INJECTION SCHEME OF X-RAYS SOURCE NESTOR*

A. Zelinsky, I. Karnaukhov, A. Mytsykov, V. Skirda, NSC KIPT, Kharkov, Ukraine

Abstract

In the paper, the injection scheme of the X-ray source NESTOR based on the compact storage ring and Compton scattering is described. It is supposed to inject electron beam through fringe fields of a bending magnet. For final beam deflection electrical inflector on the running wave will be used.

The layout of the injection scheme and elements characteristics are presented. The results of simulations of electron beam motion through 3-d fields of electro-magnetic devices of the injection channel are presented.

INTRODUCTION

It is known that injection in a compact storage ring, such as NSC KIPT X-ray source NESTOR [1], is a very difficult task due to very dense facility lattice. During NESTOR design it was decided to inject electron beam through fringe fields of a bending magnet [2]. In this way one can provide smooth trajectory of injected beam and save room in the ring. But such decision requires few special characteristics of transportation beam line [3]. The second distinction of the NESTOR injection scheme is multiturn injection. After septum injected beam enters the ring in 16 mm away from the design orbit. Further, injected beam damps and another portion of injected beam can be delivered. This scheme demands very careful and accurate design and calculations as of the whole beam trajectory as well as of injection devices.

Recently it has been decided to use electrical inflector on the running wave as a final beam deflector and power source on the base of SOS diode [4] for it. The paper is devoted to the description of the recent results on design of NESTOR electrical inflector and beam tracing trough fringe fields of the final part of the injection channel considering focusing properties of the newly designed inflector.

INJECTION SCHEME

The layout of the electron beam injection scheme in the NESTOR storage ring is shown in Fig. 1

Electron beam with energy of ~ 60 MeV from the injector (linear accelerator) trough transportation channel with parallel transition of the beam and final doublet of quadrupoles is delivered to the fringe field of a bending magnet. The effect of the magnetic field is reduced with magnetic screen. The magnetic induction of the fringe field along the beam trajectory is changed in the range of 500-600 Gs of the magnetic field gradient in the magnet of 150 Gs/cm. This field deflects the beam to the reference orbit. Magnetic screen is made of soft steel like ARMCO and is tube with inner diameter of 10 mm and outer diameter of 20 mm. The length of the screen is 200 mm. The reduction rate of the screen is 50. Position of the screen with respect to the bending magnet is shown in Fig. 2. Such position of the magnetic screen was chosen taking into account the effect of the screen on the bending magnet field distribution. The location depicted in the Fig. 2 leads to the local deviation of the field of about ~5 Gs. This field change can be improved with a correction coil of the bending magnet. Effect of the screen on the magnetic field topography of the bending magnet is shown in Fig. 3.

