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MODERNIZATION OF THE LASER-OPTICAL SYSTEM OF THE X-RAY GENERATOR NESTOR*

O. Cherkashyn, A. Zelinsky†, National Science Centre,
Kharkiv Institute of Physics and Technology, Kharkiv, Ukraine

Modernization of the accelerating ring of the NESTOR hard X-ray generator for switching to the operating frequency of the accelerator of 2.856 GHz requires corresponding changes in the design of the high-frequency system, and this, in turn, leads to the need to modernize the laser-optical system (LOS). The necessary calculations were carried out to determine the new characteristics of the pulsed laser, the Fabry-Perot cavity, and the lens system matching the beam geometry in the path and the optical resonator. The results obtained confirm the possibility of using an already existing LOS at a new operating frequency of the accelerator with some changes in the design.

INTRODUCTION

The development of a highly efficient X-ray source based on Compton backscattering requires the presence of short electron and photon bunches that have a small cross section and a sufficiently high collision frequency [1-4].

It is currently not possible to obtain high-intensity photon bunches from laser sources, even with the use of quantum amplifiers. To significantly increase the energy of photon bunches, it was proposed to use high-Q optical cavities (a two-mirror Fabry-Perot resonator or a four-mirror optical cavity with two focusing reflectors), which are part of laser-optical systems (LOS) [5-7].

LASER-OPTICAL SYSTEM OF THE X-RAY GENERATOR NESTOR

The structural block diagram of the LOS of the NESTOR generator is shown in Fig. 1. As a powerful pulsed laser, it is planned to use a PICOLASER 10 IR series laser from the German company ALPHALAS. It has an average output power of 10 W, at a wavelength of λ=1064 nm. The duration of the generated pulses is 10 ps, and their repetition rate is about 350 MHz with the possibility of slight tuning, which is a necessary condition for matching the operating frequencies of the electronic storage ring fRF and the laser pulse repetition frequency frep at the interaction point. The beam diameter at the laser output is 1 mm.

Figure 2 shows a 3D model of the optical cavity for a laser beam of X-ray source NESTOR.

The main optical elements of the NESTOR LOS are described in Table 1. Such an LOS with a phase-locked loop can provide photonic bunches that meet the required conditions for obtaining of the high-intensity X-rays.

Table 1: The Main Optical Elements of the LOS

№	Optical element	Model
1	Pulsed infrared laser	ALPHALAS PICOLASER 10 IR
2	Faraday isolator	1030-1080nm ISO-FRDY-OPT
3	Electro-optical modulator	Broadband phase modulator, 1000-1600 nm
4	Profiler	LBP2 laser beam profiler, 190-1100 nm
5	Photodetector	Biased photodetector, 1000-1650nm, InGaAs, 12.5 GHz, Newport 818-BB-35
6	Polarization cube	Laser line polarizing cube Beamsplitter, 25.4 mm, 1064 nm
7	Polarizing plate $\lambda/2$	Zero-order quartz wave Plate, 25.4 mm, 1064 nm, $\lambda/2$
8	Polarizing plate $\lambda/4$	Zero-order quartz wave Plate, 25.4 mm, 1064 nm, $\lambda/4$
9	Mirrors for an optical resonator	UVFS plano-concave mirror, R_M = 215 mm,

During the works on the physical start-up of the NESTOR source, it became necessary to modernize and optimize both storage ring and linear accelerator-injector. During the reconstruction we suppose to change the operating RF-frequency from 2797 MHz to 2856 MHz. It leads to the need to modernize the LOS because it is an integral part of the facility and is closely connected with the RF system of the storage ring.

The first element that we have to rework is an intense IR laser ALPHALAS PICOLASER 10 IR with a pulse repetition rate frep = 350M Hz. It is this parameter that needs to be changed: it must be a multiple of both injector and storage ring RF-frequency. Unfortunately, the laser pulse repetition frequency tuning, which was provided by the manufacturer, does not cover the required range from frep0 = 350 MHz to frep = 357 MHz, and we will have to turn to ALPHALAS to upgrade the laser.

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† email: zelinsky@kipt.kharkov.ua

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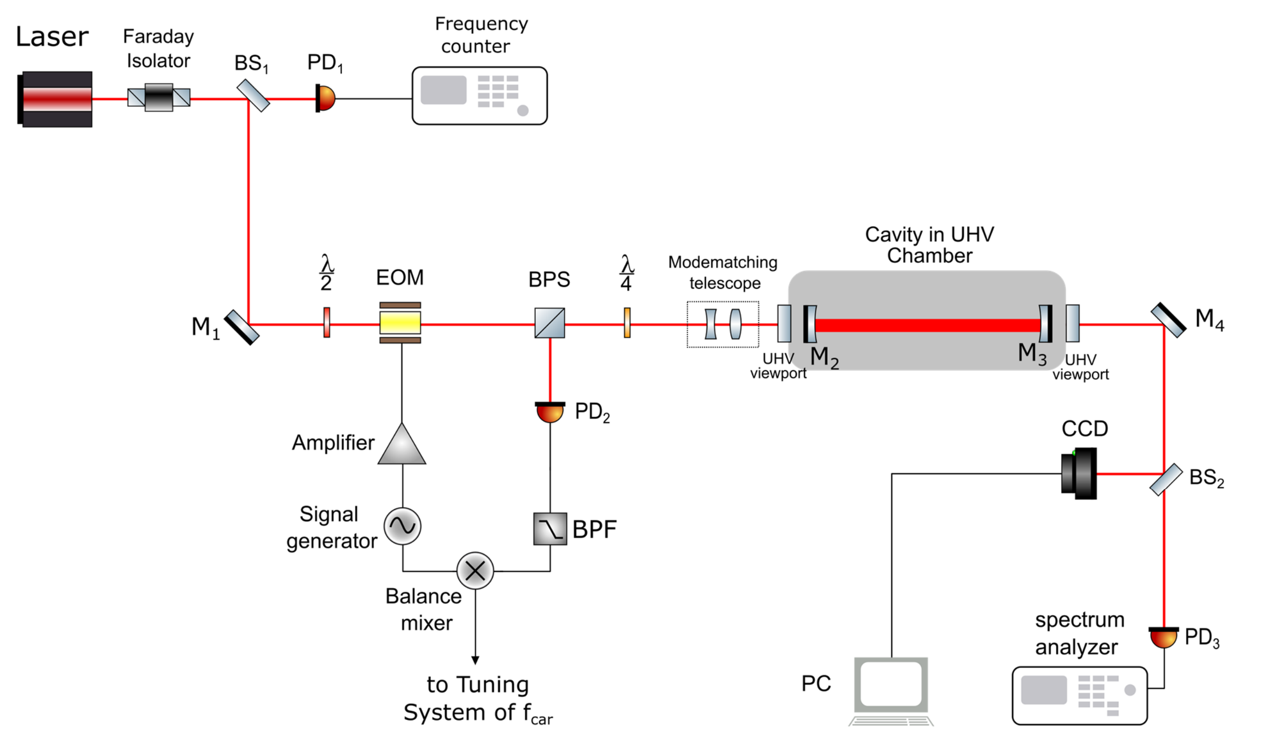

