THE START OF X-RAY GENERATOR NESTOR COMISSIONING

V. Androsov, O. Bezdetko, V. Boriskin, P. Gladkikh, S. Gokov, 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, A. Ryezayev, V. Sergienko, A. Shcherbakov, V. Skirda, Y. Telegin, V. Trotsenko, A. Zelinsky, O. Zolochevskij, O. Zvonarjova
National Science Center “Kharkov Institute of Physics and Technology”, Kharkov, Ukraine
E-mail: Mytsykov@kipt.kharkov.ua

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. The beamh of electrons was observed and controlled in the screen monitors in the expected range.

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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.

1. THE TRANSPORTATION CHANNEL LATTICE

1.1. BEAM EXTRACTION FROM LINAC

Fig. 1 shows a diagram of the location of the generator NESTOR. The electron beam was emited from a linear accelerator, the parameters of which are given in Table 1. Linac control console is shown in Fig. 2. In Fig. 2 there also is a picture of the beam with a fluorescent screen (ZnS), set in position 1 (see Fig. 1).

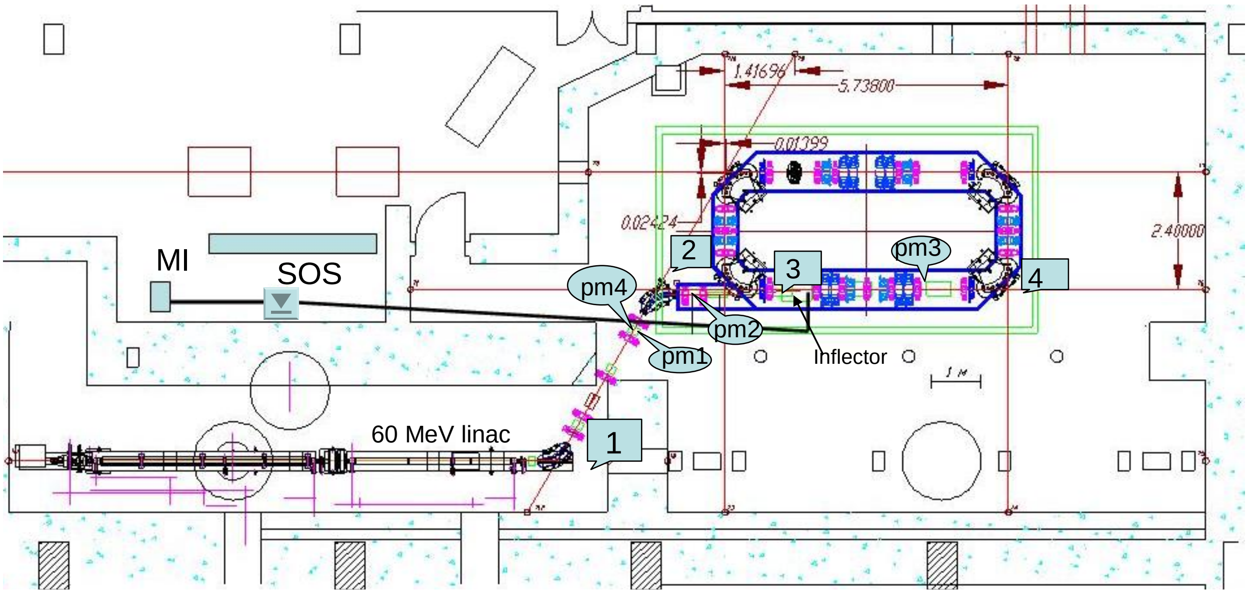
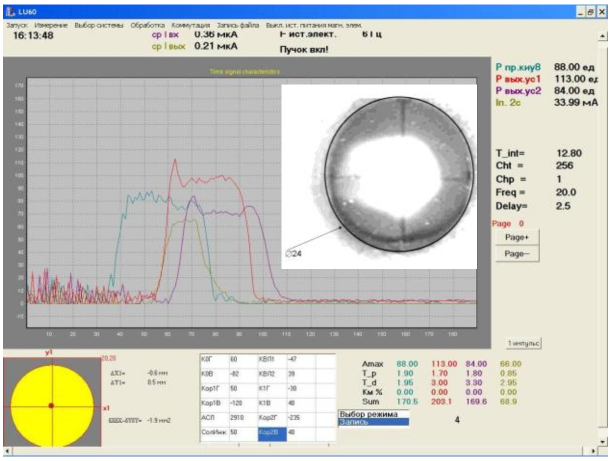


Fig. 1. Layout diagram of NESTOR. 1-4 positions of fluorescent screens; pm1-pm2 beam position and current monitors, pm3-pm4 beam position (fluorescent + wire) monitors

The magnetic system of the accelerator allows to focus the electron beam to the size of 5mm in diameter.

