THE KHARKOV X-RAY GENERATOR FACILITY NESTOR

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Abstract

The last few years the source of the X-rays NESTOR based on a storage ring with low beam energy and Compton scattering of intense laser beam is under design and development in NSC KIPT. The main task of the project is to develop compact intense X-ray generator on the base of relatively cheap accelerator equipment and up-to-date laser technologies.

The paper is devoted to description of the last results on construction and commissioning of the facility.

INTRODUCTION

The new Kharkov accelerator facility NESTOR (New Electron STOrage Ring) [1-3] 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 cavity. 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 NESTOR storage ring is shown.

Table 1

Parameter	Volume
Storage ring circumference, m	15.418
Electron beam energy range, MeV	40-225
Betatron tunes, Qx , Qz	3.155, 2.082
Amplitude functions βx , βz at IP, m	0.14, 0.12
Linear momentum compaction factor $\alpha 1$	0.01-0.08
RF acceptance, %	>5
RF frequency, MHz	700
Electron bunch current, mA	100
Number of circulating electron bunches	1,2,3,4, 36

Figure 1: NESTOR storage ring.

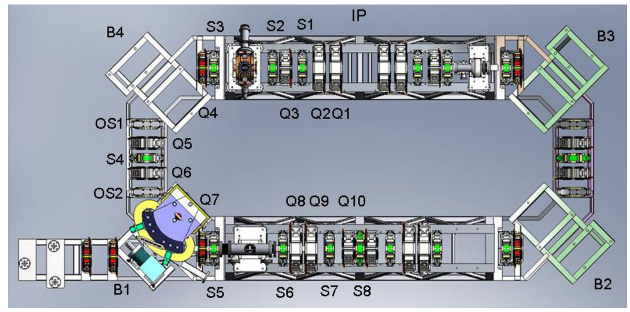

Figure 2: NESTOR storage ring lattice layout. B1-B4 are dipole magnets with combined focusing function, Q1-Q10 are quadrupole magnets, S1-S7 are sextupole magnets, OS1-OS2 are octupole magnets combined with sextupole magnets.

During last year NESTOR team activity was directed to the following:

- modification of the NESTOR storage ring lattice;
- design and development of the NESTOR facility control system [4];
- commissioning of the RF system;
- development of LLRF system;
- design and development of the NESTOR beam instrumentation system;
- preparation, assembling, testing and commissioning of the NESTOR vacuum system [5];
- optimization of the linear accelerator in order to improve the initial electron beam parameters;
- leading of the electron beam through the injection channel and fringe field of the first storage ring bending magnet to the inflector [6];
- injection of the electron beam to the storage ring [6].

LATTICE MODIFICATION

At lattice modification the following factors were taken into account:

- interaction point (IP) straight section length should be increased to 0.75 m;
- The positions of all but IP triplet magnets should not be changed;
- The force of lenses could be changed within 20% from maximal magnet forces

As a result of calculations parameters of modified NESTOR storage ring lattice were determined (see Fig. 3). First, the lattice parameters were determined in linear approximation. The lattice satisfied all requirements and in needed range of quadrupole magnet

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changes. In Fig. 3 the beta functions of modified lattice are shown. It is clear that theirs value is similar to the deisgn project beta functions. The betatron oscillation frequencies values are Q_x=3.10, Q_z= 1.79 and momentum compaction factor $\alpha = 0.01$. Second, the natural chromaticity was suppressed with sextupole magnets OS1-OS4 and S4-S12. Third, the dynamic aperture of the storage ring was corrected with sextupole magnets S1-S3, S17-S19. The value of the dynamic aperture at the injection point is about 42 mm in horizontal direction and about 26 mm in vertical direction. It is bigger then in initial design project and provides the effective injection in NESTOR storage ring.

In Fig. 4 dynamic aperture of the storage ring calculated with use of MAD code [7] is shown.

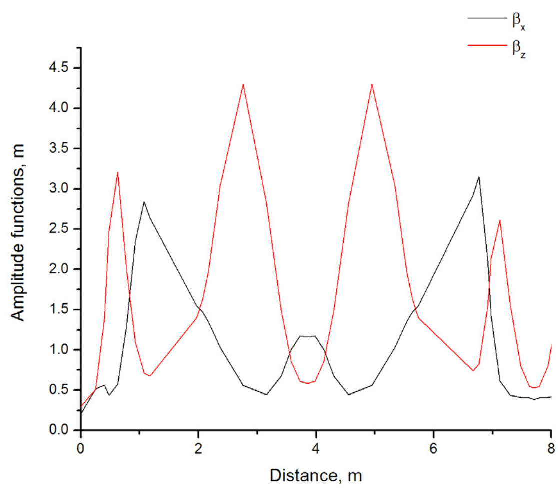

Figure 3: The beta functions of modified lattice.

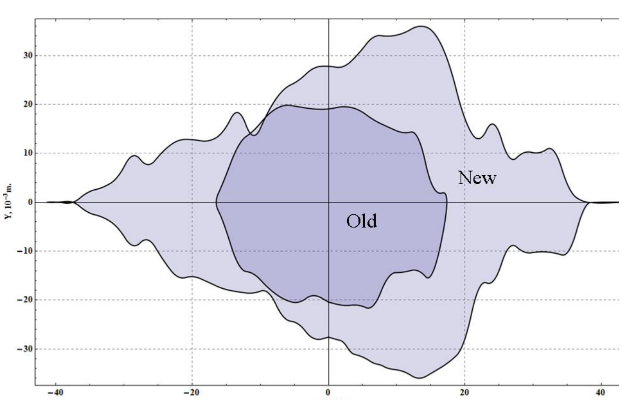

Figure 4: The dynamic aperture of the NESTOR storage ring.

