A LATTICE STUDY FOR THE SYNCHROTRON RADIATION FACILITY OF THE TURKISH ACCELERATOR COMPLEX (TAC) WITH 3.56 GeV

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Abstract

The Turkish Accelerator Complex (TAC) is a project for accelerator based fundamental and applied researches supported by Turkish State Planning Organization (DPT). The proposed complex is consisted of 1 GeV electron linac and 3.56 GeV positron ring for a charm factory and a few GeV proton linac. Apart from the particle factory, it is also planned to produce synchrotron radiation from positron ring.

In this study, the lattice structure design of the positron storage ring is made to produce the third generation synchrotron light. It has been studied with different lattice structures (DBA, TBA, DDBA) for TAC. It has been compared lattice structures and tried to find the best structure for lowest emittance.

INTRODUCTION

In recent years, electron storage rings have frequently been used as light sources for research in atomic, molecular, condensed matter and solid state physics, chemistry, cell biology etc. For many experiments, it is desirable to use high brightness light, which requires a small emittance of the beam.

Storage rings are built up with different magnet structures: double bend achromat (DBA), triple bend achromat (TBA) and double-double bend achromat (DDBA). The emittance of each structure can be expressed as [1]:

$$\varepsilon_{xo}=f\cdot[1/12\sqrt{15}]\cdot[C_q]\cdot[\gamma^2]\cdot[1/J_x]\cdot[\theta^3] \qquad (1)$$

where θ is the deflection angle of the bending magnet, f is a so called quality factor for each structure, γ is the Lorentz factor of the beam, J_x is the horizontal partition factor and C_q= 3.84 x 10^{-13}m.

DBA, TBA and DDBA lattices, composed of N_p periods with iso-magnetic field dipoles and θ_p bend angle per period, have a minimum emittance given by [2]

$$\varepsilon_{DBA}=[1/4\sqrt{15}]\cdot[C_q]\cdot[\gamma]^2\cdot[1/J_x]\cdot[\theta^3]\cdot[1/8] \qquad (2)$$

$$\varepsilon_{TBA}=[1/4\sqrt{15}]\cdot[C_q]\cdot[\gamma]^2\cdot[1/J_x]\cdot[\theta^3]\cdot[1/40.707] \qquad (3)$$

$$\varepsilon_{DDBA}=[1/4\sqrt{15}]\cdot[C_q]\cdot[\gamma]^2\cdot[1/J_x]\cdot[\theta^3]\cdot[1/96] \qquad (4)$$

#cf: combined function

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THE DBA LATTICE

DBA lattice, composed of cf#-bending magnets and quadrupole doublet, has been studied for 3.56 GeV positron storage ring of the TAC [3].

The unit cell with a defocusing bending magnet (cf-magnet) has a threefold advantage [4]:

1) The number of magnets per achromat is reduced,
2) The partition number J_x is larger than 1 and thus reduces the emittance,
3) The length of the cell is small, therefore the total circumference is reduced.

Only two free parameters, which can be varied to minimize the emittance, are the strength of the focusing quadrupole and the quadrupole strength of the bending magnet. Besides, J_x is increased to 1.69.

For the theoretical minimum emittance, ε_{DBA}*=1.814 nm·rad*, ε_x*=5.544 nm·rad* can be obtained for the optical result of the minimum emittance.

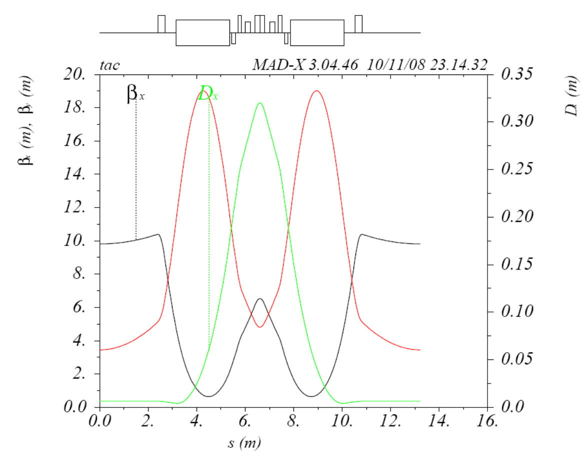

Figure 1: Lattice functions for 23 periods DBA lattice

THE DOUBLE-DOUBLE BENDING ACHROMAT

Also DDBA lattice has been studied for the TAC positron ring with 3.56 GeV, with a type of lattice composed of cf#-bending magnets and quadrupole doublet.