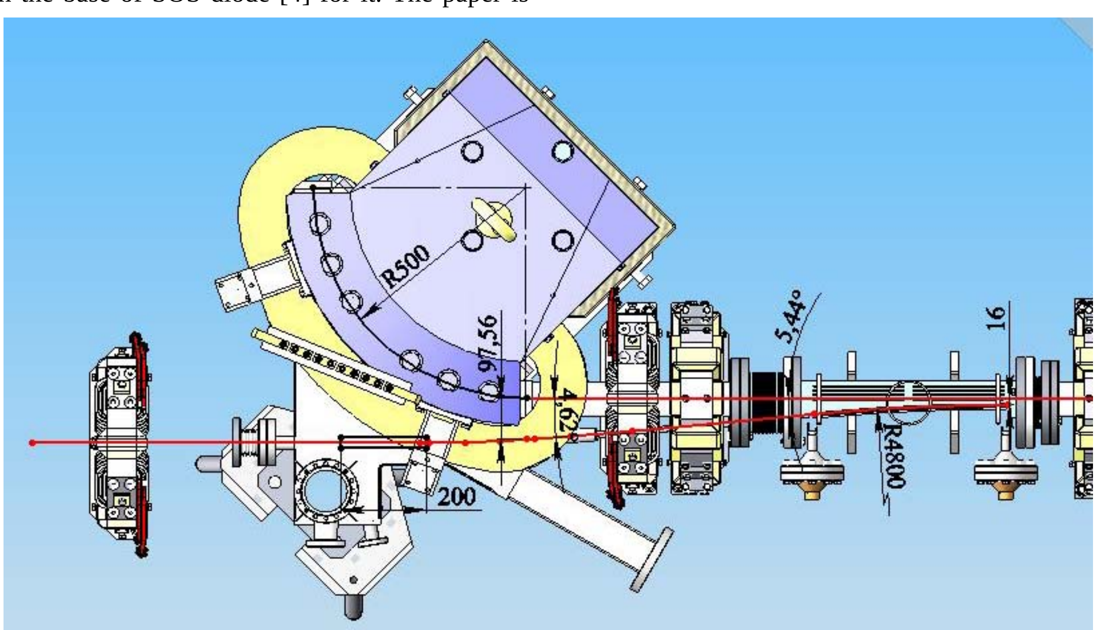


Figure 1. Layout of the injection scheme of NESTOR storage ring.

*Work supported by NATO SfP Grant #977982
zelinsky@kipt.kharkov.ua

Further, the beam through quadrupole and sextupole of the storage ring lattice arrives to the entrance of an inflector. Passing through quadrupole magnet (1.8 T/m at injection energy) 0.0782 m apart from reference orbit of the ring the beam is deflected on the 0.8º angle to the reference orbit. Magnetic field of the sextupole is weak and does not effect the injected beam trajectory.

As a result, at the entrance of the inflector the beam has angle of 5.45º to the reference orbit and its distance from the reference orbit of the storage ring is 37.8 mm. In the inflector the beam moves along arc of 600 mm length with radius of 4.8 m. At the exit of the inflector the injected beam is in 16 mm from the reference orbit under zero angle to the circulating beam. With damping time equal to 3 sec the beam is injected to the reference orbit.

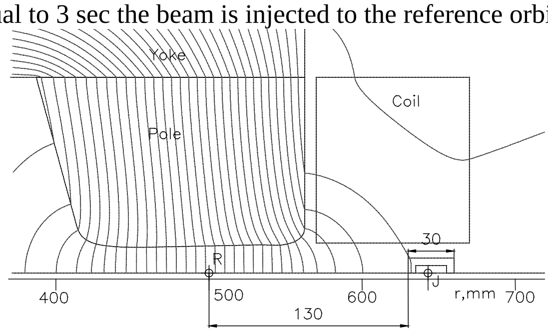


Figure 2: Magnetic screen position in the transversal cross section of the injection bending magnet.

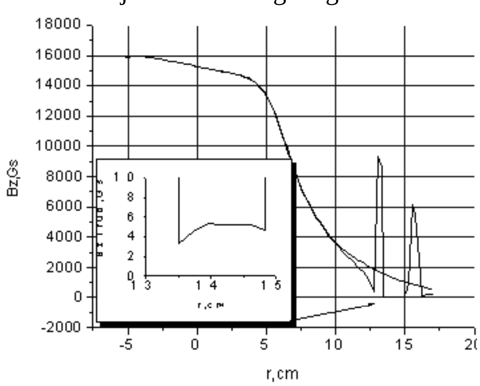


Figure 3: Radial magnetic field distribution for maximal electron beam energy with and without magnetic screen. In insertion distribution of the field inside screen's tube is shown.

INFLECTOR

Starting from the parameters, that we should provide at the injection, we designed an electrical inflector. The operation of the inflector is based on the principle of the running wave [4].

The electrical circuit of the inflector operation with parameters is shown in Fig. 4. The value of capacity $C=6.67\ 10^{-11}\ F$, inductivity $L=1.675\ 10^{-7}\ H$ and resistance $\rho=50\ \Omega$ can be changed depending on parameters of generator.

In Fig. 4 the designed inflector is depicted. The gap between septum electrodes is 8 mm. Voltage value at the anode is of about 60 KV. With impedance of inflector equal to 50 Ω the inflector current is of about ~ 1.2 KA.

