Mini-β Structure for ANKA

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Abstract

ANKA is a 2.5 GeV synchrotron radiation facility, which consists of a 500 MeV injector and 2.5 GeV electron storage ring. The storage ring has a four-fold symmetry with a double DBA-structure. The optics was designed with tune values of (6.85, 3.22) and beam emittance of $9.14x10^{-8}$m.rad suitable for x-ray lithography and micro- or nano-fabrications. There are four short drift sections (2.2m) used for injection and rf installations and the four long drift sections (5.6m) are kept for insertion devices. The lattice is studied for insertion of mini β insertion devices in the long drift section keeping the short drift section β as high as before. The optics is optimised for ~1-2m β in the long drift section with little modifications in that section and rest of the lattice is untouched. The present lattice and the modified lattice keeping sufficient marginal gap for such devices are reported in detail.

1 INTRODUCTION

The Synchrotron Radiation Source ANKA [1-2] consists of a 500 MeV injector and a 2.5 GeV storage ring. The storage ring has four-fold symmetry, with eight double bends, four long straight sections of 5.6m for insertion devices and four short straight sections of 2.2 m for injection and RF installation. The main parameters of the storage ring are given in table 1.

The complete injector [3], consisting of a racetrack microtron and a booster synchrotron, was built and commissioned by DANFYSIK in 1999. Commissioning of the storage ring started on 7th of December of same year. At present the machine is operating with 150-180mA at 2.5GeV with a beam lifetime of 10 hours dedicated to the beam line operation [4].

In this paper we explore the possibility of upgrading present ANKA lattice to a mini-β insertion lattice keeping the same periodicity and applying minimum changes in the unit cell. The RF cavities are installed in the short drift section and the long drift sections are reserved for insertion devices. In the present optics, the betatron functions are almost the same in both the drift sections. We propose betatron functions are ~ 1-2m in the insertion section and retaining the betatron function as before in the RF section. A brief account of the theoretical studies made is reproduced here.

Table 1: Parameters of ANKA at 2.5 GeV

Parameter		Unit
Energy	0.5-2.5	GeV
Circumference	110.4	m
Number of dipoles	16	
Dipole field	1.5	T
No. of quadrupoles	40	
Maximum gradient	18	T/m
Number of sextupoles	24	
Maximum gradient	520	T/m^2
Design tune (Q_x, Q_y)	6.85, 3.22	
Mom. compaction	0.00807	
Natural Chromaticity	-13.9 , -9.0	
Energy spread	0.09027	%
Revolution time	368.254	ns
Damping times(x,y,ε)	3, 2.9, 1.46	ms
Harmonic number	184	
RF frequency	499.660	MHz
Energy loss per turn	622	keV
Emittance	91.44	nm rad

2 THE OPTICS OF THE LATTICE

The classical Double Bend Achromatic lattice has two bending magnets within the cell. Between these bending magnets there is chromaticity compensation. At the beginning and at the end of the cell there is a doublet or a triplet of quadrupoles for the matching of the machine functions to the desired values within the straight sections with some tunability. In the case of ANKA only doublets are used for matching the machine parameters.

2.1 Normal ANKA lattice

The ANKA lattice is a modified version of combination of two basic DBA cells with a pair of doublets for matching of machine functions having mirror symmetry at the centre of the unit cell. The storage ring has a four-fold symmetry, with eight double bends, four long(5.6m) straight sections for insertion devices and four short straight section (2.2 m) with a circumference of 110.4m. The lattice functions are shown for this lattice at the design tune of (6.85, 3.22) in figure 1 optimised for the beam emittance of 91nm.rad keeping the betatron functions below a maximum of 20m.

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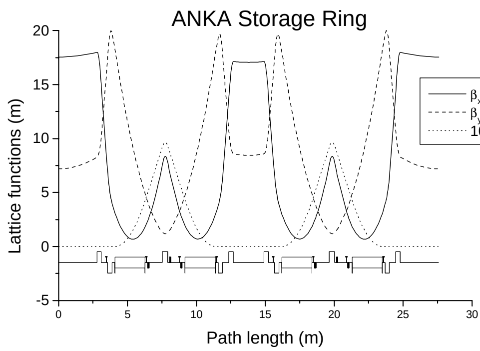

Figure 1: The lattice functions at the design tune point of ANKA.

At the centre of the long drift sections, the horizontal and vertical betatron amplitudes are 17.5 and 7.2m respectively. The resulting beam sizes with an emittance coupling factor of 1% are 1.27mm, 0.081mm in horizontal and vertical plane respectively. At present no insertion device is installed. The beam lines are tapped from the bending magnets. The machine is now operating at the tune point of (6.82, 3.27) very near to the design tune point.

