# INVESTIGATION OF INJECTION THROUGH BENDING MAGNET FRINGE FIELDS IN X-RAYS SOURCE BASED ON STORAGE RING NESTOR

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*Abstract*

In the paper injection in the X-ray source, based on the NESTOR storage ring, through fringe fields of a bending magnet is considered. The simulation of a motion of a beam of charged particles through 3-d fields of magnetic devices of the channel of injection, which ones is located in a ring, are performed. The focusing properties of the channel of injection are determined.

## INTRODUCTION

The injection in a compact storage rings is a problem due to impossibility of its realization by the general methods, i.e. by means of the septum magnets. In expected lattice of a NSC KIPT X-ray source NESTOR [1], there is a single possibility to locate pulse inflector, in which one beam is injected through fringe fields of a bending magnet. Recently the reconstruction of existed inflector of N-100 storage ring was started. Main task of this paper is description of optical properties of the injection channel from injection point up to entry into the transport channel.

## BEAM TRACING THROUGH DEVICES OF A RING

The particle tracing through the ring devices by integration of motion equations on a time in a constant magnetic field was made [2]:

$$\begin{cases} m\cdot x''(t) = \left(B_z\cdot y'(t) - B_y\cdot z'(t)\right), \\ m\cdot y''(t) = \left(-B_z\cdot x'(t) + B_x\cdot z'(t)\right), \\ m\cdot z''(t) = \left(B_y\cdot x'(t) - B_x\cdot y'(t)\right). \end{cases} \qquad (1)$$

where: m-relativistic mass; $B_{x,y,z}$ – components of magnetic field.

Using of equation set (1) for trajectory calculation allows to find out solution on any distance from a reference orbit where a field is described. The magnetic fields of all devices were calculated by POISSSON [3] (2-D) and MERMAID [4] (3-D) programs. For each device the maps of magnetic field were obtained. For the solution (1) the piecewise constant approximation of a magnetic field was used.

For definition of optical properties of the injection channel the tracing of a positrons beam with emittans $5*10^{-7}$ m*rad in the inverse direction to the direction of electrons injection (see Fig.1.) was used. The 60 MeV beam has started with 16 mm reference orbit deflection in x direction under optimal injection angle of 5.5 mrad and was passed through the inflector fields, sextupole lens, quadrupole lens, fringe field of the magnet, and pipe of magnetic shield.

In Fig.1 the relative position of bending magnet and other devices of the ring is given. The interference interaction of magnets to each other was taken into account. Two cases were examined: 3-th block of inflector switch on and off.

