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MODERNIZATION OF THE NSC KIPT HARD X-RAY SOURCE FACILITY*

O. Cherkashyn, P. Gladkikh, I. M. Karrnaukhov, A. Mytsykov, V. Grevtstev, A. Zelinsky
NSC KIPT, Kharkiv, Ukraine

Abstract

To satisfy up-to-date technical requirements NSC KIPT hard X-ray source on the base of Compton scattering NESTOR should be modified. Essential modernization should be done in accelerator-injector, lattice of the storage ring, RF and optical systems.

In the paper the technical proposals of the facility modernizations and results of beam dynamic simulations in the modified facility are presented and described.

INTRODUCTION

The NSC KIPT X-rays source NESTOR (**N**ew **E**lectron **STO**rage **R**ing) facility [1] includes linear 35–90 MeV electron accelerator as an injector, beam transportation system, compact 40–225 MeV storage ring, Nd:YAG laser system and optical cavity. During the last few years the detail tests of the NESTOR accelerating systems were carried out [2, 3].

The test results showed to provide the proper electron beam storage and X-rays flux generation value of about 10^{12} phot/s the essential facility modernization should be done.

LINEAR ACCELERATOR

The linac-injector consists of a diode electron gun, which accelerates a beam with a current of 0.2 A to an energy of 25 keV with modulator, an injector on evanescent wave, which accelerates particles to an energy of 1 MeV and two traveling wave accelerating sections the first of which is the section"Kharkiv-85" [4] 4,22 m long, and the second is the LU-60 section [5] 3,22 m long with output beam energy up to 90 MeV. The accelerator operating RF frequency is 2797 MHz.

Operation showed some disadvantages of this accelerator associated with used of accelerator injector hardware and long sections without additional beam focusing. In addition, the use of 2797 MHz operation frequency makes it difficult to purchase components of the RF system with such a frequency for further operation.

Thus, it became necessary to develop a new up to date injector and accelerator with commonly use operation RF frequency of 2856 MHz. In turn, changing the injector frequency necessitates upgrading of the storage ring lattice.

The injector part of the NSC KIPT subcritical assembly accelerator-driver uses a triode EIMAC Y824 gun with fast pulser, a pre-buncher, a buncher, and a 1.38-m accelerating structure, which provide a beam with a bunch charge of 300 pC at an energy of 12.5 MeV [6]. We plan to use the same kind of injector when upgrading the accelerator.

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† zelinsky@kipt.kharkov.ua.

Another possibility is use of F102414 triode electron gun by ALTAIR with 20-30 kV high voltage and 1 A beam current along with accelerating section of 20 Mev electron beam energy.

The injection energy into the NESTOR storage ring was chosen to be 60 MeV, which provides a beam lifetime of about 20 minutes. The adjustment of the storage ring to the required energy is ensured by its adiabatic change.

Based on the hardware mentioned above, few variants of the accelerator layout can be realized with similar parameters of electron beam.

The most natural but the most expensive way is a brand new accelerator on the base of above described injector part and three or four 1.38 m accelerating structures with about 15 MeV electron energy gain in each section.

More flexible and less expensive accelerator layout based on recirculator with two accelerating sections is presented in Fig. 1. Such a scheme provides intense electron beam with energy up to 90 MeV.

STORAGE RING MODERNIZATION

The NESTOR storage ring lattice was developed in the early 2000s. The main initial data for calculating the X-ray intensity were the charge in the electron bunch of 0.5 nC and the energy stacked in the laser bunch of the optical resonator equal to 1 mJ (about 350 kW of power incident on the mirrors). The maximum calculated intensity of the beam of scattered photons under these conditions was approximately 1014 phot/s, and the beam energy losses due to Compton scattering were approximately equal to the losses due to synchrotron radiation. Because of such a high intensity of the Compton beam, the calculated energy spread of the electron beam would reach about 1.5%, which required the storage ring lattice with a large energy separatrix. For its implementation, a lattice with an adjustable momentum compaction factor was proposed. Along with the main advantage - a large separatrix, this lattice also had a disadvantage - a small dynamic aperture due to the asymmetry of the storage ring focusing.

At the state art of laser-optical technologies, it is possible to create an optical resonator with a power incident on mirrors not exceeding several tens of kW. Under these conditions the scattered photons beam intensity will not exceed of about 1012 phot/s. Considering this circumstance, it would be expedient to weaken the requirements for the beam separatrix and symmetrize the ring lattice.

The NESTOR storage ring circumference is equal to C = 15.418 m, harmonics number is h = 36 under RF frequency of fRF = 2797 MHz. The simplest option for upgrading the ring with minimal alterations when switching to a frequency of 2856 MHz would be to increase the RF harmonics number to 37.