2.2 Mini-β configuration of ANKA lattice

In the future ANKA will have insertion devices in the long drift sections. In particular undulators introduce some vertical focussing effect on the electron beam when installed in a storage ring, and therefore change the vertical tune slightly. This tune shift is given simply by the following equation [5].

$$\Delta\nu = \frac{1}{4\pi}\beta_y\left(\frac{0.3}{E}\right)^2 \frac{B_0^2 L_u}{2}$$

Where β_y is the beta function at the undulator section in meter, E is the electron beam energy in GeV, B_0 is the peak undulator magnetic field. To minimise this tune shift, the betatron amplitude function is made small in this section, as it is directly proportional to the same. For nominal tune shift the betatron functions are chosen around 1-2m.

The investigation of feasibility of ANKA machine to operate in a mini-β configuration was initiated with an idea not to change the defocussing quadrupole near the dipole in the long drift section. With different doublets and triplets the mini β solutions are obtained. The results show that above mentioned quadrupole needs strength higher than specified. So, one has to modify this quadrupole too. In practice, a doublet with modified lengths and a triplet with similar lengths were taken for investigation of mini β solutions. The solutions of such a doublet structure is discussed below.

The modification of the lattice functions from 17.5, 7.2m to 0.3, 2m in both the planes in the long drift section while the short drift section is kept untouched, is accomplished by modifying the lengths of the doublet in the long drift section. The allowable field strength is 2.1m^{-2} at 2.5GeV keeping the magnetic field gradients at 18T/m in quadrupole magnets and replacing only in the long drift section. To find some reasonable solutions for the mini-β configuration, it is found that the existing quadrupoles with 320mm lengths cannot be used. The lengths of the doublet are now 400mm and 500mm. A drift of 4.6m is still available for utilisation for insertion devices. The lattice functions at the selected tune point of (8.82, 3.74) are shown in figure 2 where the beam emittance is reduced further from 91nm.rad to 77nm.rad.

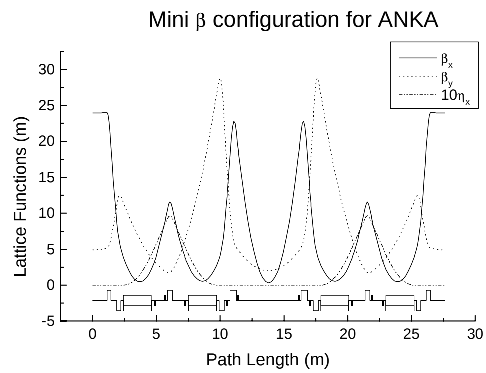

Figure 2: The lattice functions at the tune point of (8.82, 3.74) with beam emittance of $7.722\text{x}10^{-8}$ m.rad.

The energy acceptance of the machine is reduced in the mini-β configuration. To improve this, one can introduce harmonic sextupoles in the dispersion free section. The energy acceptance is still better by introducing the harmonic sextupoles in the RF section too. But, in practice there is no space available for such insertion of sextupoles over there. As a realistic upgrade one can think of changes in the long drift section with suitable redesign of vacuum chambers and quadrupoles.

Table 2: The beam sizes in the long drift for 1% coupling

Parameter	Normal	Mini-β
Tune	6.85, 3.22	8.82, 3.74
β_x, β_y (m)	17.5, 7.2	0.3, 2
ε_x(nm.rad)	91.4	77.2
σ_x(mm)	1.27	0.154
$\sigma_{x'}$(mrad)	0.072	0.501
σ_y(mm)	0.081	0.0393
$\sigma_{y'}$(mrad)	0.011	0.0196
ξ_x, ξ_y	-13.9, -9.0	-24.6,-12.5

The dynamic aperture is the tracking result of BETA [6] for 100 turns in the beginning of the RF section with harmonic sextupoles installed in the insertion section along with the existing chromaticity correcting sextupoles as shown in figure 3 at the above tune point. For optimisation of dynamic aperture the harmonic sextupole strengths (S_1, S_2) are adjusted manually and the chromaticity correcting sextupoles (S_h, S_v) are adjusted automatically for zero chromaticity. In this calculation, no magnetic multipole field errors are considered. The integrated sextupole strengths are found out to be 4.11, 3.51 m^{-2} for horizontal and vertical chromaticity correcting sextupoles respectively. The integrated harmonic sextupole strengths found out are 0.75, 0.48 m^{-2} for horizontal and vertical sextupoles respectively and are comparatively weak. It is seen that the dynamic aperture is rather good without harmonic sextupoles also.

