THE STATUS OF TURKISH SYNCHROTRON RADIATION SOURCE MACHINE DESIGN*

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Abstract

Turkish synchrotron radiation source named TURKAY, is a part of the TAC (Turkish Accelerator Center) Project, is at conceptual design process. The radiation properties of a SR sources are strongly depends on the magnetic lattice of the storage ring. The storage ring is designed to obtain low emittance electron beam at 3 GeV energy. Optimization of the lattice properties, including the non-linear dynamics, is described in detail. Radiation properties are calculated by the example of some existing undulators from the other SR facilities.

INTRODUCTION

TAC is a national project aimed to build an accelerator center to Turkey and it is founded by Turkish Ministry of Development [1]. The first stage is TARLA facility which is in construction stage in Ankara [2]. The possible second facility is TURKAY which is third generation synchrotron radiation source and it is in design process. The design goals of Turkish light source is dedicated from the light source user meetings arranged by the TAC project.

The design goals of TURKAY are:

- Energy: 3 GeV
- High Brillance
- Long Beam Lifetime
- Low emittance with relatively short ring circumference
- Many straight sections.

The schematic of the facility is shown in Fig. 1. As it is seen from the figure the design concept of accelerator is composed from three part: Injector, Full Energy Booster Ring and Storage Ring. The electrons generated by a electron gun are firstly accelerated to 100 MeV in a linear accelerator and they are injected into a booster synchrotron which raises the electron energy up to 3 GeV which is the nominal energy of operation. Then, they are transferred into the circular storage ring of 477 m in length where they are maintained as long as possible. The synchrotron radiation will be produced from the undulators placed the straight sections and bending magnets on the storage ring.

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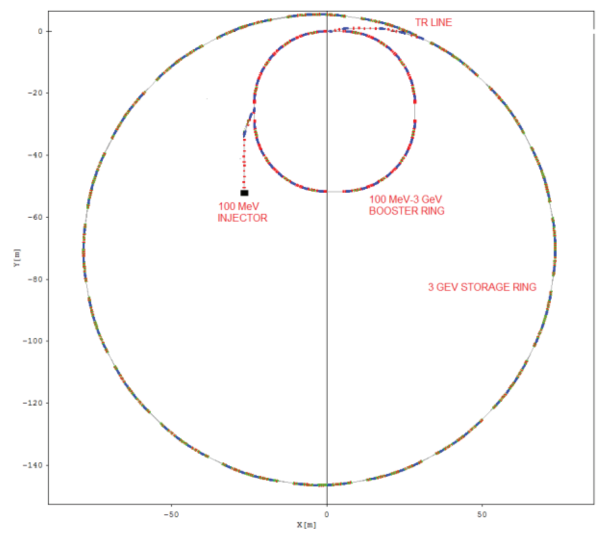

Figure 1: General layout of TURKAY.

STORAGE RING

Optical structure of the storage ring is basic part of the design and the properties of the radiation strongly depend on the parameters of the storage ring.

Parameters and Lattice of Storage Ring

The main consideration of the magnetic lattice is to achieve low emittance electron beam in order to achieve high brilliance photon beam. To reach low emittance value a new design concept is developed. In the design, the storage ring is composed with 20 main cells and its circumference is 477 m. The optical functions of the storage ring is given in Fig 2. Optical functions are calculated by OPA and MADX codes [3, 4]. The main cell consist of 4 bending magnet and 4 different type 16 quadrupoll magnet. The length of the bending magnets is 1.4 m and the required magnetic field is 0.52 T. 6 family of sextupoll magnet are used to correct chromaticity and to compensate nonlinear effects. The number of straight sections on the ring is 20 and their length are 5 m. The emittance value is 0.51 nm rad.

The ring has finite dispersion at straight sections but it can be tuned to achromatic mod by little change of quadrupolls strength. In that case the emittance value is around 0.90 nmrad. The main parameters of the storage ring are presented in Table 1.