Parameters of the linear accelerator:

Energy, MeV	60…90
RF frequency, MHz	2797.15
Repetition rate, Hz	1…50
Pulse current, mA	90
Pulse duration, ns	1400
The width of the energy spectrum (steady-state), %	1.5
Emittance (steady-state) mm mrad	0.1.



16:13:48

ср I вх 0.36 мкА
ср I вых 0.21 мкА
F ист.элект. 6 Гц
Пучок вкл!

P пр.киу8 88.00 ед
P вых.ус1 113.00 ед
P вых.ус2 84.00 ед
In. 2c 33.99 мА

T_int= 12.80
Cht = 256
Chp = 1
Freq = 20.0
Delay= 2.5
Page 0

ΔX1= -0.6 мм
ΔY1= 0.5 мм
δXX-δYY= -1.9 мм2

К0Г	60	КВЛ1	-47
К0В	-82	КВЛ2	39
Кор1Г	50	К1Г	-30
Кор1В	-120	К1В	40
АСП	2910	Кор2Г	-235
СолИнж	50	Кор2В	40

Amax	88.00	113.00	84.00	66.00
T_p	1.90	1.70	1.80	0.85
T_d	1.95	3.00	3.30	2.95
Км %	0.00	0.00	0.00	0.00
Sum	170.5	203.1	169.6	68.9

Выбор режима
Запись
4

Fig. 2. The LINAC console and the portrait of the beam at the output of the accelerator

1.2. THE INJECTION CHANNEL LAYOUT

Fig. 3 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 (see Fig. 3) [2]. This type of lattice has flexible focusing properties and allows to change the beam parameters in a wide range.

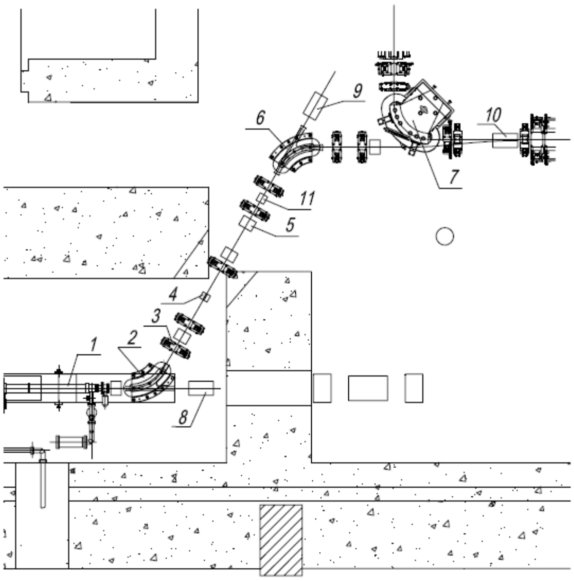


Fig. 3. Layout of the NESTOR facility injection transportation channel: 1 – linear accelerator; 2 – the first transportation channel dipole magnet; 3 – quadrupole lenses; 4 – collimator; 5 – dipole beam position correctors; 6 – the second transportation channel dipole magnet; 7 – the first storage ring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

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 (pos. 7 Fig. 3) 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

2. STEPS OF BEAM INJECTION THROUGH THE TRANSPORTATION CHANNEL

Now the beam instrumentation system of the injection channel and storage ring involves two beam position and current detectors (see pm1, pm2 Fig. 1) and indicating blocks mounted on the exit of straight sections of injection channel dipole magnets (position 1, 2, 34 Fig. 1). The beam has been registered with switched off dipole magnets. Measurement block (position 1, 2, 4 Fig. 1) 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.

Measurement block (see pos. 3 Fig. 1) consists only scintillating screen and wire beam position monitor. This sensor was installed temporarily in place of the inflector.

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:

- *Stage 1.* In this mode, the first bending magnet (see pos. 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 (see pos. 8 Fig. 3). With use of a quadruplole doublet between two accelerating sections and two dipole correctors the beam sizes were formed, the beam position was centered. 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 (see pos. 8 Fig. 3) were 5×5 mm (see Fig. 2).

- *Stage 2.* For this stage the first bending magnet of the transportation channel was switch on (see pos. 2 Fig. 3) but the second magnet (see pos. 6 Fig. 3) was switched off. During the second stage for beam transportation the special focusing mode of the parallel transportation with specific quadrupole forces was designed (Figs. 4, 5).

