LATTICE DESIGN FOR THE TRISTAN MAIN RING

Susumu KAMADA and Yoshitaka KIMURA
National Laboratory for High Energy Physics
Oho-machi, Tsukuba-gun, Ibaraki-ken, 305, Japan

ABSTRACT

The latest version of the TRISTAN Main Ring lattice is presented together with the related parameters. Some open questions connected with chromaticity correction are introduced briefly.

INTRODUCTION

There has been a rather long history in the lattice design of the TRISTAN Main Ring(MR) since that was proposed by T.Nishikawa in 1973.(1)

The design of the TRISTAN lattice as an electron-positron collider was presented in 1976 for the first time (2), although there were wide range of possibilities for the future of TRISTAN project, and the character of TRISTAN-MR had not been fixed yet.

Finally the official approval of the TRISTAN project phase I in 1981 fixed the characteristics of MR as an electron-positron collider of 30 GeV in beam energy. Since then, the version number of the lattice design of TRISTAN-MR have rapidly risen to 11th owing to the more practical and serious discussions.

Due to such a long and complicated history of the lattice design study, there might exist some confusions about the TRISTAN lattice and its parameters. In the present paper, we will concentrate our efforts to make clear the TRISTAN lattice and its parameters.

GEOMETRICAL FEATURES OF MR

TRISTAN-MR has been designed as a site filler of KEK on the condition that the ring should have at least four-fold symmetry. Some geometrical parameters are summarized in Table 1.

The ring circumference of MR is eight times as long as that of the Accumulation Ring(AR) which supplies electron and positron bunched beams to MR, and also integral multiples of the rf wave length of KEK-PS which might become a hadron beam booster of MR in the future option of the TRISTAN project.

According to the super periodicity of MR, it can be divided into four quadrants whose both ends are marked off by neighbouring pair of the colliding points. Each quadrant consists of two mirror symmetrical octants whose one end is a colliding point and the other end is the centre of the quadrant, called a symmetry point.

The length of the long straight section was decided considering a space for installation of experimental insertions and a room for rf cavities which must provide enough rf voltage to sustain electron and positron beams at energy as high as 30 GeV.

Table 1
Geometrical Parameters

circumference	3018.08m
average radius of ring	480.34m
average radius of arc	346.69m
length of long straight section	4x194.35m
length of wiggler straight section	4x15.59m
number of colliding points	4
length of magnet free area	
at collision point with QCS	5.4m
without QCS	9.0m

LATTICE STRUCTURE

An octant of MR is divided to three sections which are, counting from a symmetry point to a colliding point, a wiggler straight section, an arc section which consists of normal cells and dispersion suppressor cells, and a long straight section to which rf cells and an experimental insertion belong. Principal parameters of the MR lattice are shown in Table 2 and those of the dipole and quadrupole magnets are listed in Table 3.

<u>A WIGGLER STRAIGHT SECTION</u> Here prepared is a magnet free space of 9.0m long for installation of wiggler magnets which should provide additional stabilizing mechanisms against undesirable beam instabilities especially during the injection process. A big dispersion function is desirable here for the effective work of wiggler magnets.

The time separation of the electron and positron bunch takes a maximum value of 2.5 microsec at the symmetry point because number of bunches per beam is two. Then the wiggler straight sections are the most suitable place for tools that monitor or handle electron and positron bunches independently.

