INJECTION EFFICIENCY SIMULATION IN THE ELECTRON STORAGE RING OF X-RAY GENERATOR NESTOR*

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Abstract

In the paper the results of the beam dynamics and injection efficiency simulation in the storage ring of the X-ray generator NESTOR are presented.

INTRODUCTION

The new Kharkov accelerator facility NESTOR (New Electron STOrage Ring) [1, 2] is going to generate intense X-rays trough Compton back scattering. The facility consists of the compact 40, 200 MeV storage ring, linear 35, 90 MeV electron accelerator as an injector, transportation system, Nd:Yag laser system and optical resonator. It is expected that the facility will generate X-rays flux of about 10^{13} phot/s. The main parameters of NESTOR X-ray source are presented in the Table 1. In Fig. 1 and 2 the up to date view and layout of the NESTOR storage ring are shown.

Table 1: Parameters of the Ring

Parameter	Value
Storage ring circumference, m	15.418
Electron beam energy range, MeV	40-200
Betatron tunes, Qx , Qz	3.13, 1.77
Amplitude functions βx , βz at IP, m	0.14, 0.12
Linear momentum compaction factor α1	0.01
RF acceptance, %	4
RF frequency, MHz	700
Electron bunch current, mA	100
Number of circulating electron bunches	1,2,3,4, 36

Figure 1: NESTOR storage ring.

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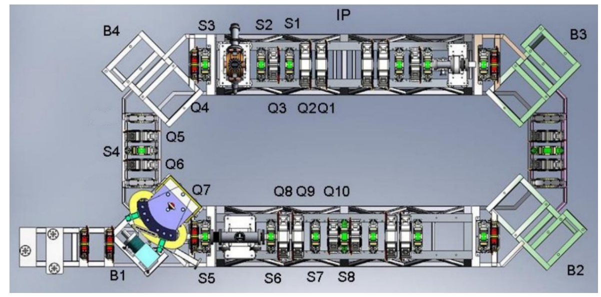

Figure 2: NESTOR storage ring lattice layout. B1-B4 are dipole magnets with combined focusing function, Q1-Q10 are quadrupole magnets, S1-S8 are sextupole magnets.

DESIGN ALIGNMENT ERROR EFFECT

For the simulations of RMS electron beam center displacement relative to the reference orbit of the Compton storage ring due to errors of the electromagnetic elements alignment it was supposed that all electromagnetic elements that are quadruple lenses and bending magnets have the alignment errors are showed in Tables 2-4.

Table 2: Alignment Errors for the 16 Quadruple Lenses with 150 mm Effective Length

Plane shift	Rms (µm)	Angle shift	Rms (mRad)
Dx	100	*xs*	0.7
Dy	100	*ys*	0.7
Dz	300	*xy*	1.25

Table 3: Alignment Errors for the 4 Quadruple Lenses with 100 mm Effective Length

Plane shift	Rms (µm)	Angle shift	Rms (mRad)
Dx	100	*xs*	1
Dy	100	*ys*	1
Dz	100	*xy*	1.25

Table 4: Alignment Errors for the 4 Bending Magnets

Plane shift	Rms (µm)	Angle shift	Rms (mRad)
dx	100	*xs*	0.33
dy	100	*ys*	0.33
dz	300	*xy*	0.20

These errors lead to the RMS beam position displace-

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ment are shown in Fig. 3. As one can see in Fig. 3, on the injection azimuth [3] the RMS beam displacement in the horizontal plane is about 1.7 mm and about 3.5 mm in the vertical plane.

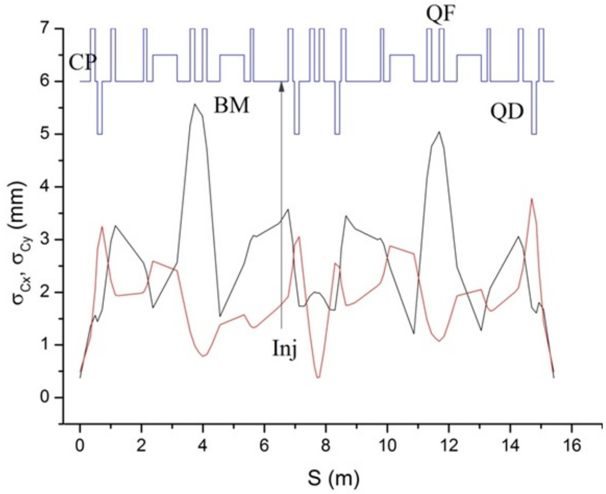

Figure 3: RMS electron beam displacement. Inj (injection point), CP (collision point).

