STATUS OF KHARKOV X-RAY GENERATOR BASED ON COMPTON SCATTERING NESTOR

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Abstract

Nowadays the sources of the X-rays based on a storage ring with low beam energy and Compton scattering of intense laser beam are under development in several laboratories.

In the paper the state-of-art in development and construction of cooperative project of a Kharkov advanced X-ray source NESTOR based on electron storage ring with beam energy 43 – 225 MeV and Nd:YAG laser is described. The layout of the facility is presented and latest results are described. The designed lattice includes 4 dipole magnets with combined focusing functions, 20 quadrupole magnets and 19 sextupoles with correcting components of magnetic field. At the present time a set of quadrupole magnet is under manufacturing and bending magnet reconstruction is going on. The main parameters of developed vacuum system providing residual gas pressure in the storage ring vacuum chamber up to 10^{-9} torr are presented. The basic parameters of the X-ray source laser and injection systems are presented.

The facility is going to be in operation in the middle of 2006 and generated X-rays flux is expected to be of about 10^{13} phot/s.

INTRODUCTION

The progress of the NESTOR X-ray generator based on Compton scattering of an intense laser beam on electron beam with low energy circulating in a storage ring has been regularly reported [1-4] since its very first proposal in 1998 [5]. But in reality the project entered in construction phase after SfP NATO Grant #977982 award in early 2003.

At present a full scale definition of the magnetic system design specification was completed and design projects of vacuum and laser systems are under development. Results of beam dynamics investigations and main technological systems design have been completed with the production of a technical design report.

X-RAY PARAMETERS OF NESTOR

Luminosity and brightness are the main characteristics of any light source. Table 1 shows luminosity and spectral brightness of NESTOR source in the main operation modes [6].

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Table 1. NESTOR X-ray parameters.

	Angiography	Biology	Hard X-ray
X-ray energy, keV	33	5-16	900
X-ray luminosity, phot/(mm^{2}s)	10^{15}	4×10^{13}	4×10^{14}-4×10^{15}
Spectral brightness, phot/(s mm^2 mrad^2 0.1%BW)	5×10^{12}	2×10^{11}	5×10^{12}-5×10^{13}

MAIN NESTOR FACILITY PARAMETERS

Based on the strategy of maximum X-ray intensity with feasible parameters of technological systems the main NESTOR facility parameters were worked out (Table 2).

Table 2. The main NESTOR facility parameters.

Parameter	Value
Storage ring circumference, m	15.418
Electron beam energy range, MeV	40-225
Betatron tunes Q_x, Q_z	3.155; 2.082
Amplitude functions β_x, β_z at IP, m	0.14; 0.12
Linear momentum compaction factor α_1	0.01-0.078
RF acceptance, %	> 5
RF frequency, MHz	700
RF voltage, MV	0.3
Harmonics number	36
Number of circulating electron bunches	2; 3; 4; 6; 9; 12; 18; 36
Electron bunch current, mA	10
Laser flash energy into optical cavity, mJ	1
Collision angle, degrees	10; 150
Scattered photon energy (Nd laser, ε_{las} = 1.16 eV), keV	6-900

NESTOR ALLOCATION AND LATTICE

NESTOR X-ray source is constructed on the base of N-100 electron storage ring and is located in a building of 300 MeV linear accelerator complex. Such decision makes the total cost of the project much cheaper for the reasons of existed infrastructure using and absence of building construction costs. Layout of the NESTOR facility is presented in Fig.1. For new equipment allocation an old radiation shelter has been broken down and new one is going to be build. Old accelerators sections and N-100 storage ring were dismounted and new accelerator section, injection channel and magnetic system of the storage ring along with a laser system will be assembled as it is shown in the figure.