<u>NORMAL CELLS</u> Betatron phase advances in a normal cell were chosen to be 60 degree in both horizontal and vertical planes because of the existence of the simple method of chromaticity correction. The length of the normal cell was decided to maintain high betatron tune in the arc sections, that is essential for beam

Table 2
Lattice Parameters

number of normal cells	116
length of normal cell	16.12m
phase advance in a normal cell	60deg
beta-function in normal cell (max/min)	27.7m/9.38m
dispersion function in normal cell (max/min)	0.961m/0.585m
number of dispersion suppressor cells	20
length of dispersion suppressor cell	15.42m
number of rf cells	40
length of rf cell	14.15m
phase advance in a rf cell (hori/ver)	57deg/78deg
beta-function in rf cell (hori/ver) maximum	26.8m/21.6m
minimum	8.2m/5.8m
beta-function at colliding point (hori/ver) in mini-beta optics	0.8m/0.05m
in backup optics	1.6m/0.1m
maximum beta-function (hori/ver) in mini-beta optics	164m(QC1)/180m(QCS)
in backup optics	240m(QC2)/274m(QC1)
betatron tune (hori/ver)	32.75/38.60
betatron tune in arc (hori/ver)	23.5/23.7
momentum compaction factor	1.5x10-3
horizontal damping partition number	1.00005
momentum dependence of horizontal damping partition number	-285.6
natural chromaticity (hori/ver) in mini-beta optics	-59.1/-91.6
in backup optics	-64.5/-95.5

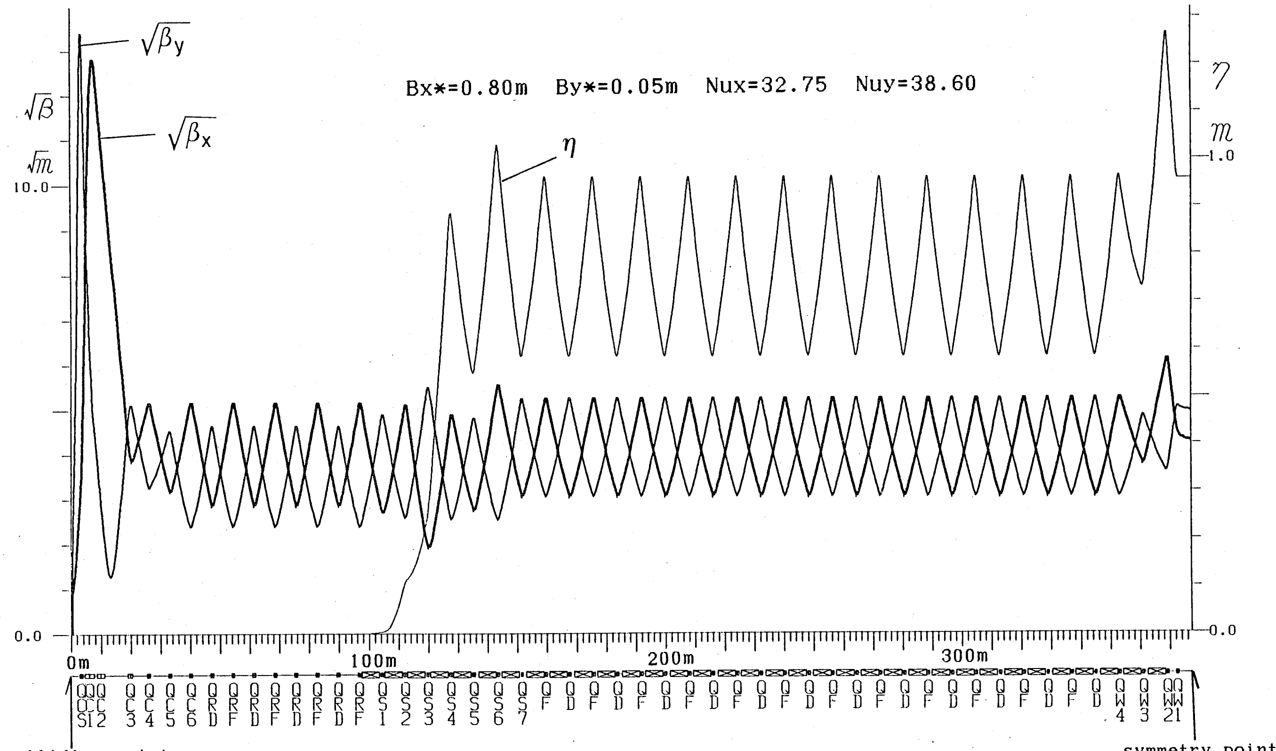

Fig. 1 TRISTAN-MR Mini-beta Optics along the Octant

operation at higher energy than 25 GeV.