There are two physical apertures in the ring that are welding edges at the azimuth of beam position monitor installation as it showed in Fig. 4. This welding edges form the effective physical aperture. So, the effective aperture of the inflector is 4 mm in the vertical plane and 20 mm in the horizontal plane (Fig. 5).

In the Nestor storage ring the beam is injected in horizontal plane in 16 mm from the reference orbit (Fig. 5).

Therefore, taking into account the sizes of effective aperture, electron beam injection conditions and beam orbit displacement value due to alignment errors, one can see that alignment errors will lead to the injection efficiency decrising.

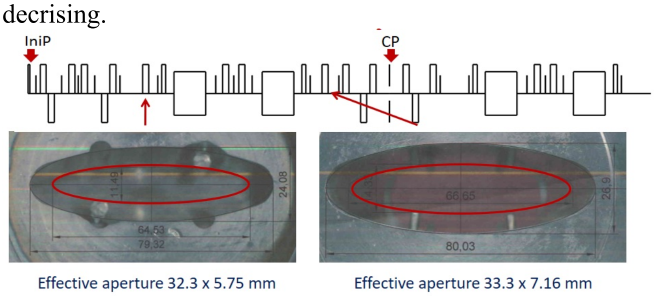

Figure 4: Physical apertures in the NESTOR storage ring

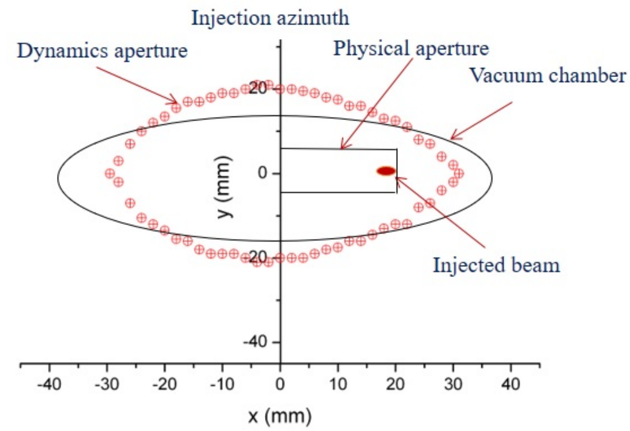

Figure 5: The effective aperture of the inflector.

OTHER FACTORS

There are other factors that lead to injection efficiency decreasing in the NESTOR storage ring.

The frequency of the accelerating RF voltage in the ring is 700 MHz. And the accelerating RF voltage in the linear accelerator is 2800 MHz. Therefore, only each fourth bunch will be captured in a storage process, and three others will be out of RF acceptance and lost at physical apertures of the storage ring. So, the efficiency of the injection can not be more than 25 % of the total accelerator particles.

In addition, the design Twiss parameters of the facility transportation channel do not meet with the Twiss parameters at the injection point of the storage ring. Therefore, according to the calculation results, the maximum injection efficiency is about approximately 35% of the particles that can be captured in the storage ring. Beam losses in the ring without and with alignment error under consideration are shown in Fig. 6.

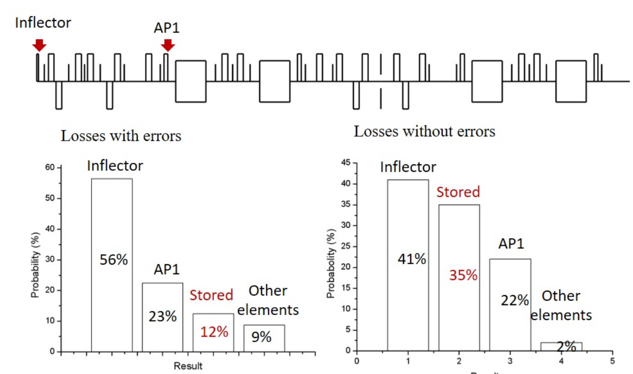

Figure 6: Beam losses at the NESTOR storage ring elements.

ALGORITHMS FOR FIRST TURN

For the successful close procedure of the first storage ring turn with possibilities of the beam position correction one four beam position monitors per one betatron oscillation period. In NESTOR storage ring horizontal tune (Q_x) is 3.13, and vertical (Q_y) is 1.77. Unfortunately, at the

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moment, beam instrumentation system of the NESTOR storage ring cannot provide regular procedure of the beam orbit correction with measurement equipment. Because of it, two algorithms were considered to provide the close of the first turn:

1. Local correction of the beam position at the injection azimuth. Due to the fact that up to 60% of the beam losses takes place at the physical aperture of the inflector, local correction of the beam position can improve the efficiency of injection. This algorithm allows to store certain number of particles in 85% cases.
2. Serial correction of beam position at four storage ring bending magnets using scintillation screens.