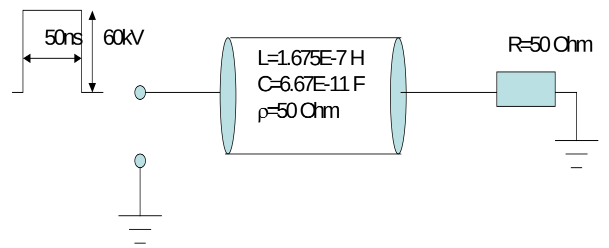


Figure 4: The electrical circuit of the inflector operation with parameters.

The size of the slot in the second electrode (cathode) is 8 mm and was chosen from the condition of minimal inflector field at the storage ring reference orbit for providing acceptable lifetime of the circulating beam.

With chosen geometry of the inflector the field at the reference orbit is of about 2.5% of the field in the inflector gap. It allows to carry out the injection with repetition of 0.1 Hz.

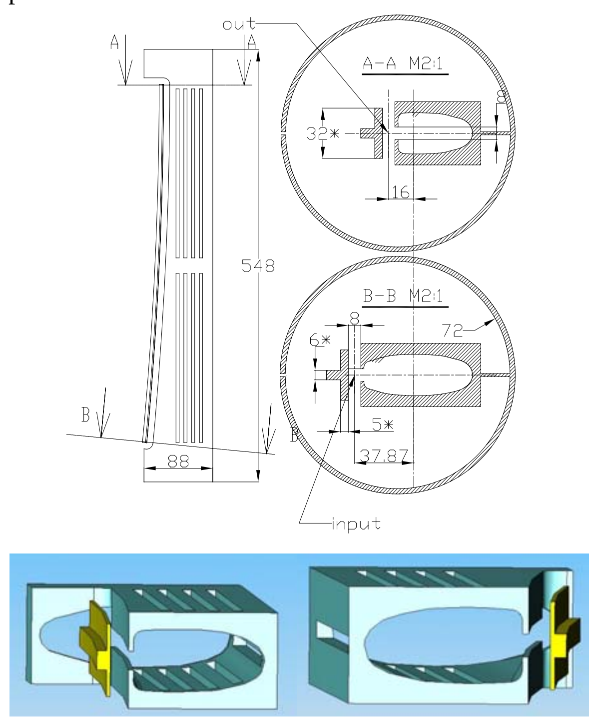


Figure 5: Layout of the inflector on the base of the running wave.

The main parameters of the inflector, that determine requirement to the generator-power source of the inflector are presented in Tab. 1.

Table 1: The Main Parameters of the Inflector

Impedance, Ω.	50
Deflection angle, ˚	5.44
Pulse voltage, KV	60
Pulse current, KA	1.2
Pulse duration, nsec	50
Time of growth and drop, nsec (no more)	5
Start synchronization, nsec	2
Pulse stability, %	1

Magnetic and electrical field distributions are shown in Fig. 6.

Below the components of magnetic and electrical fields in the gap of the designed inflector are presented:

$$B_x[T] = -0.88y - 3.5\times10^2 xy - 8\times10^4 x^2 y - 1.2\times10^7 x^3 y + 2\times10^4 y^3;$$

$$B_y[T] = 0.021 - 0.91x - 1.8\times10^2 x^2 - 2.5\times10^4 x^3 + 2.2\times10^2 y^2 + 7.2\times10^4 xy^2;$$

$$E_x[V/m] = 6.1\times10^6 - 2.6\times10^8 x - 5.2\times10^{10} x^2 - 7.2\times10^{12} x^3 + 6.5\times10^{10} y^2 + 2.1\times10^{13} xy^2;$$

$$E_y[V/m] = 2.5\times10^8 y + 9.9\times10^{10} xy + 2.3\times10^{13} x^2 y + 3.5\times10^{15} x^3 y - 5.8\times10^{12} y^3.$$

So, we can estimate focusing properties of the inflector fields.