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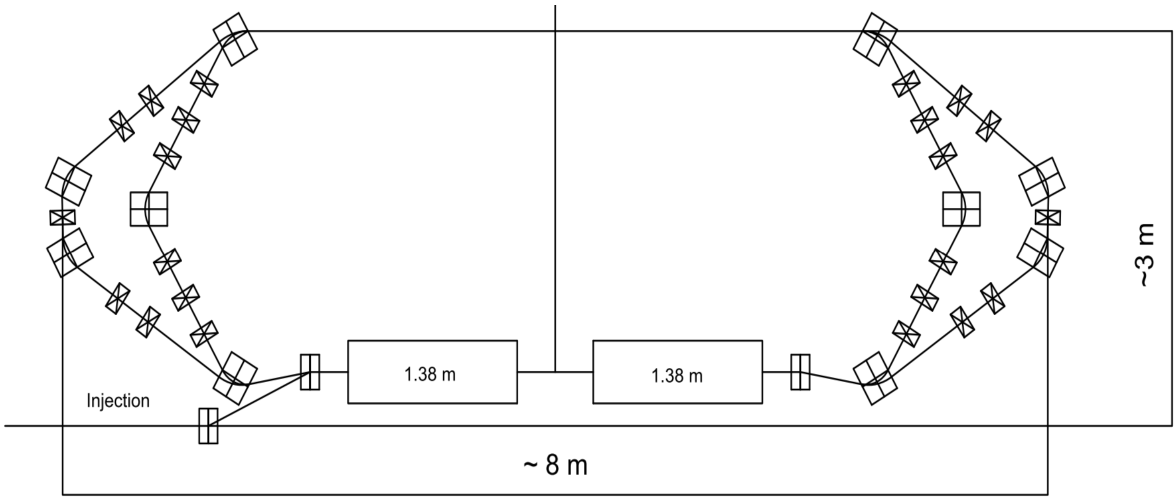

Figure 1: Modernised accelerator layout based on recirculator.

To match the ring perimeter with new RF frequency it is needed to enlarge the ring circumference of about 12 cm. It may be performed by the lengthening of both ring long straight sections by 6 cm. The injection path of the ring remains unchanged.

The ring amplitude and dispersion functions after modernization are shown in Fig. 2a, 2b. The strengths of the elements in above described lattice remain practically unchanged (not more than ± 3%).

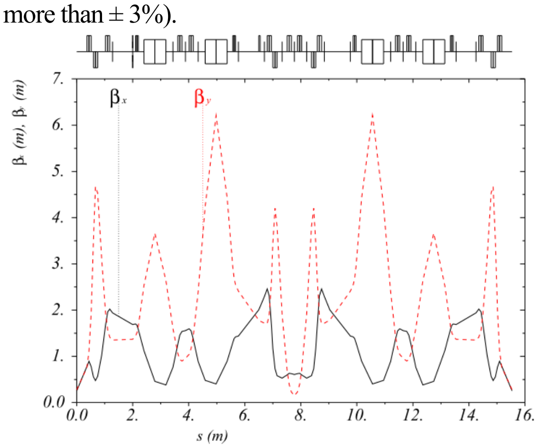

Figure 2a: Amplitude functions at harmonics number h = 37.

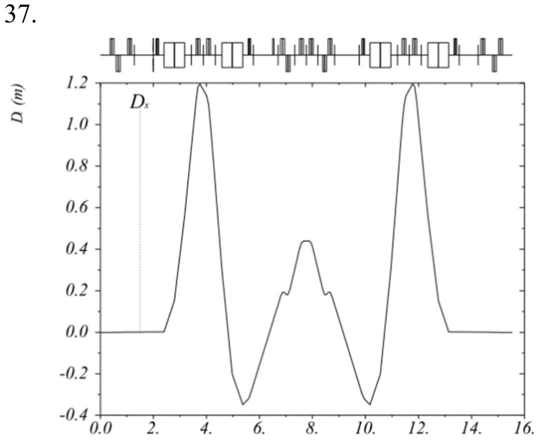

Figure 2b: Dispersion function at harmonics number h = 37.

Much more significant changes will be required in the symmetric lattice with RF harmonics number h = 36. Its amplitude functions over single superperiod are shown in Fig. 3.

Table 1 shows the comparative parameters of the lattices described above.

