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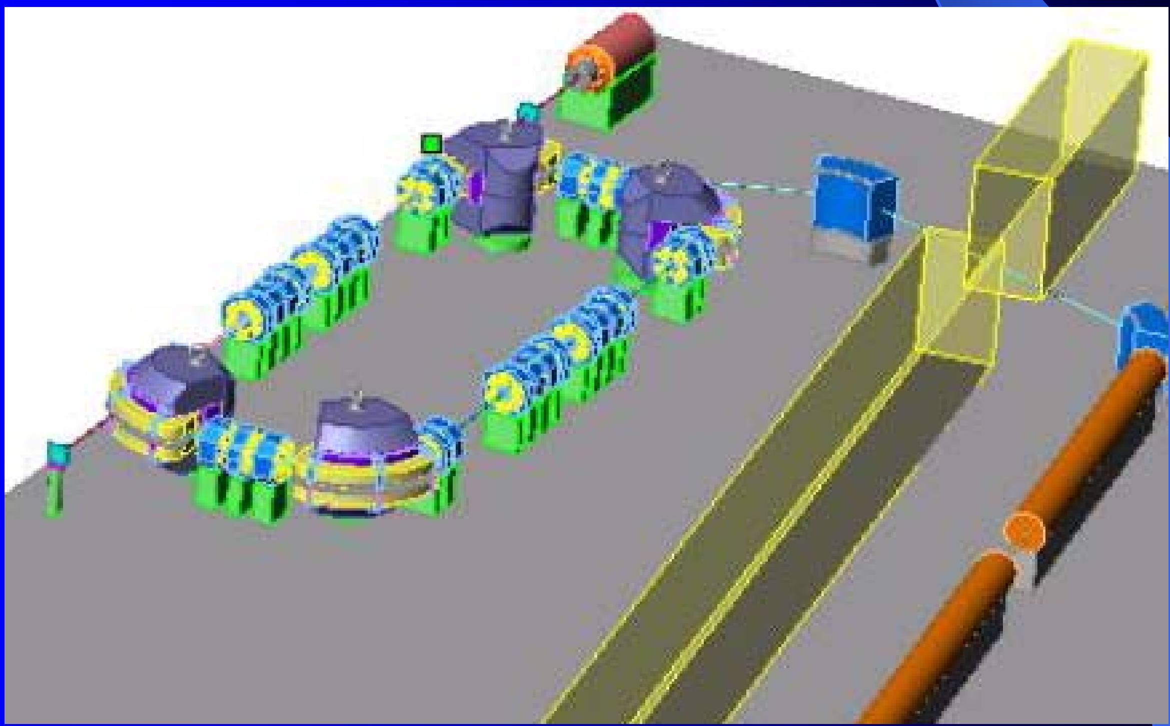
The NESTOR† X-Ray Generator

- Tunability
- Low cost
- Flexibility
- Compactness
- High flux



† "Next-generation Electron STOrage Ring"

A.Shcherbakov

DEVELOPMENT OF AN ADVANCED X-RAY GENERATOR BASED ON COMPTON BACK-SCATTERING: A PROPOSAL FOR THE SCIENCE FOR PEACE SUB-PROGRAMME OF NATO

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An extended form of a cooperative project proposal is presented. The main goal of the proposal is the design and construction of a storage ring X-ray generator based on Compton backscattering. The project's primary objectives and organisation, together with a draft plan for the required N-100 storage ring reconstruction effort, are outlined.

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INTRODUCTION

Intense X-ray beams are widely used in basic and applied research. The beams are generally produced using bremsstrahlung, synchrotron radiation, and Compton backscattering (CBS). An advantage of CBS is the possibility of generating hard X-rays with low energy electron beams.

In 1963, Arutyunyan, Tumanian, and Milburn [1] suggested that Compton backscattering of laser light by an electron beam could be used for producing hard γ-quanta. Some years later, a scheme based on multiple passes of electrons circulating through an optical resonator located in a storage ring's interaction region was proposed for increasing the intensity of the backscattered photons.

Subsequently, Huang and Ruth proposed a laser-electron storage ring (LESR) based on this principle [2]. In the LESR the transverse beam emittance is significantly reduced and intense X-rays are produced. The electron beam is injected into the storage ring, and then an intense laser pulse is introduced into a high-Q

collide with the laser pulse at the interaction point (IP). The laser pulse in the LESR interacts with the electron beam much like an undulator, acting to decrease its emittance.

During the project we plan to design and construct an X-ray generator based on the CBS idea.

PROJECT INFORMATION

The main objectives of our project are:

- development of the underlying physics and design of an X-ray generator based on Compton backscattering of intense laser light off a relativistic electron beam in a storage ring;
- development of the necessary X-ray optical and diagnostic systems
- study of the problem of concurrent X-ray generation and laser cooling of an electron beam circulating in a storage ring.

- reconstruction of the N-100 storage ring [3]
- commissioning of the upgraded N-100 storage ring

We have already developed a preliminary focusing lattice design and performed initial simulations of electron beam dynamics in the storage ring.

The layout of the lattice is shown schematically in Fig. 1. The arc lattice and phase advances of the betatron oscillations were chosen to provide optimal conditions for the correction of the natural chromaticity of the ring. The matching of arcs and long straight sections is accomplished by quadrupole lens triplets. The existing bending magnets of the N-100 ring, with bending angles of $\varphi = 90°$, will be used in the proposed lattice. [4]

The main parameters of the storage ring for a stored beam energy of $E = 100$ *MeV* are given in Table 1.