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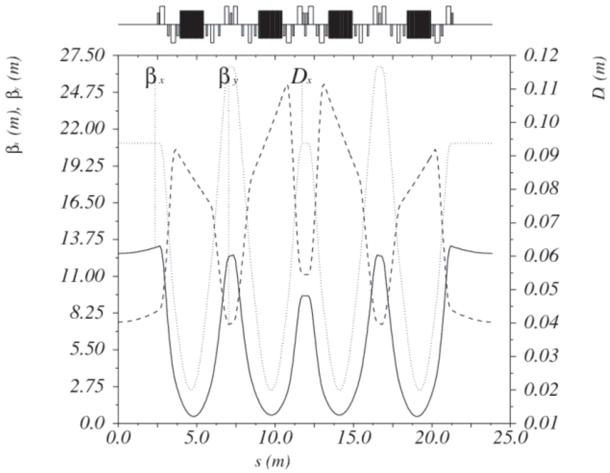

Figure 2: Optical functions of main cell.

Table 1: Main Parameters of Storage Ring

Parameters	Value
Energy (GeV)	3
Circumference (m)	477
Beam Current (mA)	500
H. Emittance (nm rad)	0.51
V. Emittance (nm rad)	0.0051
Betatron Tunes (Q_x/Q_y)	31.19/6.15
Natural Chromaticity ξ_x/ξ_y	-70/-38
Corrected Chromaticity ξ_x/ξ_y	0.0/0.0
Rf Frequency (MHZ)	500
Rf Voltage (MV)	3.5
RMS Bunch Length (mm)	2.1

Nonlinear Dynamics

The sextupol magnets are needed to compensate of the chromaticity but also they have negative effect the dynamic behaviour of the beam. This nonlinear effect limit the effective aperture for the particle motion. The reduced space is termed the dynamic aperture. For stable and reliable operation of the accelerator it is important to have as possible as large dynamic aperture. The dynamic aperture is calculated with particle tracking code ELEGANT [5]. Figures 3 and 4 show the dynamic aperture for different momentum offset and for different magnet error respectively. The dynamic aperture is large enough for such a low emittance ring. Also the effects of the magnet errors to dynamic aperture is not high.

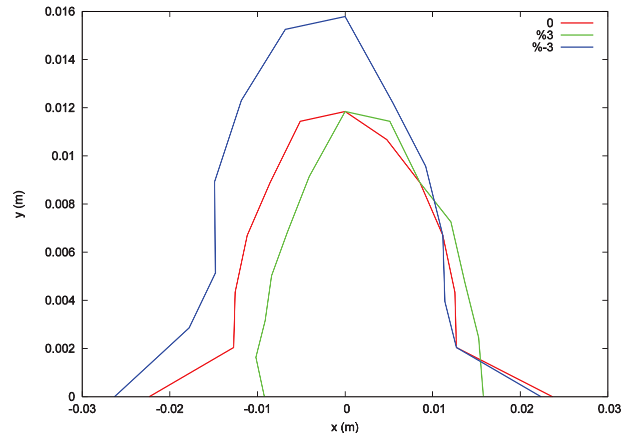

Figure 3: Dynamic aperture for different momentum offset (1024 turn).

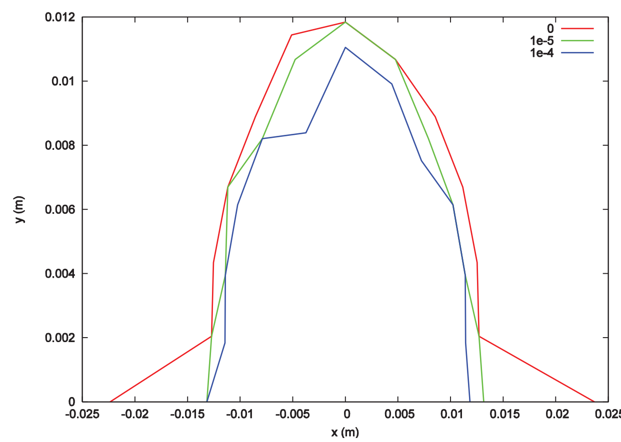

Figure 4: Dynamic aperture for different magnet error (1024 turn).

SYNCHROTRON RADIATION

The radiation properties of designed storage ring are investigated by the example of some existing or planned insertion devices from other synchrotron radiation facilities [6] with some little changes. The amended undulator parameters are sown in Table 2. CU, SU and IU refer to cryogenic, superconducting and in vacuum undulators, respectively.