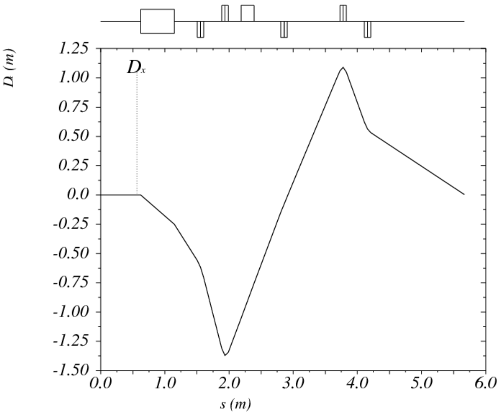


Fig. 4. Dispersion function along the transport channel in the second stage

The mode provides stable registration of the beam parameters using current transformer detector (see pos. 11 Fig. 3) and registration block (see pos. 9 Fig. 3). 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 (see pos. 9 Fig. 3) 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 (see pos. 11 Fig. 3).

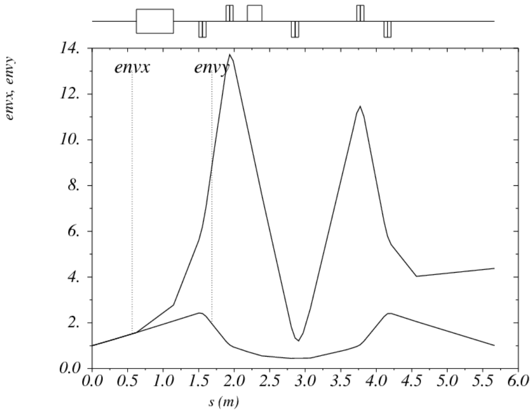


Fig. 5. Transverse sizes of the beam along the transport channel in the second stage. Envx, Envy – horizontal and vertical beam size, respectively

Formed beam on the scintillating screen (see pos. 9 Fig. 1) is shown in Fig. 6. Beam sizes are in a good agreement with the calculated (see Fig. 5). 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.

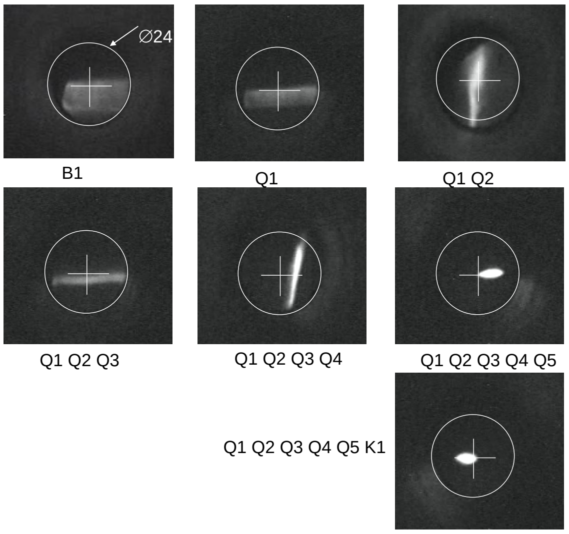


Fig. 6. Electron beam shape behind the second bending magnet of the transport channel the (see pos. 9 Fig. 1)

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.

Stage 3. During the stage three the transportation channel dipole magnets were switched on (see pos. 2, 6 Fig. 3). The first bending magnet of the storage ring (see pos. 7 Fig. 3) 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.

The lattice of the injection channel in the third stage corresponded to the NESTOR facility operation mode. Calculation and measurement results are shown in Figs. 7-9.

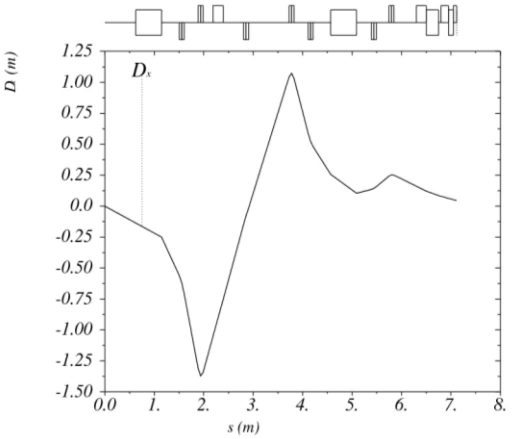


Fig. 7. Dispersion function of the beam along the beam transportation channel at the stage 3

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.