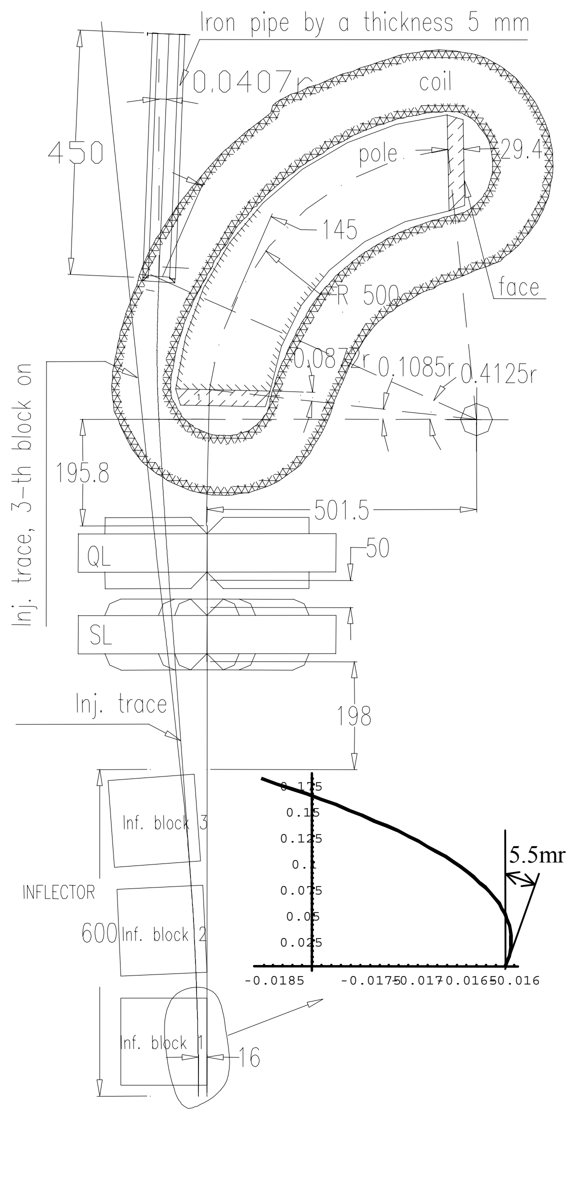


Figure 1. Trace of injections beam.

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## INFLECTOR

At the inflector design the following requirements were taken into account:

| | |
|---|---|
| Pulse acceleration time Tr, ns | ≤10 |
| Pulse fall time Td, ns | ≤10 |
| Pulse width Tp, ns | 50ns |
| Field in a point of injection B, Gs | ≥400 |
| Field on a reference orbit B, Gs | ≤10 |

In Fig. 2 the inflector cross-section, which one allows to satisfy this requirement, is shown.

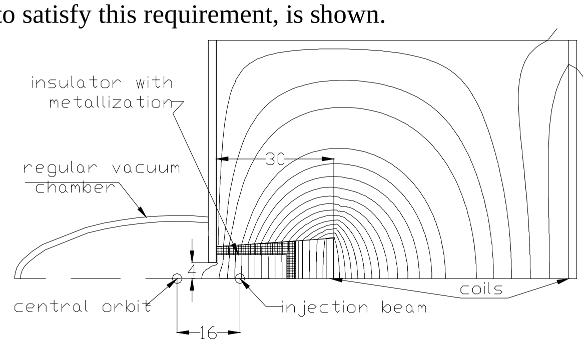


Figure 2. The inflectors cross-section.

Time characteristic of supply pulse allows to use metallic vacuum chamber in area of the equilibrium orbit and ceramic with thin (0.5µ) metallic shield in area of injection beam. At calculation it was assumed, that the material permeability does not exceed 20. Current of the main winding is 800 A. Distribution of magnetic field in the median plane of the inflector is shown in Fig.3.

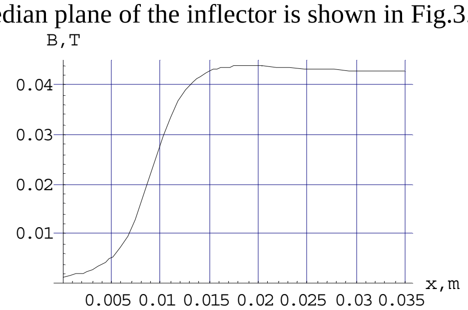


Figure 3. Distribution of magnetic field in the median plane of the inflector.

The inductance for magnet of length 0.16m is 0.25µH.

Existed 2 blocks have a length of 0.16 m each and a gap of 18mm (Fig.4). There are systems of positioning and high voltage current supply.

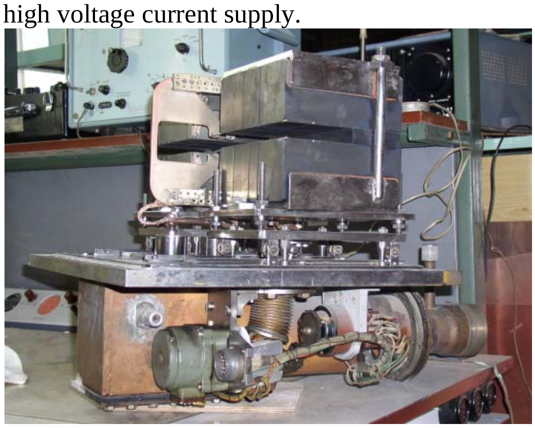

Figure 4. N-100 inflector.