Table 2: Main Parameters of Insertion Devices

Parameters	CU18	SU15	IU28
Period Length (cm)	1.8	1.5	2.8
Number of Period	222	67	142
Min. Gap.	5	5.6	7
K_{max}	2.25	2.10	2.35
Length (m)	4.0	1.005	4.0
Photon Energy (keV)	1.4-20	1.8-23	0.8-12

The quality of the beam is described by the brilliance and it is defined as the number of photons emitted per

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second, per photon energy bandwidth, per solid angle and per unit source size. The brilliance is inversely proportional to the horizontal and vertical emmittances. This is the reason why we want the emittance as possible as small. The brilliance spectrum is calculated by SPECTRA [7] simulation code and brilliance curves up to fifth harmonic are shown in Fig. 5. U90 is conventional undulator with 90 mm undulator period.

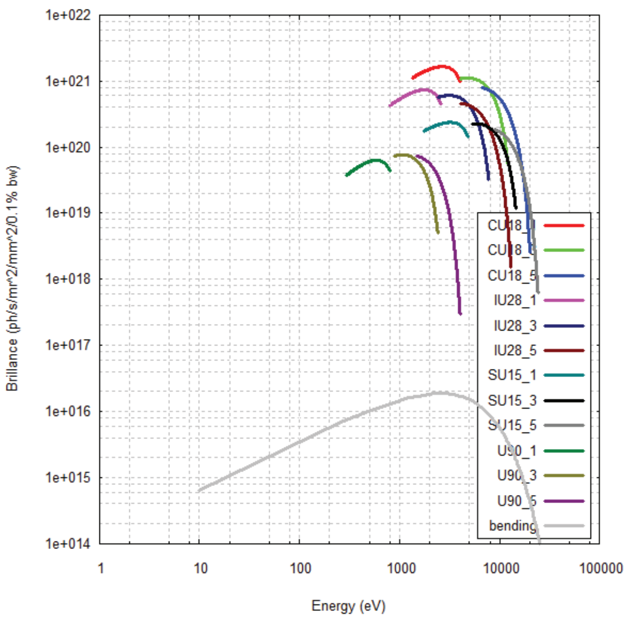

Figure 5: Brilliance spectrum of insertion devices.

THE SR USER POTENTIAL IN TURKEY

In 2011, Turkish scientists established an organizational structure for representation of Turkish synchrotron radiation community within the TAC Project under the name of TURKAY User Group. It aims to serve as an instrument to increase awareness of application areas of SR in TURKEY through workshops and seminars, to provide input for the development of the scientific case for the Turkish synchrotron. The group has now 135 members from 24 universities and institutes and continues building up the user community. TAC Project provides funds to these researchers. Annually, a Users' Meeting is held.

In Turkey, the researches performed by using SR are focused on five major areas; material science, characterization of nanomaterials, structure analysis of biomolecules, medical applications, pure physics and chemistry studies. Depending on that, TURKAY User Group proposed the following first phase beamlines; Extended x-ray absorption fine structure (EXAFS), Soft x-ray beamline, Infrared Microspectroscopy, Inelastic hard x-ray scattering, X-ray imaging for magnetic materials, X-ray diffraction (XRD), High pressure powder diffraction, Macromolecular crystallography, Small angle x-ray scattering (SAXS), X-Ray Optics and Instrumentation Beamline (XOI). The scientific case is being prepared for each proposed beamline by the group members. The expected and essential technical properties are discussed between the machine design group and the user group.

CONCLUSION

According to the demands of the users the goals of synchrotron radiation source are determined and the storage ring for TURKAY is designed. The natural emittance value is 0.51 nm rad with the 477 m ring circumference. This emittance value is comparable with the synchrotron radiation source projects around the world. It is shown that the dynamic aperture of the ring is large enough for such a low emittance ring. Also the radiation properties of the machine are investigated. It is shown that the brilliance value more than 10^{21} photon/s/mm^2/mrad^2/%0.1bw can be produced with some appropriate undulators.

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