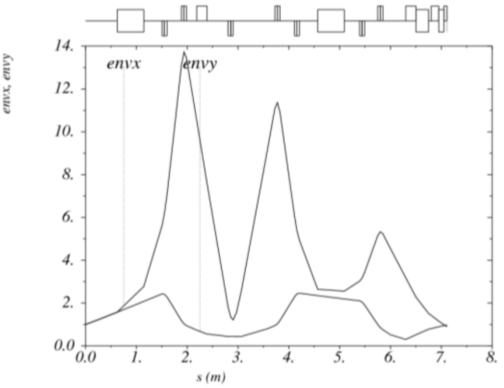


Fig. 8. Transverse sizes of the beam along the beam transport channel in the stage 3. Envx, Envy – horizontal and vertical beam size, respectively

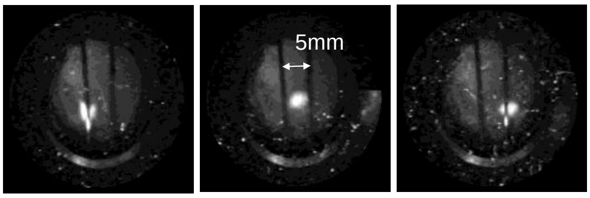


Fig. 9. Focused beam at the inflector point with different forces of correctors (displacement of about 5 mm)

Stage 4. In this mode, all the magnets were included in the normal mode of the storage ring. Unfortunately, at the time of injection testing the authors were not able to power the pulsed inflector. Therefore, we developed a special mode that allows pass the beam through a long straight section to the screen in Fig. 1, pos. 4. The images of the beam at the screen for different value of correctors field are shown in Fig. 10. As one can see from the figure it is possible to adjust the beam inside storage ring aperture with correctors of the first straight section.

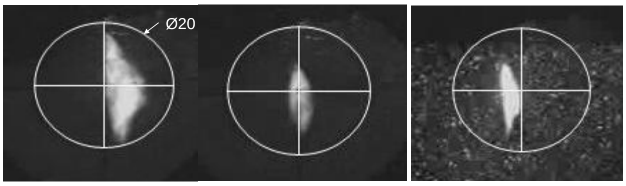


Fig. 10. Focused beam at the inflector point with different forces of correctors

CONCLUSIONS

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.

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НАЧАЛО ЗАПУСКА РЕНТГЕНОВСКОГО ГЕНЕРАТОРА НЕСТОР

В. Андросов, А. Бездетко, В. Борискин, П. Гладких, С. Гоков, А. Гордиенко, В. Гревцев, А. Гвоздь, В. Иващенко, А. Каламайко, И.И. Карнаухов, И.М. Карнаухов, Д. Коржов, В. Козин, В. Кушнир, В. Лященко, М. Моисеенко, В. Маргин, Н. Мочешников, В. Митроченко, А. Мыцыков, Ф. Пеев, А. Резаев, В. Сергиенко, А. Щербаков, В. Скирда, Ю. Телегин, В. Троценко, А. Зелинский, А. Золочевский, О. Звонарева

Представлены первые результаты ввода в эксплуатацию генератора НЕСТОР. Инжектор-линейный ускоритель на 60 МэВ электронов был испытан, и первый пучок с проектными параметрами был зарегистрирован на экранах мониторов. Электронный пучок проведен через канал транспортировки и системы ввода в вакуумную камеру накопителя. Пучок электронов наблюдается и контролируется на экране мониторов в ожидаемом диапазоне.

ПОЧАТОК ЗАПУСКУ РЕНТГЕНІВСЬКОГО ГЕНЕРАТОРА НЕСТОР

В. Андросов, О. Бездетко., В. Борiскiн, П. Гладкiх, С. Гоков, О. Гордiєнко, В. Гревцев, А. Гвоздь, В. Iващенко, А. Каламайко, I.I. Карнаухов, I.М. Карнаухов, Д. Коржов, В. Козiн, В. Кушнiр, В. Лященко, М. Моiсєєнко, В. Маргiн, Н. Мочешнiков, В. Мiтроченко, А. Мициков, Ф. Пєєв, А. Рєзаєв, В. Сергiєнко, О. Щербаков, В. Скирда, Ю. Телегiн, В. Троценко, А. Зелiнський, О. Золочевський, О. Звонарьова

Першi результати вводу в експлуатацiю генератора НЕСТОР представленi. Iнжектор-лiнiйний прискорювач на 60 МеВ електронiв був випробуван, та перший пучок iз проектними параметрами було зареєстровано на екранах монiторiв. Електронний пучок проведено крiзь канал транспортування та системи вводу в вакуумну камеру накопичувача. Пучок електронiв спостерiгається i контролюється на екранах монiторiв в очiкуваному дiапазонi.