# THE FIRST RESULTS OF THE NESTOR COMMISSIONING

V. Androsov, O. Bezditko, V. Boriskin, P. Gladkikh, A. Gordienko, V. Grevtsev, A. Gvozd, V. Ivashchenko, A. Kalamayko, I.I. Karnaukhov, I.M. Karnaukhov, D. Korzhov, V. Kozin, V. Kushnir, V. Lyashchenko, M. Moiseenko, V. Margin, N. Mocheshnikov, V. Mytrochenko, A. Mytsykov, F. Peev, O. Ryezayev, V. Sergienko, A. Shcherbakov, S. Sheyko, V. Skirda, Y. Telegin, V. Trotsenko, A. Zelinsky, O. Zolochevskij, O. Zvonarjova
NSC KIPT, Kharkov, Ukraine

*Abstract*

In the paper the first results of the NESTOR facility commissioning are presented. 60 MeV electron linac injector has been tested and the first electron beam with project parameters was registered at the screen monitors. Electron beam was passed through the transportation channel and injection system. As a result, the first turn of the storage ring was closed.

## 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 40-225 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. NESTOR facility commissioning was started in 2012.

During 2012 NESTOR team activity was directed to the following:

- preparation, assembling, testing and commissioning of the NESTOR vacuum system [3];
- optimization of the linear accelerator in order to improve the initial electron beam parameters;
- transportation of the electron beam through the injection channel and fringe field of the first storage ring bending magnet to the inflector;
- injection of the electron beam to the storage ring.

In the paper the first results of the NESTOR facility commissioning are described.

## THE TRANSPORTATION CHANNEL LATTICE

Fig. 1 shows the injection channel layout. Injection channel lattice is based on the classic five lenses parallel translation focusing system with a 60 degree beam bending angle in the dipole magnets (Fig. 1) [2]. This type of lattice has flexible focusing properties and allows to change the beam parameters in a wide range.

The electron beam from linear accelerator (1) goes to the 60 degree dipole magnet (2) and passes through the five lenses part of transportation channel (3). To eliminate the particles with big energy deviation the collimator with an aperture of 20 mm and length of 100 mm is placed after the second quadruple lens (4). It provides the energy spread of the beam of about ± 1% after collimation. After the second dipole magnet (6), the beam enters the final quadruple doublet, which provides the matches of the injected beam emittance and acceptance of the storage ring. The beam passed through the first storage ring bending magnet fringe field (7, Fig. 1) and through the storage ring lenses is transported to the inflector (injection pulse septum on the traveling wave [4]). The inflector forms the optimum conditions for the injection of the beam to the storage ring. The amplitude of the betatron oscillations in x plane at the injection azimuth is about 16 mm, and the optimal injection angle is equal to 5 mrad [4].

The main problem of the developed injection scheme is the necessity to lead the electron beam through the fringe field of the first storage ring dipole magnet, where magnetic screen (metal pipe with aperture of 10 mm) is installed, and further through the vacuum chamber elements with the same aperture. The trajectory of the injection beam at this storage ring section was simulated, taking into account fringe field calculated with POISON code [5]). It should be noted that the dipole magnet of the storage ring is surrounded by a large number of other devices, so that the value of the fringe field in practice may be different from the calculated value. To compensate possible magnetic field differences five beam position dipole correctors were introduced in the injection channel.

## STEPS OF BEAM INJECTIONS THROUGH THE TRANSPORTATION CHANNEL

Now the beam instrumentation system of the injection channel and storage ring involves two current transformer detectors (one for transportation channel and one for the ring) and indicating blocks mounted on the exit of straight sections of injection channel dipole magnets (8,9 Fig.1). The beam has been registered with switched off dipole magnets. Each measurement block consists of:

- Faraday cup for measurement of the average beam current and beam absorption;
- scintillating screen (an aluminum plate coated with a layer of zinc sulfide ZnS) registered with a video recording system;
- wire beam position monitor.

Such minimized beam instrumentation system has conditioned the special tactics of the beam injection into the storage ring. The beam pass was realized in a few stages, and for each stage a separate focusing regime was calculated. Below the stages are described.




