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# A DESIGN STUDY FOR THE SOR FACILITY

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Abstract A design calculation of the low emittance 2 Gev storage ring, magnets, RF cavity for a synchrotron radiation facility has been carried out.

## INTRODUCTION

There are several projects[1–3] for the construction of third-generation dedicated synchrotron radiation sources have planed as high priority projects. One having a 6-8 Gev electron beam energy and the other having a 1-2 Gev beam. The latter project is intended to provide a facility optimized for the production of ultraviolet and soft x-ray photons from magnetic insertion devices. In this work, design of the low emittance 2 Gev storage ring, storage ring magnets (bending,quadrupoles and sextupoles) and RF cavity are presented here.

## STORAGE RING

There are many kinds of the lattice structure for synchrotron radiation sources[4–6] . Among these candidates we have chosen the Chassman-Green lattice(CG) with sector type bending magnet for the model calculation. The parameters of the model ring are compared with those of CG with rectangular and special(with arbitrary edge focusing) types of bending magnets. They are also compared with those of the Triple Bending Achromat (TBA) structure with rectangular bending magnets and with combined function type bending magnets as shown in Table I.
There are 12 long dispersion free straight sections of 5.2 m in length. They are used to install the superconducting wiggler,RF cavities, injection and new devices for synchrotron radiation sources. The storage ring has 12 superperiods. The circumference is 168.72 m for the CG structure and is 217.2 m for the TBA structure. Fig.1 shows the

dynamic aperture of the CG structure without and with the magnetic multipole errors of the random and normal cases. The dynamic aperture is considerably reduced by the effects of the magnetic multipole errors. Fig.2 shows the dynamic aperture of the TBA structure with the combined function type bending magnets. We expect the beam life time of about 15 hours to be attainable considering residual gas scattering at $10^{-9}$ Torr of CO equivalent pressure.

TABLE I Summary of major storage ring parameters

| Type | CG | | | | TBA | |
|---|---|---|---|---|---|---|
| Bending Magnet | A | B | C | A | D | E |
| Nominal energy(Gev) | 1.5 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Max. current(mA) | 500 | 500 | 500 | 500 | 500 | 500 |
| Natural emittance ($10^{-8}$ m.rad) | 2.05 | 4.25 | 3.42 | 3.64 | 1.07 | 1.06 |
| Hor.emittance(10%) | 1.86 | 3.87 | 3.11 | 3.31 | 0.97 | |
| Ver.emittance(10%) | 0.18 | 0.38 | 0.31 | 0.33 | 0.09 | |
| Circumference( m ) | 168.7 | 168.7 | 168.7 | 168.7 | 168.7 | 217.2 |
| Harmonic number | 282 | 282 | 282 | 282 | 282 | 282 |
| Radio freq.(MHz) | 501.08 | 501.08 | 501.08 | 501.08 | 501.08 | 389.16 |
| No.of superperiod | 12 | 12 | 12 | 12 | 12 | 12 |
| Straight section(m) | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 |
| Mean radius(m) | 26.86 | 26.86 | 26.86 | 26.86 | 26.86 | 34.75 |
| Bending field(T) | 0.873 | 1.164 | 1.164 | 1.164 | 1.164 | n=18 |
| No.of dipoles | 24 | 24 | 24 | 24 | 36 | 36 |
| No.of quadrupoles | 60 | 60 | 60 | 60 | 72 | 72 |
| Betatron tunes | | | | | | |
| Horzontal | 9.32 | 8.92 | 9.42 | 9.32 | 17.28 | 13.24 |
| Vertical | 4.43 | 4.27 | 4.26 | 4.43 | 3.93 | 7.30 |
| Beta function(m) | 15.13 | 16.19 | 15.11 | 15.13 | 33.0 | 9.84 |
| (Hor./Ver.) | 8.56 | 7.98 | 8.21 | 8.56 | 23.9 | 6.50 |

The notations A,B,C indicate the sector,rectangular and special type bending magnets for the CG structure,and D and E indicate the rectangular and combined function type bending magnets for the TBA structure,respectively.

