A STUDY OF LATTICE STRUCTURE AND INSERTION DEVICES AT THE POSITRON RING OF THE TAC PROJECT

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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. The parameters of complementary undulators and wigglers are determined. It is shown that the insertion devices with the proposed parameter sets produce maximal brilliance to cover 10 eV – 100 keV photon energy range.

INTRODUCTION

In recent years, electron and positron 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 brilliance light, which requires a beam with small emittance.

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

$$\varepsilon_{xo} = f.\frac{1}{12\sqrt{15}}.C_q.\gamma^2.\frac{1}{J_x}.\theta^3 \quad (1)$$

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.

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

$$\varepsilon_{DDBA} = C_q\frac{\gamma^2}{4\sqrt{15}}\frac{\theta_p^3}{J_x}\frac{1}{96} \quad (2)$$

In this study, we have designed DDBA lattice for the positron storage ring of TAC and determined properties of the radiation produced at undulators and wiggler placed on it. In the next section, we give the results of the study on DDBA lattice that has been investigated in order to provide more brilliance for the synchrotron radiation.

At the rest of the paper, we present the effects of insertion devices (IDs) at the ring on the beam parameters and spectral brightness that obtained from IDs.

DOUBLE-DOUBLE BEND ACHROMAT

A DDBA lattice, composed of cf#-bending magnets and quadrupole doublet, has been studied for 3.56 GeV positron storage ring of the TAC [3]. Table 1 present parameters of the storage ring and figure 1 gives the behaviour of the lattice functions for 12 period DDBA lattice.

Table 1. Main parameters of the storage ring

Achromatic structure	**Units**	**DDBA**
Nominal energy	GeV	3.56
Superperiod		12
Circumference	m	370.56
Max. Beam Current	mA	400
Energy loss/turn	keV	846.357
Total radiation power	kW	338.543
Energy spread	%	0.0916
Momentum compaction factor		0.0008
Beam lifetime	h	36.29
Horizontal emittance-ε_x	nm·rad	8.824
Vertical emittance-ε_y	pm·rad	88.243
Betatron tunes[Q_x/Q_y]		20.19/9.7
Chromaticities[ξ_x/ξ_y]		-29.6/-47.7
Beta functions at long straight section		
Horizontal	m	2.76
Vertical	m	2.9
Dispersion	m	0
Long straight section		12 x 8m
Short straight section		12 x 6m

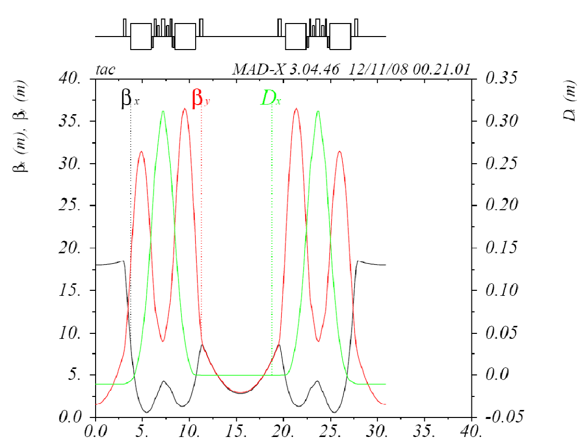

Figure 1. Lattice functions for 12 period DDBA lattice

EFFECTS OF THE IDs ON THE LATTICE

We have investigated the effects of the IDs on the betatron tune, the energy spread, the emittance and beta

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#cf: combined function

functions. Table 2 presents parameters of the IDs in the storage ring. Table 3 presents variations of the emittance, the energy spread, the horizontal tune and the beta functions that are obtained from numerical calculations performed by using of BEAMOPTICS [4] and MAD-X [5].

When the five insertion devices are included at the ring, it is shown that the emittance is reduced from 8.824 nm·rad to 7.493 nm·rad. Besides, after first four undulators, the energy spread is reduced from 0.0916% to 0.0897%, but after the last wiggler (33mm-W_{sc}), it is increased by 0.09621%. In general, the energy spread is increased by 5.03%. The working point at the tune diagram of the main ring with five IDs is shown at figure 2.