ISBN 978-3-95450-122-9

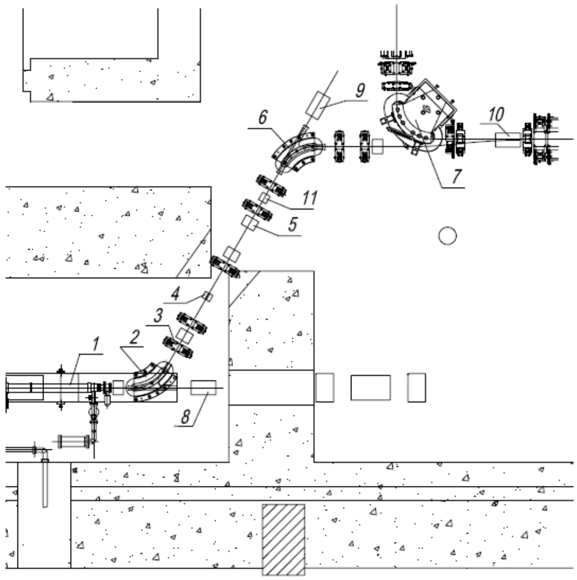


Figure 1: Layout of the NESTOR facility injection transportation channel: 1- linear accelerator, 2 – the first transportation channel dipole magnet, 3 – quadrupole lenses, 4 – collimator, 5 – dipole beam position correctors, 6 - the second transportation channel dipole magnet, 7 - the first storage ring dipole magnet, 8, 9 – scintillation screens and Faraday cups, 10 – inflector, 11 – beam current and beam position monitor.

- *Stage 1*. In this mode, the first bending magnet (2, Fig. 1) of the injection channel was switched off and electron beam was observed with the detector system at the direct output of the accelerator (8, Fig. 1). With use of a quadruple doublet between two accelerating sections and two dipole correctors the beam sizes were formed, the beam position was centered.
- *Stage 2*. For this stage the first bending magnet of the transportation channel was switch on (2, Fig. 1) but the second magnet (6, Fig. 1) was switched off. During the second stage for beam transportation the special focusing mode of the parallel transportation with specific quadrupole forces was designed (Fig. 2, 3). The mode provides stable registration of the beam parameters using current transformer detector (11, Fig. 1) and registration block (9, Fig. 1). Due to large value of dispersion function in the registration point in normal operation focusing mode the transverse size of the beam in the horizontal plane at block point (9, Fig. 1) is equal to 20 mm, that does not allow certainly define the parameters of the beam. Channel tunings at this stage allow to evaluate the alignment accuracy of the magnetic elements in the parallel transport channel and correct the electron beam position with dipole correctors (11, Fig. 1).

*Stage 3*. During the stage two transportation channel dipole magnets were switched on (2,6 Fig. 1). The first bending magnet of the storage ring (7, Fig. 1) was switched on. The beam position and transfer sizes were optimized to provide the maximum efficiency of the beam injection to the azimuth on the inflector with effect of the storage ring dipole magnet and ring quadrupoles fringe field.

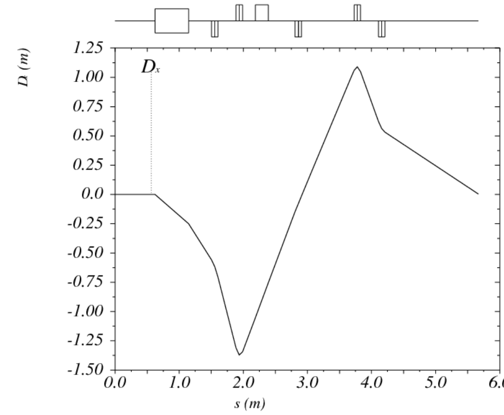


Figure 2: Dispersion function along the transport channel in the second stage.

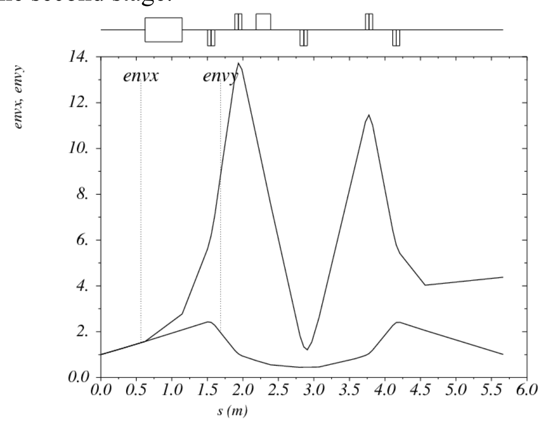


Figure 3: Transverse sizes of the beam along the transport channel in the second stage. *Envx, Envy* - horizontal and vertical size, respectively.


Figure 4: Optimized electron beam sizes at the exit of linear accelerator (RMS sizes: x-direction is about 5 mm, RMS sizes: z-direction is about 5 mm,)

## EXPERIMENTAL RESULTS

The measured parameters of the linear accelerator beam during the first commissioning shifts are the following:

- The output beam current of the electron gun was 140 mA.
- Current after the first accelerating section was 46 mA.
- Current after the second accelerating section was 33 mA.

The optimized transverse electron beam sizes at the exit of the linear accelerator at screen (8, Fig. 1) were 5×5 $mm^2$ (Fig. 4).