For the theoretical minimum emittance with J_x=1.68, ε_{DBA}*=0.642 nm·rad* , for the optical result of the minimum emittance, *4.13 nm·rad* < ε_x < *8.82 nm·rad*

Only two free parameters, which can be varied for the optimization of the emittance, are the strength of the outer focusing quadrupoles of the half lattice and the quadrupole strength of the bending magnet. We can optimize the beam emittance to have any value from 4.13 nm·rad to 8.82 nm·rad. Figures 1 and 2 show the lattice functions for DBA and DDBA performed by using of MAD-X [5].

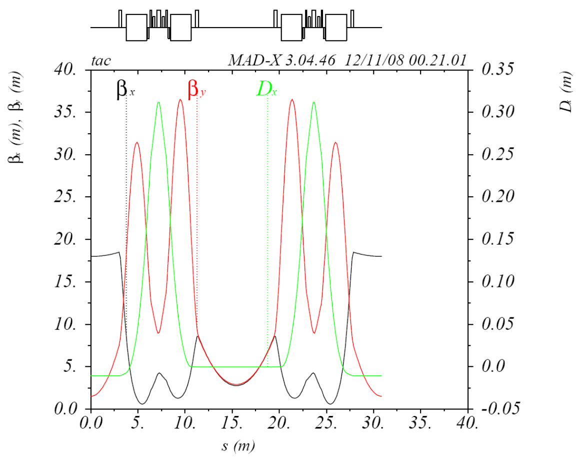

Figure 2: Lattice functions for 12 periods DDBA lattice.

Table 1 presents the main parameters of the storage ring for two alternative lattice structures.

It is shown that the DDBA with 12 superperiods is more effective than the DBA with 23 superperiods. The DDBA is quite flexible due to having two alternative straight section. The one of them is 6m short straight section and the other is 8m long straight section. The rate of the total straight section to full circumference is 45.34% at the DDBA. Thus, convenient points where the insertion devices (IDs) are included in the storage ring, are obtained.

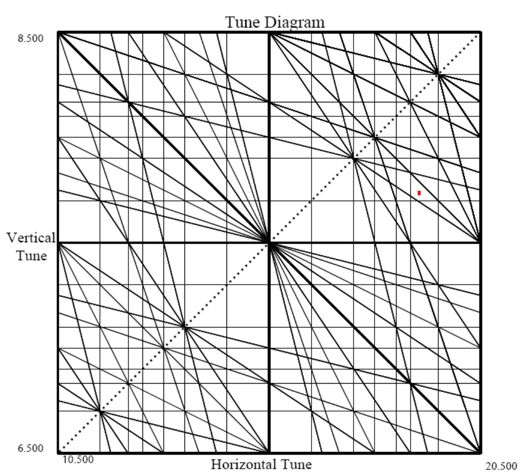

Figure 3: Tune diagram of the DBA lattice.

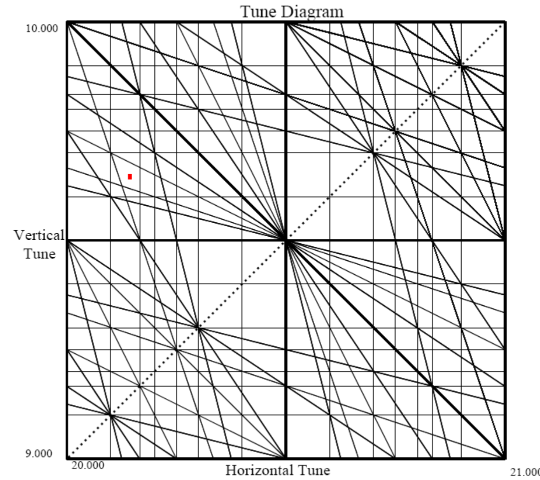

Figure 4. Tune diagram of DDBA lattice.

Besides, the beta functions and dispersion at long straight section (8m) in the DDBA lattice are property of the round beam size. The zero dispersion can be reached only in this case.

Injection point from booster to storage ring has to be long straight section. The long straight section (8m) in the DDBA is acceptable for this requirement. The short straight sections can be considered for radio-frequency (RF) cavities or extraction point.