Table 2. Parameters of the IDs at the ring

ID	Length (m)	Period number	Magnetic field (T)	Max.K
185-U	3.515	19	0.751	12.97
75-U	3.45	46	0.747	5.23
22-U	1.606	73	0.91	1.87
45-U	2.97	66	0.843	3.54
33-W_{sc}	2.442	74	1.917	5.91

Figures 3(a) and 3(b) show the lattice with and without insertion devices (five IDs given in table 2) in the ring, respectively. Although the five IDs remarkably affect the horizontal beta functions at the short straight sections (6m), it is shown that there are relatively low effects at the horizontal beta functions at the long straights sections (8m). This result is quite acceptable since we propose long straight sections for the locations of the IDs. In addition, the total beam life time reduces from 36.29 h to 35.8 h.

Table 3. Effects of the IDs on the beam parameters

ID	$\Delta\varepsilon/\varepsilon$	$\Delta\sigma_\varepsilon/\sigma_\varepsilon$	$\Delta\nu_x$	$\Delta\beta/\beta$
185-U	-2.4%	-0.7%	0.0046	-2.24%
75-U	-2.05%	-0.71%	0.0034	-1.6%
22-U	-1.33%	-0.21%	0.0021	-0.9%
45-U	-2.17%	-0.45%	0.0036	-1.5%
33-W_{sc}	-7.95%	7.3%	0.0145	-5.3%

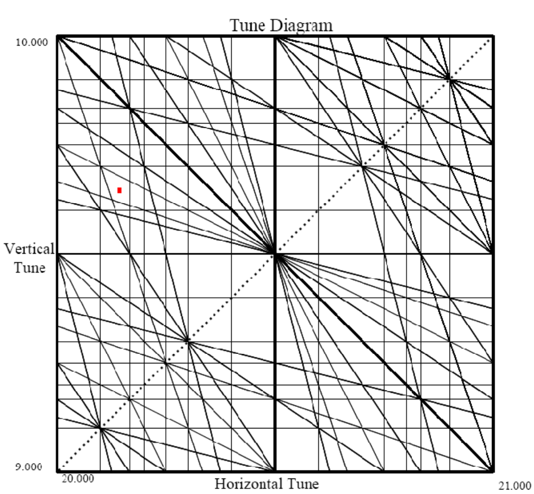
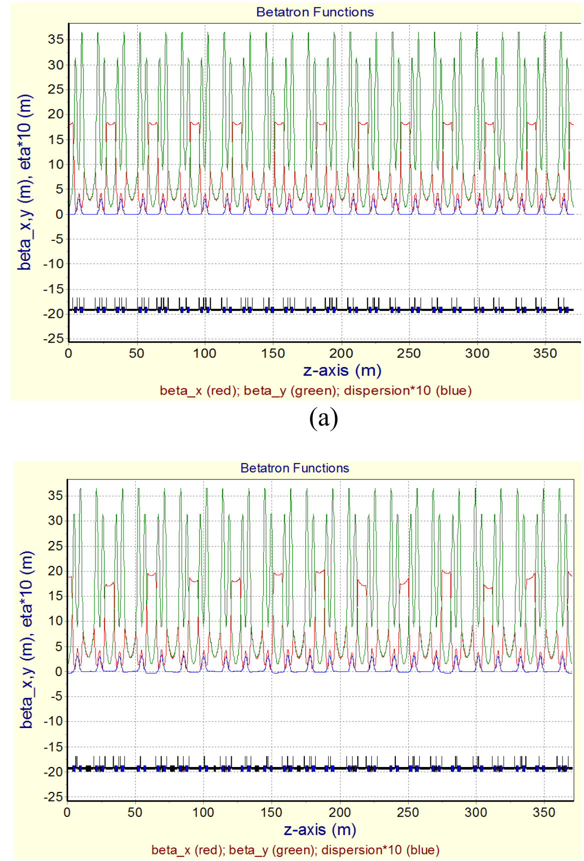


Figure 2. Tune diagram of the main ring with IDs



(a)

(b)

Figure 3. Optics at the storage ring: (a) without IDs, (b) with five IDs.

SPECTRUM OF THE RADIATION PRODUCED AT IDs

In this study, the lattice structure design of the positron storage ring is made to produce third generation synchrotron light.