Formed beam on the scintillating screen (9, Fig. 1) is shown in Fig. 5. Beam sizes are in a good agreement with the calculated (Fig. 3). To determine the necessary forces of dipole correctors of the parallel transport channel sensitivities of the beam gravity center to each corrector were calculated. The measurements showed good agreement between calculations and experimental data.

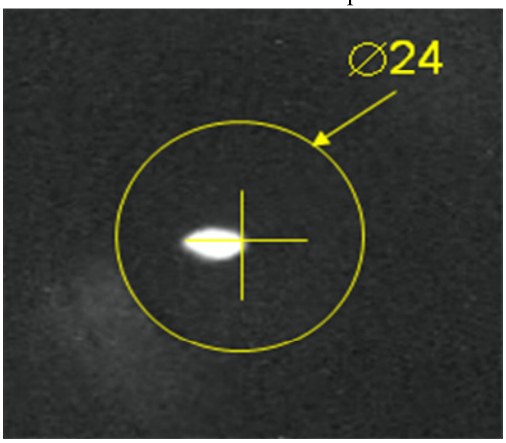


Figure 5: Electron beam shape behind the second bending magnet of the transport channel the (9, Fig. 1).

Measured distortions of equilibrium beam orbit at point 9, Fig. 1 are about 4 mm in both transfer directions that indicates the 100 mm RMS accuracy of magnetic elements installation along transportation channel.

Electron beam current measured with current transformer detector in parallel transfer channel is about 20 mA (66% of the current at the exit of the linear accelerator). Beam losses due to its energy selections are in a good agreement with calculation results.

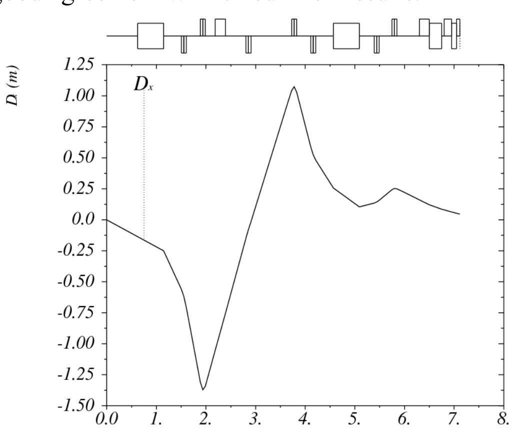


Figure 6: Dispersion function of the beam along the beam transportation channel at the stage 3.

The lattice of the injection channel in the third stage corresponded to the NESTOR facility operation mode. Calculation and measurement results are shown in Fig. 6, 7, 8. Measurements have shown that the position of the beam at the azimuth of the injection can be changed within range of ±5 mm using the correctors, that allows to select the optimum conditions for the beam injection. Within the accuracy of the experimental measurement the forces of correctors match with the calculated.

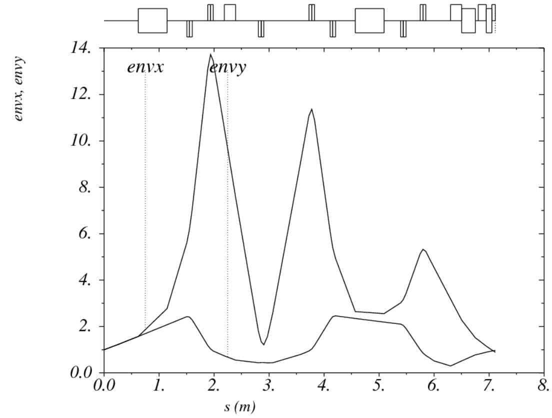


Figure 7: Transverse sizes of the beam along the beam transport channel in the stage 3. *Envx, Envy* - horizontal and vertical beam size, respectively.

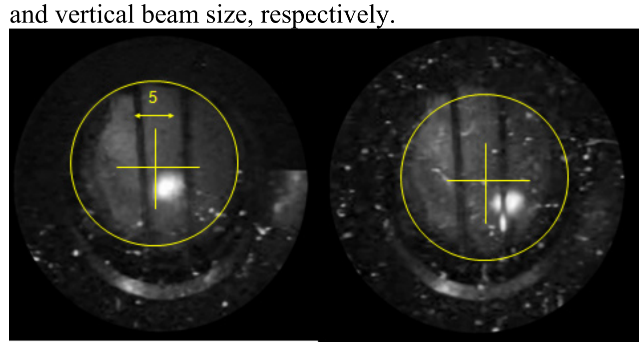


Figure 8: Focused beam at the inflector point with different forces of correctors (displacement of about 5 mm).

## CONCLUSION

As a result of the beam transportation through the injection channel the calculations for injection into the NESTOR storage ring were experimentally tested. It was shown that the intensity of the beam and its sizes correspond to the design within the experimental error. This work was supported by grant NATO SfP-977982.

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ISBN 978-3-95450-122-9