In each normal cell, a pair of sextupole magnets are installed for chromaticity correction.

<u>DISPERSION SUPPRESSOR CELLS</u> In contrast with the completely periodic beta and dispersion functions in the normal cells, dispersion function is modulated to vanish in the long straight section and beta-function is adjusted to become completely periodic in the rf cells.

The dipole magnet located nearest to the rf cells bends beams only by 1mrad compared to 24mrad of the normal bending magnet so that strong synchrotron radiation should not hit directly the experimental apparatus which is placed 100m downstream of this dipole magnet.

<u>RF CELLS</u> The length of an rf cell is 24 times as long as an rf wave length of 0.5895m in order that rf cavities are situated periodically in every rf cell. Number of rf cavity cells in one rf cell is 36 for normal conducting cavities. For superconducting cavities, this number is reduced to 20 because of the space for cryogenic vessels.

The cell length is made shorter by about 2.0m and the vertical betatron phase advance is higher by 18 degrees in the rf cells than those in the normal cells, so that the averaged beta-function is smaller by about 30 percent in the rf cells. The reduction of beta-function and the vanishing dispersion in the rf cells aim at increasing of threshold current of the beam instabilities that may be caused by long rf cavities of high impedance.

Some of the rf cells are occupied by the injection tools such as septum magnets, kicker magnets and bump magnets and by the active damper system of coherent transverse oscillations.

<u>EXPERIMENTAL INSERTION</u> For electron-positron collisions, two kinds of optics are prepared, namely mini-beta optics and backup optics. In the mini-beta optics that aims at the highest luminosity, super-conducting quadrupole magnets QCS are switched on, conventional low-beta magnets QC1 are horizontal focusing and QC2 magnets are turned off. The backup optics is necessary for some beam exercises at the early stage of MR operation and back up of the integrated luminosity for the case of QCS's failure. In the backup optics, the polarity of QC1 is reversed to vertical focusing and QC2 magnets are switched on.

Table 3
List of Dipoles and Quadrupoles

name	number	length m	bending radius m
B	264	5.86	246.53
BW	8	5.86	5860.0

name	number	length m	strength(B'/B*rho) m-2
QW1	8	0.8	-0.1274
QW2	8	0.8	0.1800
QW3	8	0.8	-0.1312
QW4	8	0.8	0.1362
QD	96	0.8	-0.1603
QF	96	0.8	0.1605
QS7	8	0.8	-0.1784
QS6	8	0.8	0.1759
QS5	8	1.0	-0.1570
QS4	8	1.0	0.1774
QS3	8	1.0	-0.1656
QS2	8	1.0	0.1800
QS1	8	1.0	-0.1646
QRF	32	1.0	0.1544
QRD	32	1.0	-0.1784
			mini-beta/backup
QC6	8	1.0	0.1445 / 0.1497
QC5	8	1.0	-0.1439 /-0.1230
QC4	8	1.0	0.1196 / 0.0864
QC3	8	1.5	-0.1501 /-0.1902
QC2	8	2.5	0.0 / 0.1021
QC1	8	3.0	0.1230 /-0.1398
QCS	8	1.0	-0.5922 / 0.0

In both cases of the mini-beta optics and the backup optics, this experimental insertion is endowed with the function of the constant phase tunable insertion (3) in which the optics can be detuned without changing the phase advances by adjusting quadrupoles in the experimental insertion. While beam filling or energy ramping is going on, in use is the detuned optics where the maximum beta-function and strengths of sextupoles are made smaller in order to make MR less sensitive to error fields and beam instabilities.