Table 1: Main Parameters of the Storage Ring

Achromatic structure	**Units**	**DBA**	**DDBA**
Nominal energy	GeV	3.56	3.56
Superperiod		23	12
Circumference	m	304.6	370.56
Harmonic number		512	624
Max. Beam Current	mA	400	400
Energy loss/turn	keV	883.2	846.4
Total radiation power	kW	353.3	338.5
Energy spread	%	0.094	0.092
Momentum compaction factor		0.0011	0.0008
Beam lifetime	h	38.5	36.3
Damping times			
Horizontal damping	msec.	2.406	3.095
Vertical damping	msec.	4.09	5.201
Synchrotron damping	msec.	3.146	3.941
Horizontal emittance-ε_x	nm·rad	5.544	8.824
Vertical emittance-ε_y	pm·rad	55.4	88.24
Betatron tunes[Q_x/Q_y]		18.9/7.6	20.2/9.7
Chromaticities[ξ_x/ξ_y]		-28.2 -24.7	-29.6 -47.7
Beta functions at long and fixed straight sections			
Horizontal	m	10.4	2.7
Vertical	m	5.2	2.9
Dispersion	m	0.006	0
Straight Section			
Fixed straight section	m	23 x 4.8	-
Long straight section	m	-	12 x 8
Short straight section	m	-	12 x 6
Total straight section	%	36.24	45.34

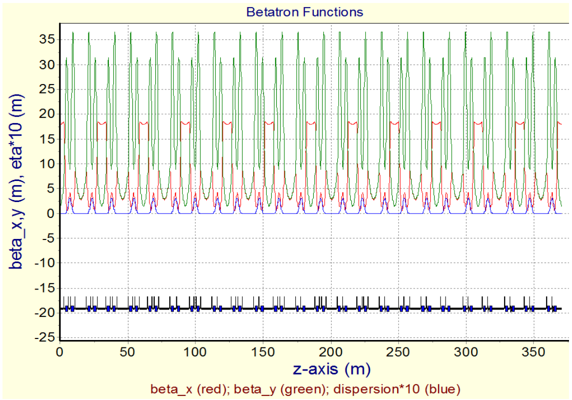

Figure 5: Lattice functions for the full storage ring with the DDBA.

Figure 5 shows the lattice functions for the full storage ring with the DDBA performed by using BEAMOPTICS [6]. Figure 6 shows the schematic view of the full storage ring given by the DDBA with 12 superperiods.

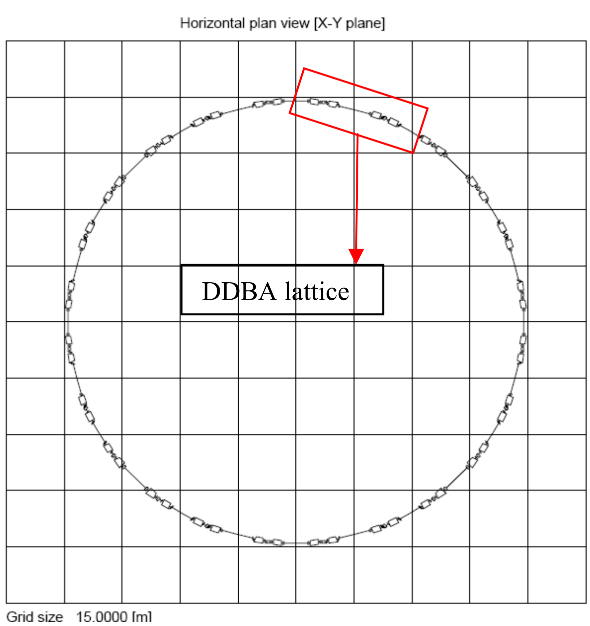

Figure 6: The schematic of the full storage ring with DDBA lattice.

CONCLUSION

Various lattices for 3.56 GeV positron synchrotron light source on the bases of TAC has been investigated: DBA and DDBA. Out of these lattices, DDBA structure gives the most effective solution and it determines parameters of the storage ring. Therefore, the DDBA lattice for the unit cell was preferred on designing the ring to provide more brilliant synchrotron radiation.

The given DDBA lattice provides an approach to obtain significantly lower emittances compared to conventional DBA and TBA lattices. The advantages of DDBA are contribution of cf-bending magnets to the emittance, a large horizontal partition number which further reduces the emittance, a small number of quadrupole magnets and a short unit cell.

REFERENCES

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