Figure 1: The structure of the LOS of the NESTOR generator.

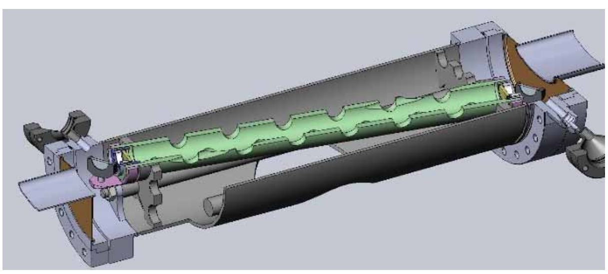

Figure 2: 3D model of the optical resonator for a laser beam x-ray source NESTOR.

Another element of the LOS that needs to be changed is a two-mirror optical cavity. Its length is directly related to the repetition rate of laser pulses

$$f_{rep} = c / 2L \tag{1}$$

where c is the light speed, L is the resonator length. In the case of frep0 = 350 MHz, the length of the Fabry-Perot resonator is L≈428.27 mm, and for frep = 357 MHz, L≈419.88 mm for the resonator with geometry closed to the concentric one.

The resonator length together with the radius of curvature of the mirrors RM will determine the beam waist ω0 inside the resonator

$$\omega_0^2 = \frac{\lambda}{2\pi}\sqrt{L\left(R_M - L\right)} \tag{2}$$

with the RM from Table 1 and the new resonator length, the beam waist size in the resonator will increase from 60 µm to about 105 µm, so we suppose to reduce the RM to 210 mm. In these conditions the beam waist will be approximately 40 µm.

CONCLUSION

The article describes possible alterations of the LOS of the NESTOR X-Ray source caused by the modernization of the storage ring. A block diagram of the system is briefly presented and the necessary changes associated with tuning the laser pulse repetition rate are indicated. The solution of this problem requires the replacement of several key elements of the LOS, but the structure and principle of operation of the setup remain the same.

REFERENCES

[1] E. Bulyak *et al.*, "Compact X-ray source based on Compton backscattering," *Nucl. Instrum. Methods Phys. Res., Sect. A*, vol. 487, no. 3, pp. 241-248, Jul. 2002. doi:10.1016/s0168-9002(02)00904-x

[2] F. V. Hartemann *et al.*, "Compton scattering and its applications: The Pleiades femtosecond X-Ray source at LLNL," *World Sci: Quantum Aspects of Beam Physics*, Oct. 2004. doi:10.1142/9789812702333_0005

[3] A. Variola *et al.*, "The ThomX Project Status", in *Proc. IPAC'14*, Dresden, Germany, Jun. 2014, pp. 2062-2064. doi:10.18429/JACoW-IPAC2014-WEPRO052

[4] H. Shimizu *et al*, "X-ray generation by inverse Compton scattering at the superconducting RF test facility," *Nucl. Instrum. Methods Phys. Res., Sect. A,* vol. 772, pp. 26-33, Feb. 2015. doi:10.1016/j.nima.2014.10.080

[5] L. Xiao-Ping and P. Guo, "Experiment studies on the polarized gamma-rays generation at KEK-ATF", *Chinese Phys,* vol. C 33, no. 8, pp. 691-695, Jul. 2009. doi:10.1088/1674-1137/33/8/018

ISBN: 978-3-95450-231-8 ISSN: 2673-5490 doi: 10.18429/JACoW-IPAC2023-MOPA076

[6] H. Shimizu, A. Aryshev, Y. Higashi, Y. Honda, and J. Urakawa, “Development of a 4-mirror optical cavity for an inverse Compton scattering experiment in the STF,” *Nucl. Instrum. Methods Phys. Res., Sect. A*, vol. 745, pp. 63-72, May 2014. doi:10.1016/j.nima.2014.01.055

[7] J. Bonis *et al.*, “Non-planar four-mirror optical cavity for high intensity gamma ray flux production by pulsed laser beam Compton scattering off GeV-electrons,” *J. Instrum.*, vol. 7, no. 01, pp. P01017-P01017, Jan. 2012. doi: 10.1088/1748-0221/7/01/p01017