We plan to reconstruct these blocks (see Fig.2) and to use theirs parallel connection (see Fig.5). Natural capacity of one block of the inflector is 30 pF. Impedance is 300 Ω. To reduce required voltage (300 Ω×800 A = 240 kV) and simultaneously to meet the Tr requirements the impedance will be decrease to 50 Ω. Then common for the both blocks current 1600 A will require 90 kV at a transmission line. Pulse rise-to-down time due to parameters of load and transmission lines is 4 ns. Real time will be inevitable longer due to inductance of connections and a switch.

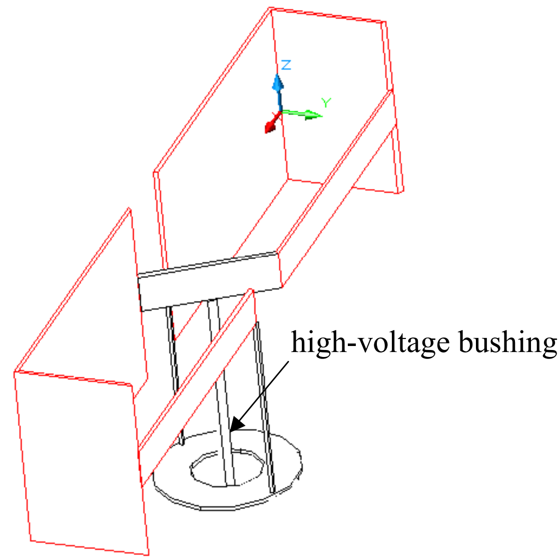


Figure 5. High voltage connection of inflector blocks

Supply of 3-th block of inflector will be made with additional high voltage block. As a distance in this block between central orbit and injection beam is relatively large (about 35-40 mm) the switching of 3-th block do not need such strict requirements on time. It is needed pulse overlap of 1,2 and 3-th blocks. (Theoretically 3-th block may be switched on constantly)

## SEXTUPOLE QUADRUPOLE LENS

Influence of the lenses is low since theirs fields (about 0.01T) are with opposite signs and center of the injection beam is displaced up to 70-100 mm from a reference orbit Fig. 1.

Therefore vacuum chamber for pass of injection beam in this place can be dissociated from a vacuum chamber of a circulating beam

## BENDING MAGNET

Passing through the fringe field of a dipole magnet, the beam of particles is under strong X-defocusing. If to allow to the beam to move in the decrease fringe field then at the entry into the transport channel beam size will be unacceptable. Therefore it is necessary to shield the magnetic field of the dipole magnet by means of the magnetic pipe Fig. 6.

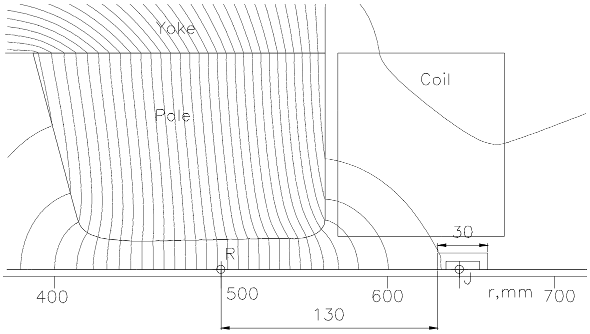


Figure 6. Shielding of the magnetic field by the magnetic pipe.

However presence of magnetic material near the reference orbit can give inadmissible field distortions on a reference orbit. For an estimation of this perturbation calculations of the field was carried out at the presence of the magnetic pipe near the reference orbit. The results of these calculations are shown in a Fig. 7.