SIMULATION OF PARTICLE MOTION

The particle tracing through the ring devices by integration of motion equations on a time in a crossed fields using equation system (1) was made [5]:

$$\begin{aligned}
&\mathrm{d}/\mathrm{d}t\left\{\left[1-\left(1/c^2\right)\left(x'^2+y'^2+z'^2\right)\right]^{-1/2} x'\right\} = \left(e/m_0\right)\left(E_x + B_z\cdot y' - B_y\cdot z'\right),\\
&\mathrm{d}/\mathrm{d}t\left\{\left[1-\left(1/c^2\right)\left(x'^2+y'^2+z'^2\right)\right]^{-1/2} y'\right\} = \left(e/m_0\right)\left(E_y + B_x\cdot z' - B_z\cdot x'\right),\\
&\mathrm{d}/\mathrm{d}t\left\{\left[1-\left(1/c^2\right)\left(x'^2+y'^2+z'^2\right)\right]^{-1/2} z'\right\} = \left(e/m_0\right)\left(E_z + B_y\cdot x' - B_x\cdot y'\right)
\end{aligned}\qquad(1)$$

where: m_0 is relativistic mass, e is electron charge, $B_{x,y,z}$ are components of magnetic field, $E_{x,y,z}$ are components of electric field.

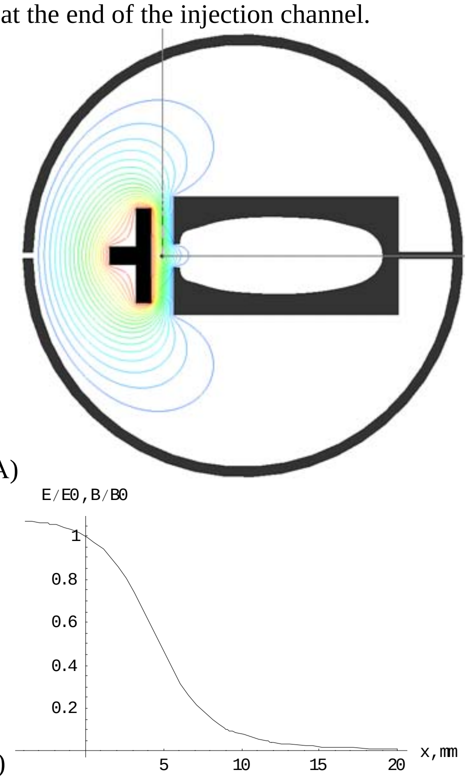
It allows to find out solution on any distance from a reference orbit where field is described.

According to the results of calculations of beam dynamics from magnetic screen exit to the end of the inflector, the beam is focused in z direction and is defocused in x direction. Beam size in x direction is changed in 2-3 times. So, the horizontal size at the entrance of the inflector should be no more than 0.5 mm. For that the horizontal size at the entrance of the transportation channel should be no more than 0.2 mm and accuracy of the beam position set is 0.1 mm.

Finally, beam sizes and its position at the entrance of the injection region will be formed with doublet of quadtrupoles depending on real distribution of the magnetic field in the injection bending magnet. This field distribution will be defined after magnetic measurements of the bending magnet.

CONCLUSION

Using the electric inflector on running wave it is possible to carry out the injection to the NESTOR ring through the fringing field of the dipole magnet. In this case the transportation from Linac to inflector is quite simple. Results of calculations of beam dynamics in the injection section show, that with chosen parameters of injection channel and electric inflector, injection in the NESTOR ring will be successful. The final beam sizes at the exit of magnetic screen will be defined after measuring of magnetic field distribution in the injection bending magnet and determination of generator – power supply source for inflector. But such correction of the injected beam sizes can be carried out with quadrupole doublet at the end of the injection channel.



A)

B)

Figure 6: Distribution of magnetic and electrical fields in the inflector on the base of running wave.

REFERENCES

[1] E.Bulyak et. al, “Compact X-ray Source Based on Compton Backscattering,” NIM, A487, 2002.

[2] P.Gladkikh et. al, “Investigation of injection through bending magnet fringe fields in X-rays source based on storage ring NESTOR”, EPAC’04, Lucerne, Switzerland; http://www.JACoW.org

[3] P.Gladkikh et. al, “Injection system for Kharkov X-ray source NESTOR”, EPAC-‘06, Edinburgh, Scotland; http://www.JACoW.org

[4] G. A. Mesyats et. al. "Semiconductor Opening Switch Research at IEP", Proceedings of the 10* IEEE International, Pulsed Power Conference, Albuquerque, NM, 1995, p. 298.-305.

[5] M. Szilgyi, “Electron and Ion optics”, Plenum press, New York and London