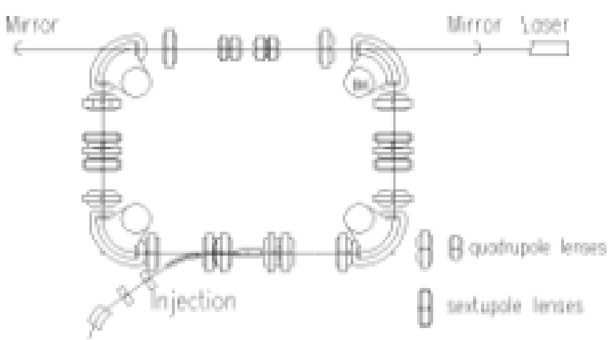

Fig. 1. Layout of the storage ring.

The straight interaction section of the storage ring and the axis of the optical resonator are coaxially aligned. The resonator is formed by two high-quality mirrors with reflection coefficients close to unity. The round-trip spacing between the resonator mirrors is equal to the electron orbit length inside the storage ring. The single-mode laser generates light pulses of 50 *ns* duration (pulse length σ_f = 15 *mm*), with a pulse-repetition frequency $f \sim 10^4$ and an average power P = 100 *W* (flash energy being about 10 *mJ*). The laser active element is manufactured from an yttrium-aluminium garnet crystal activated with neodymium (*Nd: YAG*). The wavelength of the main harmonic is $\lambda = 1.06\ \mu m$. The transverse size is attained in the middle of the interaction region.

Table 1. Main parameters of the storage ring

Parameter	Value
Operating energy range *[MeV]*	40-250
Injection energy *[MeV]*	70
Circumference *[m]*	13.716
	4
Tunes:	
horizontal, Q_x	3.427
vertical, Q_z	3.149
Amplitude functions at IP *[cm]*:	
horizontal, β_x	3
vertical, β_z	2.5
RF voltage amplitude *[MW]*	0.4
RF frequency *[MHz]*	699.28
Harmonic number *n*	32
Momentum compaction factor, α	.099
Synchrotron oscillation tune, Q_s	0.041
Energy acceptance, *[%]*	±3
Emittance ε_x, *[nm-r]*	14.7
Horizontal beam size at *IP* with *IBS*, *[μm]*	120
Natural chromaticity:	
in horizontal plane, ξ_x	-6.658
in vertical plane, ξ_z	-13.856

The laser-electron interaction gives rise to beam energy spread. For the proposed lattice the operating mode of the storage ring can be easily varied to control the value of the momentum compaction factor. This is obtained by a change of the dispersion function in the injection straight section. This allows an increase in the energy acceptance of the storage ring up to ±15 %.

Organisation, Management and Budget of the Project

Our project period is 3 years. A detailed Project Plan will be prepared later. The X-ray generator will be constructed at NSC KIPT using existing buildings and infrastructure.

The project organisation is shown in Fig.2. The role of each of the participating groups is:

Ukrainian group – design, development and construction of the storage ring. Investigation of electron beam dynamics in the storage ring and software development;

Russian group – theoretical study of the laser cooling process;

Belarus group - design, development and construction of laser and optical equipment;

USA group – theoretical and computational study of laser-electron interactions and investigation of femtosecond X-ray pulse production;

Netherlands group – theoretical and numerical studies of the laser-electron interaction.

We request from NATO for this project 12 Million

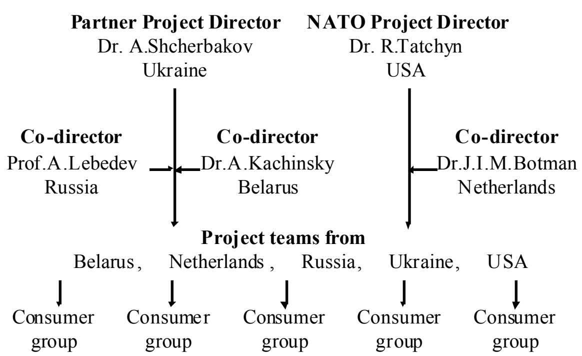

Fig.2. Structure of Project Organisation

The total budget support required from NATO is 12 Million Belgian Francs (MBEF), of which 2 MBEF will be awarded to the NATO country participants. Fig.3 shows how these funds are allocated among the project partners. These funds will be provided to the Partner country participants to cover the cost of scientific equipment, computers, software, travel, and project-specific consumables. Salaries will be covered from other sources (state, academic, STCU…)

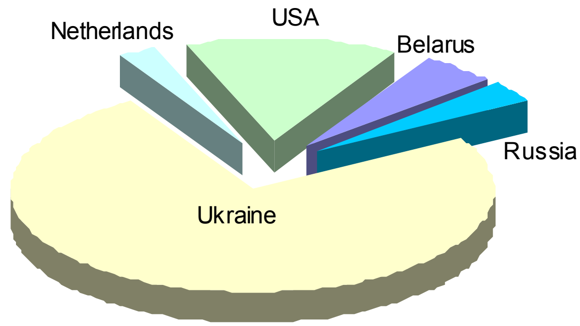

Fig. 3. Budgetary Information

We expect the professional skill and experience of the participating staff will allow us to carry out the project on time and at an exemplary scientific and technological level. We anticipate that the successful realisation of our goals will contribute to the resolution of significant problems dealing with long term industrial and environmental issues with multilateral ramifications. The capability of our developed source should also promote collaboration among scientists, industry and other end-users and improve the integration of scientists from Belarus, Russia and Ukraine into the international R&D community.

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