THE FIRST RESULTS OF THE NESTOR COMMISSIONING

During 2012 year the commissioning of the NESTOR facility linear accelerator-injector, transportation channel and injection system have been carried out.

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

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

Fig. 5 and 6 show layout and photo of the NESTOR facility injection transportation channel.

Formed beam on the scintillating screen is shown in Fig. 7. Beam sizes are in a good agreement with the calculated. 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.

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.

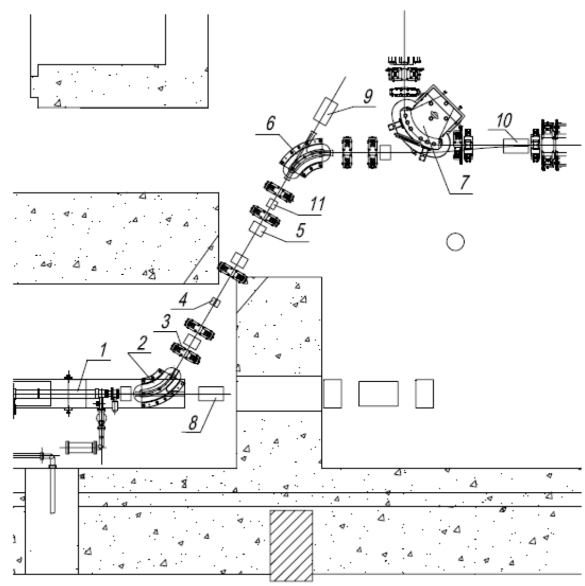

Figure 5: Layout of the NESTOR facility injection transportation channel: 1- linear accelerator, 2 – the first transportation channel dipole magnet, 3 – quadrupole lenses, 4 – collimator, 5 – dipole beam position correctors, 6 - the second transportation channel dipole magnet, 7 - the first storage ringl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

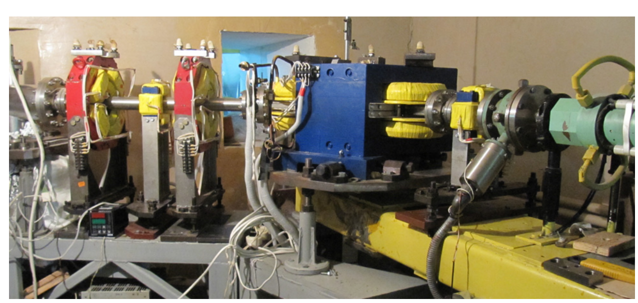

Figure 6: NESTOR injection channel (view from the linear accelerator.

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During the commissioning of the NESTOR facility the following control systems were used:

- linear accelerator control system with monitoring and control of RF voltage, RF faze, magnetic focusing elements and so on;
- storage ring magnetic element power supply control system;
- beam diagnostic system at the NESTOR transportation channel;
- cooling system of the electron accelerator;
- cooling system of the storage ring;
- video monitoring system of the facility.

Fig. 8 shows control room. At the moment the control systems of the RF, LLRF, vacuum, storage ring beam diagnostics systems are under design and development.

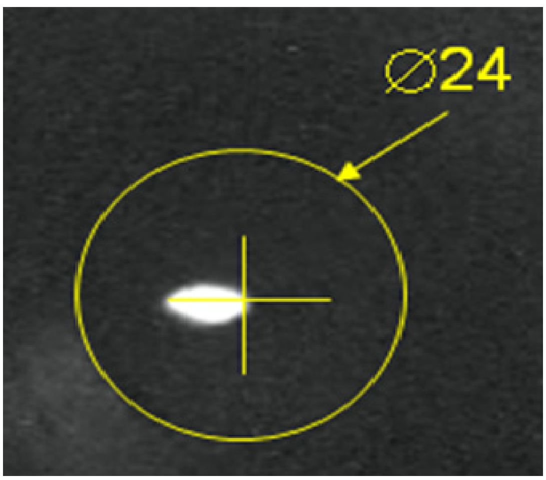

Figure 7: Electron beam shape behind the second bending magnet of the transporation channel the (9, Fig. 1).

Figure 8: NESTOR facility control room.

LASER-OPTICAL SYSTEM

In our generator, we propose to use a laser with the following parameters: $\lambda = 1.064\ \mu$, $f = 350$ MHz (with tuning), power = 10 W and Fabri Perot resonator with the parameters: $L = 0.406$ m, mirrors with R = 99.9%, waist ~ 100 μ, interaction angle ~ 10 °

The figure 9 shows a 3D model of the optical resonator for a laser beam x-ray source NESTOR

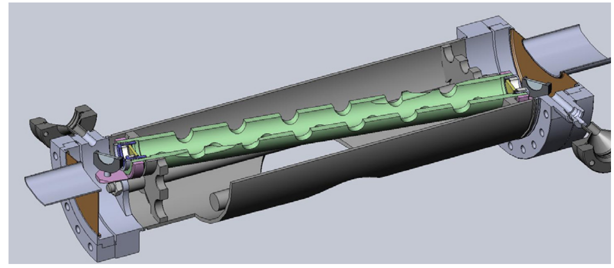

Figure 9: 3D model of the optical resonator for a laser beam x-ray source NESTOR.

CONCLUSION

NESTOR is the facility capable to generate intense X-rays (X-rays over energy range up to 900 keV with long-term stable intensity up to 10^{13} phot/s) for medicine, science and technological purpose. It is the most promising one for the reasons the values of generated radiation intensity and spectral brightness. Moreover, this facility is competitive with synchrotron radiation sources first of all for the cost and compactness.

We expect that the successful realization of our project goals (it is supposed that NESTOR storage ring will be in operation in the middle of 2014 year.) will contribute to the resolution of significant problems dealing with long term industrial and environmental issues with multilateral ramifications.

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