Since, the screen does not give any information about the angular coordinate of the beam, we should simulate it. If one knows the position of reference orbit in certain points of the storage ring, it is possible to use the local correction of the reference orbit for the orbit global correction with families of dipole correctors. This algorithm was considered for NESTOR storage ring.

Results of simulations showed that it is very difficult to measure the position of the beam on scintillation screens accurately. The RMS deviation of the angular coordinate of the beam at the inputs of the bending magnets is about 2 mrad. The distance from the entrances of bending magnet to scintillation screen is about 1 m. So, the uncertainty in the coordinate of the beam is about 2 mm/ In addition, errors of determination of beam position due to the large beam size on the screen should be added.

In other words, this system allows to measure the position of the beam in the storage ring with an accuracy not better than 2-3 mm., this is approximately equal to the RMS deviations of the reference orbit at these points. It is almost impossible to use such measurements to correct the reference orbit.

But in the case if we can reconstruct the reference orbit in 4 points of the storage ring from measurements on screens with good accuracy, we can obtain the accumulation in about 70% of cases.

OPTIMIZATION OF THE TRANSPORT SYSTEM

As it was mentioned above, one of the reason of low injection efficiency value is missmatching of Twiss parameters at the output of the transportation channel and at in the injection point. The beam is injected in the ring through the line with strong defocusing effect in the horizontal plane [4]. Because of this, beam losses, mainly at the first turns, take place.

As it turned out, the design of the NESTOR transportation channel makes it possible to install a quadruple lens on the trajectory of the beam, which allows to match the Twiss parameters. The optimization of the channel allows to increase storage efficiency from 35% to 85%. The position of the lens is shown in Fig.7. And Twiss parameters of transport channel before and after lens installation is presented in Fig. 8.

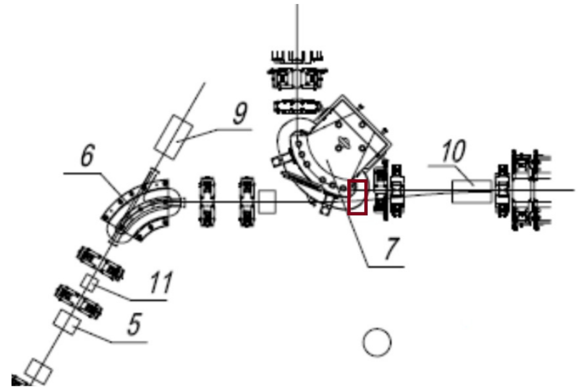

Figure 7: Additional quadruple lens in the transportation channel of the NESTOR storage ring.

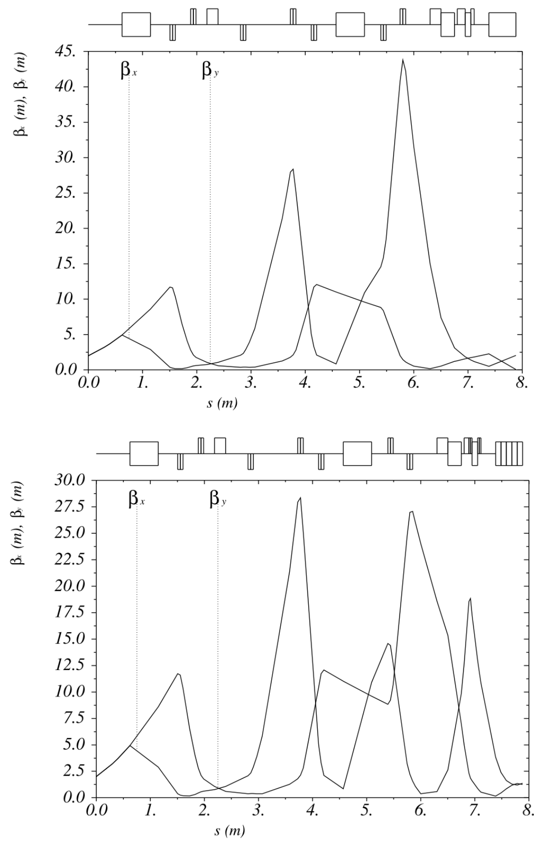

Figure 8: Twiss parameters of transport channel before and after quadruple lens installation.

CONCLUSION

Two algorithms of the electron beam position correction were considered to provide the first turn of the beam in the in the Compton storage ring NESTOR. It was shown that proposed algorithm can provide succseful injection in the storage ring.

The optimization of the transport channel lattice allows to increase storage efficiency from 35% to 85%.

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