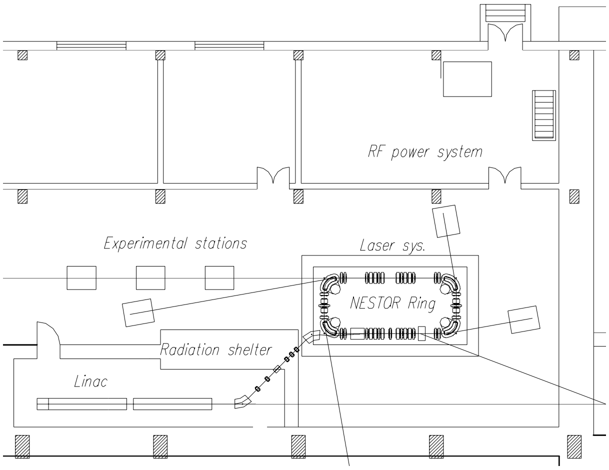

Figure1. NESTOR facility layout.

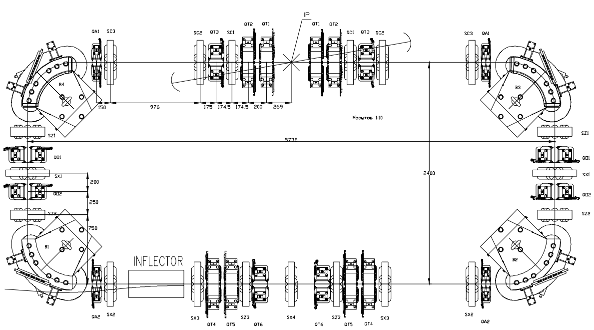

Figure 2. NESTOR ring layout.

The detail description of the magnetic lattice of the NESTOR storage ring is presented in [7]. The layout of the storage ring is shown in Fig.2. The lattice corresponds to racetrack. Long straight section with IP is dispersion free while dispersion on opposite long straight section is non-zero. The designed lattice includes 4 dipole magnets with combined focusing functions, 20 quadrupole magnets and 19 sextupoles (9 with horizontal-vertical correction, 4 with octupole component of magnetic field). Such huge number of magnetic elements as for compact storage ring with low electron beam energy is dictated by very specific and contradictory requirements to RF acceptance value, beam size at the IP and chromatic effects strength. It is supposed the reference orbit correction system will be used 12 pick-up monitors and 9 correctors. The system will provide as well global reference orbit correction along circumference with accuracy better than 240 μ as local correction at the IP. The detail description of the system is in [8].

MAGNETIC ELEMENTS OF NESTOR

Today NESTOR bending magnets are under manufacturing. The bases for the new magnets are N-100 dipole magnets. Fig.3 shows 3D drawing of the NESTOR bending magnet after reconstructuion. Table 3 lists the main magnet parameters.

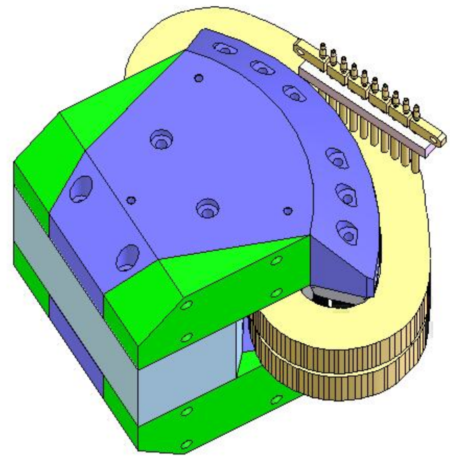

Figure 3. NESTOR bending magnet after reconstruction.

Table 3. The main parameters of bending magnets.

Parameter	Value
Number	4
Bending radius, m	0.5
Bending angle, deg.	90
Maximum induction of the field, T	1.5
Maximum field deviation, ΔB/B	1×10^{-4}
Field dipole gradient, T/m	1.8
Field index	0.6
Working area size, mm×mm	25×20
Gap, mm	36
Field gradient deviation, %	±1
Coil resistance, Ω	0.1
Coil current under 1.5 T induction,A	300

Quadrupole magnets of three different size-types but with similar design are under manufacturing. Fig.4 shows 3D drawing of the NESTOR quadrupole and Table 4 lists the main magnet parameters. The main quadrupole coils are winded with cupper rectangular pipe (10×10 mm) with inner diameter of 7 mm. All qaudrupoles are connected in series with bending magnets. To meet parameters of quadrupoles and bending magnets additional low current coils are provided (Fig. 4).