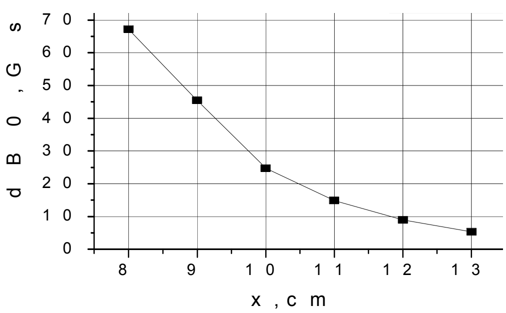


Figure 7. Dipole perturbation value versus distance between the reference orbit and edge of the magnetic pipe.

Fig. 8 shows a shielding characteristic of the magnetic pipe.

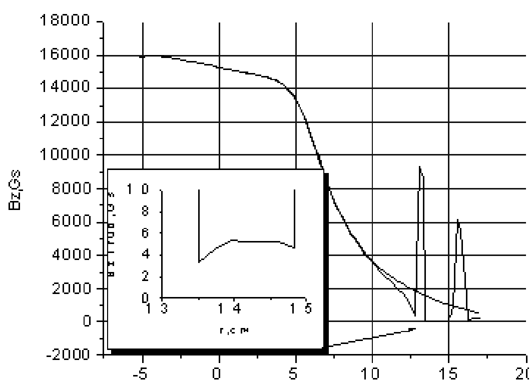


Figure 8. Magnetic field of a dipole magnet at regular part with the presence of the magnetic pipe and without one.

## THE SIMULATION OF A MOTION

The simulation of a motion of injection beam was made for two cases: 3-th block switch off and on (see Fig.1). In the first case beam passes through fringing field of dipole magnet. Horizontal and vertical sizes of a beam for the 1-st case along trace are shown in Fig.9. In 2-nd case beam does not pass through fringing fields and saves initial shape.

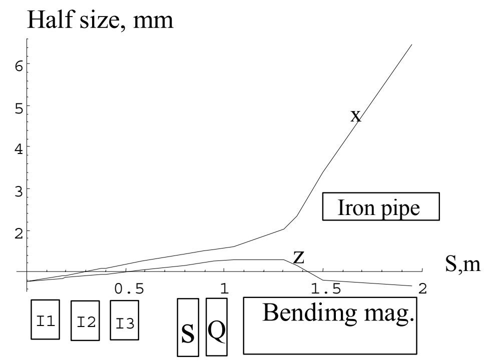


Figure 9. Envelopes of a beam in the channel of injection.

During deriving of the optimum envelopes the different variants of relations of the size and angular beam divergence at the inflector entry were calculated. The results are given in Fig.10. From obtained results it follows, that the optimum relation a size-divergence is equal 0.75 mm/0.067 mrad.

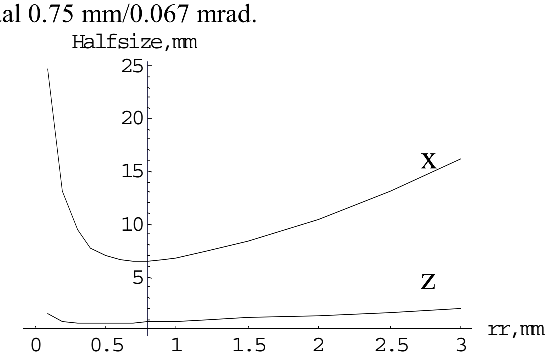


Figure 10 Dependence of x, z-size at exit of the magnetic pipe from the size on the entry into inflector.

## CONCLUSION

Using the 3-th block in the inflector allows injection to the NESTOR ring with by-passing the fringing field of the dipole magnet. In this case the transportation from Linac to inflector section is quite simple. But such solution forbids the injection at the electron beam energy is greater than 60MeV. Injection at 60 Mev with 2 blocks gives increase of horizontal sizes of injection beam and therefore complicates transportation from Linac but keeps the possibility of injection with greater energy of electron beam (with three blocks). Final choice of injection layout will be produced after final choice of Linac properties and high-voltage equipment.

## REFERENCES

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