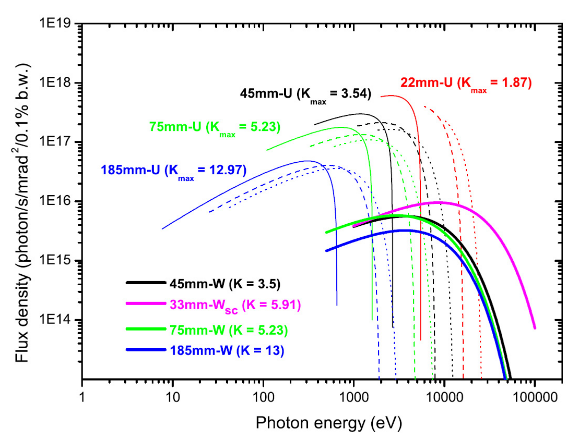


Figure 4. Flux density of the synchrotron radiation from IDs

The parameters of complementary undulators and wigglers are determined. It is shown that the insertion devices with the proposed parameter sets produce maximal brilliance values to cover 10 eV – 100 keV photon energy range.

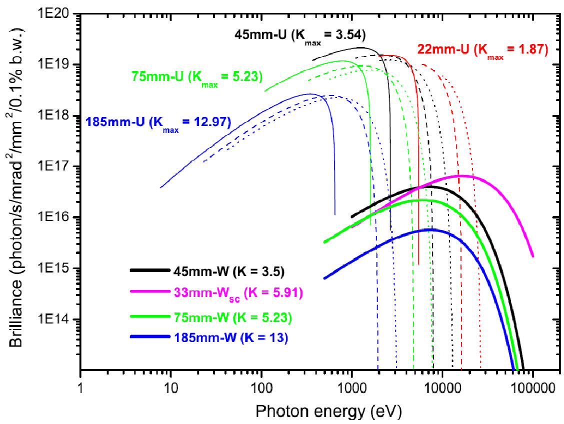


Figure 5. Brilliance of synchrotron radiation emitted from the undulators and wigglers at the TAC positron ring.

As IDs change beam parameters, spectral properties of SR produced by themselves are affected. The spectrums of the undulator and wiggler radiations might improve or deteriorate under the changes. To see the affects, we have plotted peak flux density and brilliance of the first, third and fifth harmonics by changing undulator parameter at Figs. 4 and 5. Also, the energy dependence of the wiggler radiations is shown at the same figures.

Table 4. Effects of the IDs on the quality of flux density of synchrotron radiation

ID	Max. Flux Density (photons/s/mrad^2/0.1%b.w.)		Relative change on flux density (%)
	Without optical correction	With optical correction	
185-U	$4.805 \cdot 10^{16}$	$4.398 \cdot 10^{16}$	+8.4
75-U	$1.771 \cdot 10^{17}$	$1.668 \cdot 10^{17}$	+5.8
22-U	$6.070 \cdot 10^{17}$	$3.234 \cdot 10^{17}$	+46.7
45-U	$2.989 \cdot 10^{17}$	$2.805 \cdot 10^{17}$	+6.2
33-W_{sc}	$9.548 \cdot 10^{15}$	$9.181 \cdot 10^{15}$	+3.8

Table 5. Effects of the IDs on the quality of brilliance of synchrotron radiation

ID	Max. Brilliance (photons/s/mrad^2/mm^2/0.1%b.w.)		Relative change on brilliance (%)
	Without optical correction	With optical correction	
185-U	$2.665 \cdot 10^{18}$	$2.183 \cdot 10^{18}$	+1.8
75-U	$1.186 \cdot 10^{19}$	$9.447 \cdot 10^{18}$	+20.3
22-U	$1.541 \cdot 10^{19}$	$2.038 \cdot 10^{19}$	-32.3
45-U	$2.134 \cdot 10^{19}$	$1.679 \cdot 10^{19}$	+21.3
33-W_{sc}	$6.440 \cdot 10^{16}$	$5.665 \cdot 10^{16}$	+12.0

To illustrate changes on the radiation of the IDs, we have given maximum values reached for flux density and brilliance on tables 4 and 5, respectively. One may apply some optical corrections on magnet lattice to have beam parameters unchanged even with IDs. We have also presented maximum flux density and brilliances at tables 4 and 5. Effects of the IDs are shown on last columns of the tables 4 and 5 as well.

CONCLUSION

In this study, a lattice for storage ring of the TAC is designed. Effects of IDs on both beam parameters and radiation properties are presented. Insertion of undulators and a wiggler to the storage ring seems to be tolerable. In addition, it improves radiation specs in general. However, one needs to look at other instability sources to determine if there is a need for optical correction.

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