## STORAGE RING MAGNETS

The conceptual design of the storage ring magnets for the CG structure with the sector type bending magnet has been carried out. The storage ring dipole magnets are sector and C type with the length of 1.5 m and bending angle of 15 degrees. The vertical aperture was determined to be at least 50 mm considering the beam size, closed orbital distortions and vacuum chamber thickness, etc[7].

The pole width was determined to be 240 mm to insure the requirement for the horizontal aperture. The quadrupoles have the symmetric pole profiles of xy=12.25 cm because of their good field symmetry. The bore diameter is determined to be 98.98 mm from the maximum horizontal and vertical beam sizes at 2 Gev and from cod, etc.

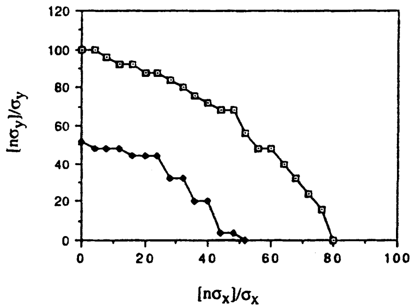


Fig. 1 Dynamic aperture of the DFA structure with the sector type bending magnets for the magnetic multipole errors.

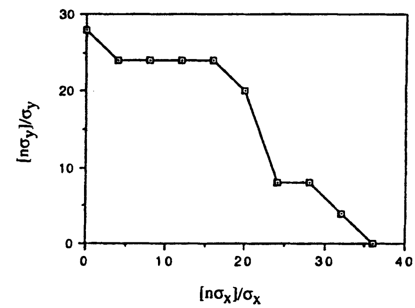


Fig. 2 Dynamic aperture of the TBA structure with the combined function type magnets.

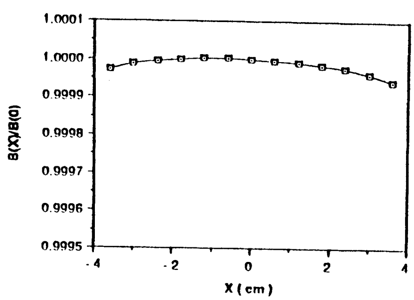


Fig. 3 Field distribution of the designed bending magnet.

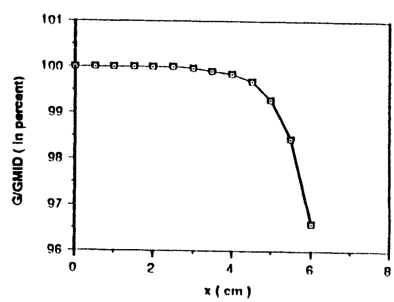


Fig. 4 Field distribution of QF (G = B'(X), GMID = B'(2 cm)).

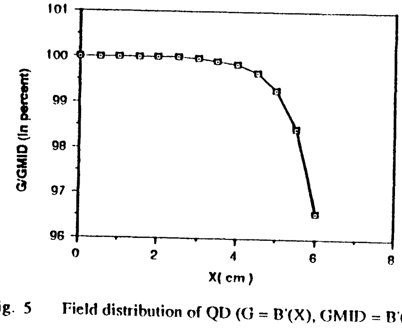


Fig. 5 Field distribution of QD (G = B'(X), GMID = B'(2 cm)).

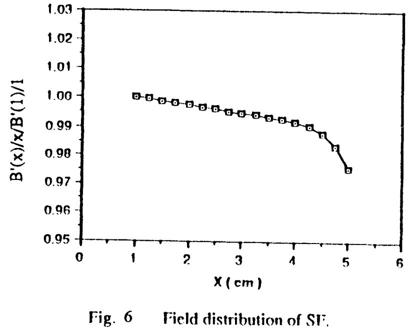


Fig. 6 Field distribution of SF.