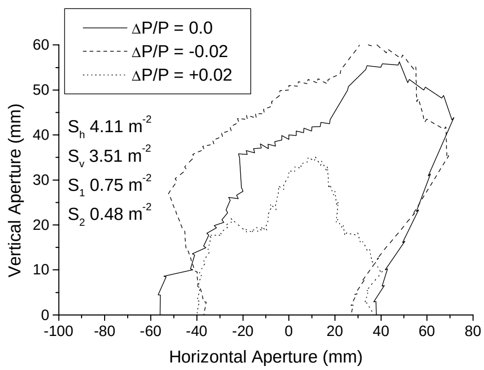

Figure 3: Dynamic aperture for the tune point (8.82, 3.74) for $\Delta P/P = \pm 2\%$

The momentum dependent tune shift from figure 4 indicates that the tune change is more sensitive to the momentum deviation.

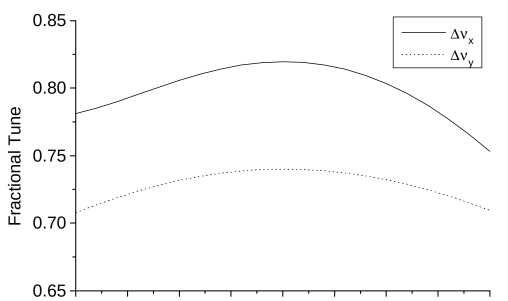

Figure 4: Momentum dependant tune shift for the mini-β configuration.

The mini-β study was also done with a triplet in the long drift section. In this case the dynamic aperture is better for higher beam emittance. The lattice functions for a minimum beam emittance of 104nm.rad is shown in figure 5.

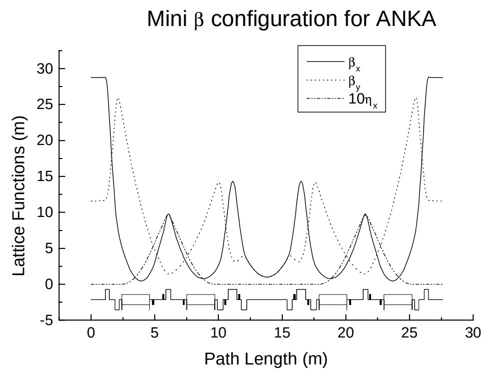

Figure 5: The lattice functions at the tune point of (8.2, 4.28) with beam emittance of 1.04×10^{-7} m.rad.

The dynamic aperture calculated for this tune point is very small even though the harmonic sextupole strengths are relatively high. From the comparison of dynamic aperture at the minimum beam emittance, it is found that the doublet configuration is better than the triplet case.

3 CONCLUSIONS

With a minimum disturbance to the ANKA machine, it is possible to provide 4.6m of drift space for insertion devices as mini-β insertions on upgrade of the machine. The beam emittance is kept at 77nm.rad in comparison to the normal beam emittance of 91nm.rad, but the beam size is reduced by a factor of 9 in the long drift section. The beam emittance is further reduced to 25nm.rad by introduction of damping wigglers in the insertion section. The injection scheme and the modification of vacuum chambers are to be studied for this mini-β configuration as it affects the position of the existing injection kickers. The possibility of modifying the present ANKA lattice to a mini-β lattice is feasible. The dynamic aperture is sufficiently large with weak harmonic sextupoles. This study will further be explored to find out possibility of any better solution.

REFERENCE

[1] R.A. Babayan, I. Ingrid, G. Buth, S. Doyle *et al*, Proc. Int. Conf. SRMS-2, Jpn. J. Appl. Phys. Vol.38 (1999) Suppl. 38-1, pp. 685-661
[2] D. Einfeld, S. Hermle, E. Huttel, A. Krussel *et al*, Nucl. Instr. Methods A 448 (2000), pp. 20-26
[3] L. Prstegaard, H. Bach, D. Einfeld, N. Hertel et al, Investigation of the ANKA injector, This proceedings.
[4] D. Einfeld, E. Huttel, F. Perez, M. Pont, G.K. Sahoo, Commissioning results of ANKA, This proceedings.
[5] M.W. Poole and R.P. Walker, IEEE Trans. Nucl. Sci. NS-32, 3374 (1985)
[6] L. Farvacque, J.L. Laclare, A. Ropert, BETA user's guide, ESRF-COMP-87-01, 1987