Fig.1 shows beta and dispersion function along the octant in the case of mini-beta optics. Some beam parameters and rf parameters are given in Table 4 and Table 5, respectively.

CHROMATICITY CORRECTION

In TRISTAN-MR it is required to attain excessive high energy for its radius. High betatron tune has, therefore, been introduced to make up for the increase of beam emittance that is proportional to the square of its energy. This situation makes chromaticity correction of MR more difficult, and still leaves some open questions related to chromaticity correction in spite of intensive works.(4)

CORRECTION SCHEME Taking advantage of 60 degree phase advance in the normal cell, sextupole magnet system of six families provides good starting points of chromaticity correction according to the strategy by which the strength of sextupoles are decided uniquely. This strategy requires not only that the natural chromaticity should be corrected to some slightly positive value but also that the momentum abberation of beta-function and its slope produced mainly in the experimental insertion should vanish at the symmetry point.

Unfortunately these starting points do not mean always the satisfactory performances in particle tracking. In some cases, the dynamic aperture is too small and the nonlinear deviation of tune is too large.

Then a linear lattice and strengths of sextupoles must be somewhat modified according to individual considerations. This modification results in the restriction of possible betatron tune.

Table 4
Beam Parameters

nominal beam energy	30GeV
number of bunches per beam	2
radiated energy per revolution	290MeV
transverse radiation damping time	2.08msec
r.m.s. natural energy spread	1.64x10-3
natural horizontal emittance	1.794x10-7rad*m
maximum r.m.s. beam size in normal cell	
horizontal(zero-coupling)	2.72mm
vertical(full-coupling)	1.57mm
maximum r.m.s. beam size in rf cell	
horizontal(zero-coupling)	2.19mm
vertical(full-coupling)	1.39mm
r.m.s. beam size at colliding point	
optimum coupling(hori/ver)	
in mini-beta optics	0.367mm/0.023mm
in backup optics	0.520mm/0.032mm
maximum r.m.s. beam size in a ring	
hori(zero-coupl)/ver(full-coupl)	
in mini-beta optics	5.43mm/4.01mm
in backup optics	6.56mm/4.96mm

Table 5
RF Parameters

revolution frequency	99.33KHz
rf frequency	508.58MHz
harmonic number	5120
unit cell length of rf cavity	0.2947m
maximum number of rf cavity cells	
for conventional rf cavity	1296
for super-conducting rf cavity	720
over voltage ratio for 24 hrs life	1.314
peak rf voltage "	383MeV
rf bucket height "	1.09x10-2
synchronous phase angle "	130.5deg
synchrotron oscillation frequency "	9.98KHz
natural bunch length "	1.17cm

EXPERIMENTAL INSERTION DESIGN The chromaticity correction is closely related to the design of the experimental insertions in which the greater part of chromatic deviation is produced. Once some beam parameters and an arrangement of the experimental insertion are fixed, given is a lower limit of the beta-function at the collision point below that the present method of chromaticity correction does not work well. This lower limit also depends on collision energy through the fact that spread of beam energy and required dynamic aperture increase with energy, then the experimental insertions must be differently optimized according to respective beam energies.

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REFERENCES

1. T.Nishikawa: Proc. U.S.-Japan Seminar on High Energy Accelerator Science, Tokyo and Tsukuba, Nov. 1973 (KEK,1973) p.209.
2. S.Kamada, M.J.Lee, and T.Suzuki: KEK Report 76-1 (1976)
3. S.Kamada: Proc. 4th Simpo. on Accelerator Science and Technology, Nov. 1982 (RIKEN, Saitama, 1982) p.89.
4. A.Ando: KEK Report 80-9 (1980)
   L.Chen: KEK Internal 82-1 (1982)
   Y.Wu: KEK Report 84-3 (1984)
   Y.Wu and K.Egawa: KEK Report 84-8 (1984)
   Y.Chin: KEK Report 84-9 (1984)