Main parameters of NESTOR sextupole magnets are listed in Table 5.

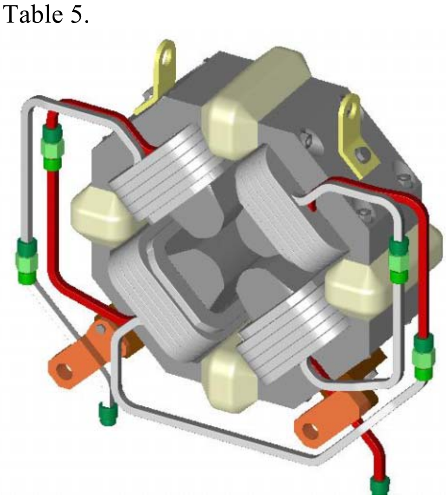

Figure 4. NESTOR quadrupole magnet.

Table 4. The main parameters of quadrupole magnets.

Parameter	Type 1	Type 2	Type 3
Number	8	8	4
Length, m	0.12	0.12	0.07
Effective field length, m	0.15	0.15	0.1
Aperture radius, m	0.026	0.026	0.026
Maximal gradient, T/m	27	12	7
Turn number	11-24	5-10	7
Excitation current, A	300	300	300
Working area, mm×mm	±35×35	±35×35	±35×35
Gradient deviation, ΔG/G	2×10^{-2}	2×10^{-2}	2×10^{-2}

Table 5. Main parameter of sextupole magnets

Parameter	Value
Number	19
Aperture radius, m	0.032
Length, m	0.07
Effective field length, m	0.10
Max. sextupole gradient, T/m^2	500
Max correction dipole field, T	0.03
Octupole gradient, T/m^3	5000

INJECTION SYSTEM

The injection in a compact storage ring is quite difficult task. The detail description of injection investigation results one can find in [9]. Single turn horizontal injection will be performed by means of three fast pulsed electromagnetic inflectors. Fast switches will regulate the voltage on the inflectors. The output of the switches will be matched to the complex load of the inflectors. Two blocks of the inflectors will be based on existed two sections of N-100 inflector (Fig. 5). Table 6 gives the main parameters of the inflector system.

Table 6. The main parameters of inflector system.

Parameter	Value
Total length, m	0.6
Injection angle, deg	6
Length of the section, m	0.16
Max voltage of inductor, kV	60
Gap, m	0.02
Rise-decay time, ns	10
Pulse width, ns	50
Repetition rate, Hz	0.1

Figure 5. NESTOR inflector prototype.

It is supposed that on the first stage NESTOR will use the 60 MeV accelerator section with the main parameters are listed in the Table 7.

Table 7. The main parameters of injector.

Parameter	Value
Electron beam energy, MeV	60
Emittance, m*rad	5×10^{-7}
Energy spread, %	3
Pulse charge, nC	0.5
Pulse duration, ps	10
Repetition rate, MHz	700

VACUUM SYSTEM DEVELOPMENT

As it was determined during vacuum system development a pressure of $5\cdot10^{-9}$ Torr will be provided at a specific out-gassing in NESTOR vacuum chamber less than $\sim3\cdot10^{-9}$ torr·l/(cm^2·s). Such value of out-gassing can be provided at stainless steel vacuum chamber using general methods of the chamber cleaning.

Consideration shows that most reasonable for NESTOR to choose 8 sites of pumping with pumping speed equal to 150 l/s. As pumping equipment a pump Trion-150-NMTO-01-1 was chosen. It provides the limiting residual pressure of ~ 10^{-11} torr, evacuates noble gases and hydrocarbons. At bending magnet sections, along with pumps, nonevaporable getters are provided for pumping. The technology of non-evaporable getter material production was designed in NSC KIPT. The structure, micro hardness, chemical compound for the alloy with the following mass components (% of mass) 74,25 Zr, 19,4 V, 4,86 Fe and 1,49 Nb were investigated.

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