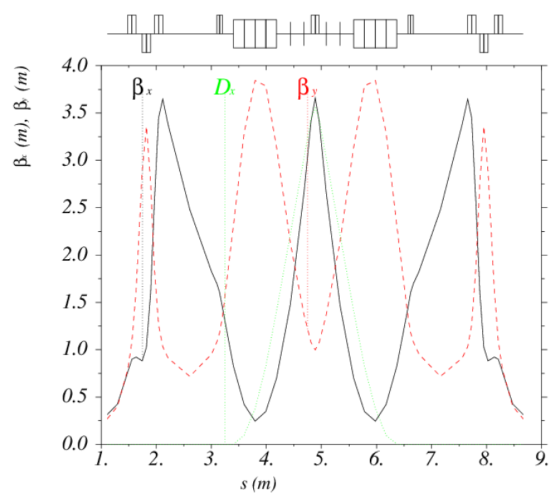

Figure 3: Amplitude functions of single superperiod of lattice with RF harmonics number h = 36.

Table 1: The main rings parameters

Parameter	NESTOR	Lattice with h=37	Lattice with h=36
Ring circumference, m	15.418	15.538	15.116
Betatron frequences Q_x/Q_y	3.141/1.765	3.149/1.785	2.927/ 2.155
Momentum compaction	0.01	0.01	0.08
Separatix value, %	>4	>4	~ 2

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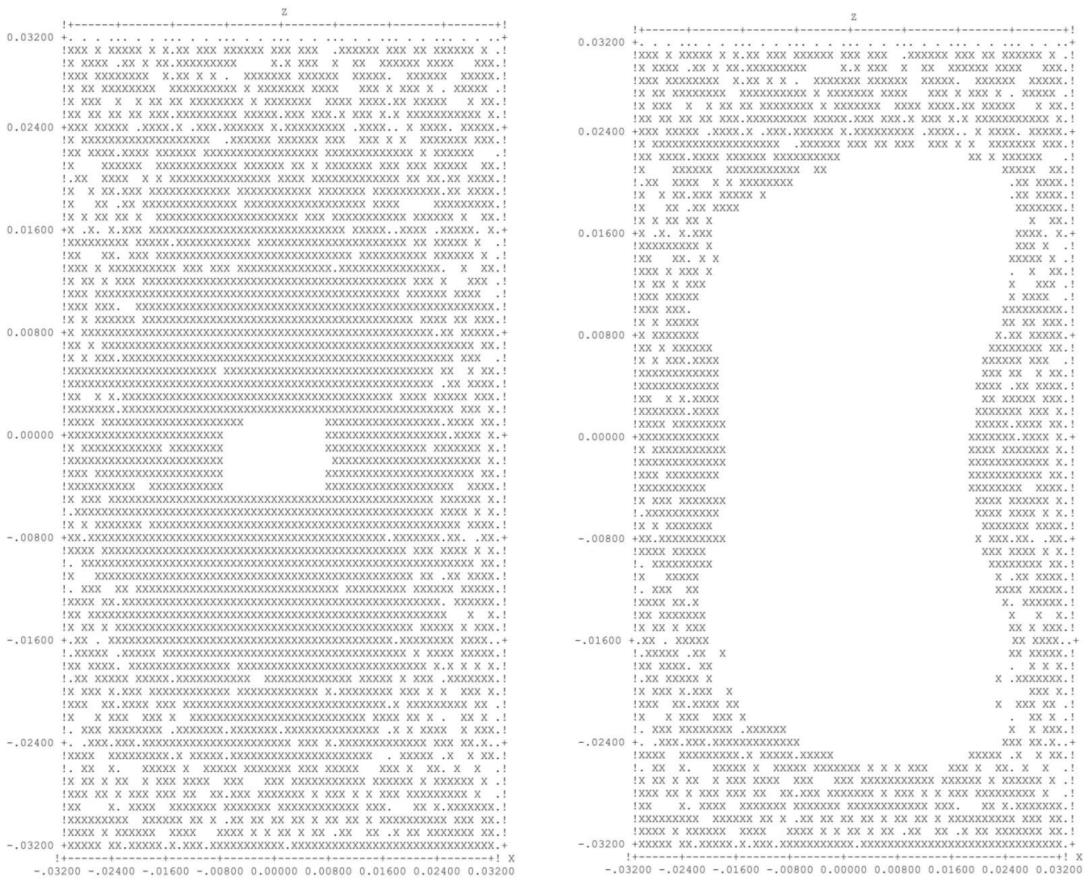

Figure 4: Dynamic apertures of the NESTOR (left) and storage ring with RF harmonics number h = 36.

Comparison of the dynamic apertures of the NESTOR storage ring and symmetrized ring with momentum compaction factor α = 0.08 (h = 36) is presented in Fig. 4.

The final choice of the upgrade option for the NESTOR hard X-ray generator will be made during the further consideration.

CONCLUSION

The ways of the NESTOR X-ray source facility modernization are under consideration at NSC KIPT. The reasons for the modernization are improvement of the injection efficiency to the storage ring and change of the accelerator operation frequency to 2856 MHz. The preliminary estimations show the possibility of the facility modernization without essential construction and engineering efforts.

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