TABLE II The major parameters of the designed magnets

| | | |
|---|---|---|
| **Bending magnets** | | |
| Type | | C |
| Length (m) | | 1.5 |
| Magnet gap (mm) | | 50 |
| Pole width (mm) | | 200 |
| Core cross-section (mm ) | | 560 x 570 |
| Coil current (Amp turns) | | 2.31 E+04 |
| **Quadrupole magnets** | | |
| Length (m) QF,QD,QFC | | 0.3 |
| Magnet aperture radius (mm) | | 49.5 |
| Pole shape (cm ) | | 12.25 |
| Coil current (Amp turns) | QF/QD | 1.63 E+04/1.76 E+04 |
| Max.gradient (T/m) | QF/QD | 17/18 |
| **Sextupole magnets** | | |
| Length (m) SF/SD | | 0.20/0.25 |
| Magnet aperture radius (mm) | | 55 |
| Pole width (mm) | | 80 |
| Coil current (Amp turns) | SF/SD | 7.00 E+03/9.12 E+03 |
| Max.gradient (T/m) | SF/SD | 450/465 |

The core length is 200 mm for the sextupoles(SF) and 250 mm for those(SD). The pole width is 80 mm and bore diameter is 110 mm for SD and SF. The main parameters of the designed dipole, quadrupoles and sextupoles are summarized in Table II. The field distributions of the designed magnets have been calculated as shown in Fig. 3-6.

## RF CAVITY

The RF parameters at the present model and the machine parameters relevant to the RF system have been calculated by computer code SUPERFISH. The cavity design is based on the accelerating structure employed at the P.F.(KEK,Japan). The accelerating frequency for 2 Gev is chosen to be 501.074 MHz. Impedance was optimized to 24.72 M ohm/m at frequency f=501.074 MHz. Q-value is achieved 4.268E+04 for the cavity with length of 40 cm, diameter of 46.035 cm and peak voltage of 1.5 MV. The major parameters for RF cavity are summarized in Table III.

TABLE III The major parameters of RF cavity

| | |
|---|---|
| Frequency | 501.074 MHz |
| Harmonic number | 282 |
| Peak effective voltage | 1.5 MV |
| Transit time factor | 0.730 |
| Cavity length | 40.0 cm |
| Cavity diameter | 46.035 cm |
| Stored energy (full cavity) | 1.1673E-01 Joules |
| Used resistance of copper | 1.720E-06 Ohm cm |
| Power dissipation (full cavity) | 8.6101E+03 Watts |
| Q-value | 4.268E+04 |
| Shunt impedance (ZTT) | 2.472E+01 Mega ohm/m |
| Magnetic field on outer wall | 2.053E+03 Amp/m |
| Max. electric field on boundary | 4.263 MV/m |

## CONCLUSION

We have designed 2 Gev low emittance storage ring, magnets and RF cavity for synchrotron radiation facility. With regard to emittance, we find that the TBA structure is better than CG structure. The horizontal emittances of the CG structure with the same coupling of 10 % have values of about $3 \times 10^{-8}$ m.rad for the cases of three type bending magnets as shown in Table I. In dynamic aperture survey, we find that the CG structure gives an enough dynamic aperture of about 6 cm. Even in the case of TBA using combined function type bending magnet, the results of the CG structure is better than those of the TBA structure as shown in Fig. 1-2.

For the design of magnets, the bending magnets are the flat block type and did not considered shims of the pole face for the technical simplicity. The major parameters and field distribution of designed magnets are presented in Table II and Fig. 3-6 respectively.

In RF cavity, we have chosen the minimum number of 2 cavities necessary to support the required peak voltage of 1.5 MV to minimize the broadband impedance seen by the beam. Impedance was optimized to 24.72 M ohm/m at the accelerating frequency of 501.074 MHz. Q-value is obtained 4.268E+04 and major parameters of RF cavity are given in Table III.

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