminary study, sextupole magnets are nominally subdivided into 16 families as listed in Table 4, although a smaller number of families probably can show a similar performance in the chromaticity correction for this lattice. The locations of the sextupole families are shown in Fig. 1. The strengths of the sextupole fields are determined by the method described elsewhere in this proceedings[2]. The dynamic aperture obtained after the chromaticity correction is shown in Fig. 3. Although the third-order resonance driving terms are still not removed sufficiently, the dynamic aperture is very large. In addition, the tune shifts with the amplitudes are very small within the dynamic aperture, as seen in Fig. 4 and Fig. 5. The tune shifts with momentum are shown in Fig. 6. The variations of betatron functions and of dispersion functions with momentum at the center of the undulator section are summarized in Table 5.

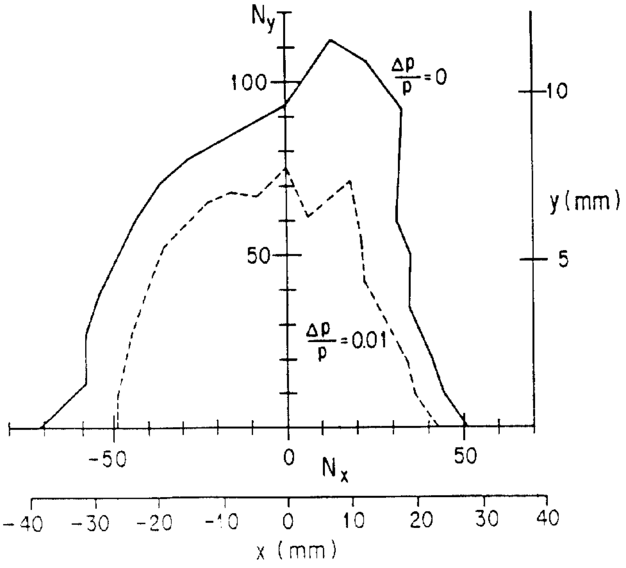

Fig. 3 The dynamic aperture at the midpoint of the undulator section.

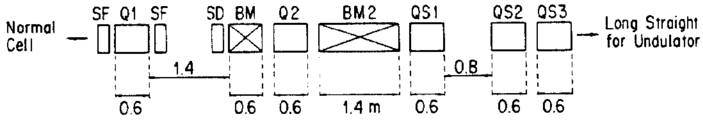

Fig. 2b The configuration of a matching section.

(4) DISCUSSIONS

Our preliminary study has shown the FODO lattice has a fairly large dynamic aperture with a moderately small emittance. In addition, there are many possibilities to increase the dynamic aperture or to reduce the emittance, which were not studied sufficiently in this work. It may be possible to obtain larger dynamic aperture by changing the members

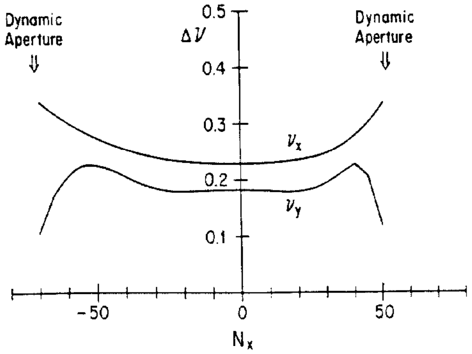

Fig. 4 The tune shifts with horizontal emittance.

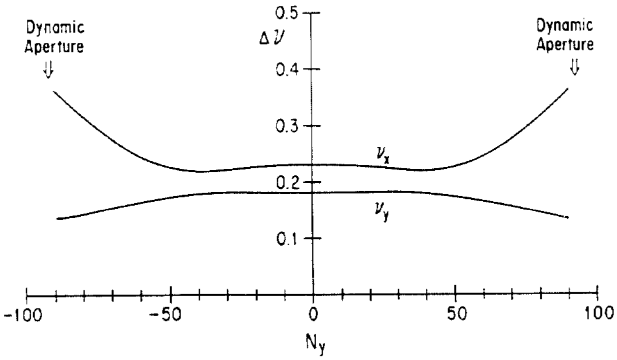

Fig. 5 The tune shifts with vertical emittance.

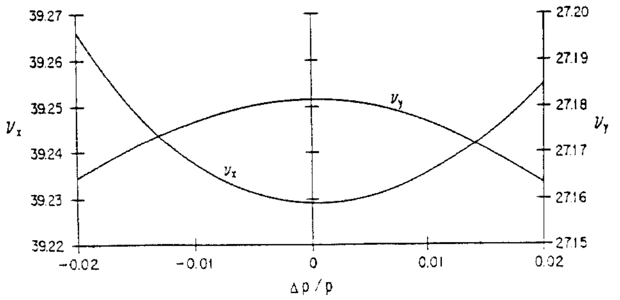

Fig. 6 The tune shifts with momentum.

of the sextupole families, the operating tunes or the number of cells in the FODO sections. A smaller emittance down to 2 nm·rad can be achieved by increasing the phase advances per unit FODO cell up to around 90 deg., although the dynamic aperture probably becomes much smaller.

In the lattice, eight straight sections with relatively low β are reserved for RF systems and for other insertion devices. It depends on the parameters of RF systems how many straight sections are necessary for them. The values of β's at these sections are only nominal ones, at this stage. They can be optimized for RF systems, undulators or multipole wigglers by changing the strengths, positions and numbers of QM's in the matching sections and in the straight sections.

One may feel that the lattice would becomes simpler by adopting combined-function magnets as proposed by some authors[3]. Actually, a defocussing QM and two BM's neighboring to it in a normal cell can be combined into one magnet. However we prefer the flexibility of the separated-function magnets rather than the simplicity of the combined-function magnets.

The effects of field errors and misalignments have not been studied. This will be done in the near future.

The circumference of around 1 km is small enough to construct the ring inside the TRISTAN Main Ring at KEK. The full energy injection of both electron and positron is possible by utilizing TRISTAN Accumulation Ring.

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TABLE 4. PARAMETERS OF SEXTUPOLE MAGNETS

	$B'' L/B\rho$ (m^{-2})		$B'' L/B\rho$ (m^{-2})
SD1	-5.45434	SF1	2.96362
SD2	-4.21114	SF2	1.95949
SD3	-0.70168	SF3	5.32765
SD4	-11.86880	SF4	6.09982
SD5	-5.51048	SF5	8.08185
SD6	-11.45310	SF6	8.01369
SDA	-3.11052	SFA	7.64299
SDB	-11.92180	SFB	3.08819

TABLE 5. MOMENTUM DEPENDENCY OF TWISS PARAMETERS

(AT THE MIDPOINT OF THE UNDULATOR SECTION)

$\Delta p/p$	β_x(m)	β_y(m)	η (m)
-0.020	34.987	3.420	-0.035
-0.015	36.168	3.264	-0.026
-0.010	37.401	3.124	-0.017
-0.005	38.680	2.999	-0.008
0.0	40.000	2.888	0.0
0.005	41.357	2.790	0.008
0.010	42.749	2.703	0.015
0.015	44.647	2.626	0.023
0.020	45.647	2.559	0.029

REFERENCE

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