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ФИЗИКА И ТЕХНИКА УСКОРИТЕЛЕЙ

DEVELOPMENT OF RECIRCULATOR WITH SUPERCONDUCTING ACCELERATING STRUCTURES TESLA IN UKRAINE

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The project of recirculator which is supposed to be created in NSC KIPT is presented. The basic solutions incorporated in the design are given. Superconducting sections TESLA are chosen as accelerating structure of an accelerating complex.

Описан проект рециркулятора, который предполагается создать в ННЦ ХФТИ. Приведены основные решения, заложенные в проект рециркулятора. В качестве ускоряющей структуры комплекса выбраны сверхпроводящие секции TESLA.

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INTRODUCTION

Most of accelerators in the territory of Ukraine were developed and created in the 50–60s of the last century. So, the electron linacs LU300 and LU2000 largest in the USSR have been started in 1963 and to 1965. Attempt of improvement of LU2000 beam parameters due to construction of the stretcher ring in the 1980s has not crowned success. At the beginning of the 1990s with the discontinuance by the industry release of some important completing devices all large accelerators in NSC KIPT have been stopped. In this connection there was a necessity of making of the modern accelerating complex, allowing one to carry out the broad circle of problems on a nuclear physics, nuclear energetics, and applied research with the use of electron beams of high energy. In 2003 NSC KIPT and Eindhoven Technical University (the Netherlands) have begun elaborate project of such an accelerator. In 2007 the development of the conceptual design of an electromagnetic system of the accelerator is finished.

Studying of world experience of making modern accelerating facilities [1–3] has led to inclining that the use of last achievements in the field producing superconducting accelerating structures in a combination to idea of multiple passage of a beam through accelerating structure allows creating enough compact accelerator on energy of the order 730 MeV [4]. This facility can be disposed in existing rooms of the accelerating complex LU2000 that will not demand capital construction and will essentially reduce a total cost of a complex.

Recirculator is designed first of all as facility for fundamental research in the field of nuclear physics [2]. One of perspective directions of experimental research on new NSC

KIPT installation can be related to precision examinations of processes of photo- and electro-productions of pions, a Compton scattering on nucleons and nucleus, examination of influence of nuclear environment on properties of hadrons and their interactions in nuclear substance, studying of three-partial forces and the meson exchange currents in nucleus. Other perspective direction is examination of electron interaction with periodic structures and making of the new sources of the intensive and polarized radiation [5].

1. RECIRCULATOR STRUCTURE

Being the Institute of High Energy and Nuclear Physics NSC KIPT base installation, designed accelerator should generate the beams, satisfying the widest class of experiments which can be executed on beams with energy up to 730 MeV including for applied research. In this connection installation is planned to equip with injectors of both polarized and not polarized electrons. For diminution of time necessary for installation framing, it is supposed to use the wide experience which has been saved at leading world centers on developing of injectors and accelerating systems.

For acceleration of electrons superconducting accelerating structure TESLA on frequency of 1.3 GHz, developed in DESY [9], is chosen. This structure allows one to gain accelerating lapse rate planned for our installation of 20 MeV/m and the underload energy straggling. For our installation we have chosen the module, containing two standard sections TESLA, made serially by firm ACCEL [9]. Such six modules will settle down in a major rectilinear recirculator gap, one will be used in an injector of the polarized electrons.

As a prototype of a source of not polarized electrons the injector developed during several years at centre ELBE in Rossendorf (Germany) [7] is chosen. The superconduct-

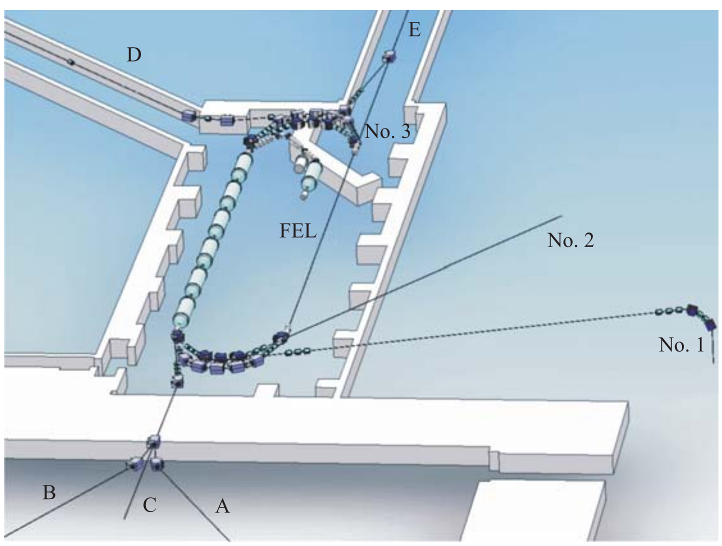

Fig. 1. SALO recirculator on the peak energy 730 MeV layout with beam transportation channels

ing accelerating structure of an injector on frequency of 1.3 GHz is produced by firm ACCEL (Germany) [8]. The peak energy of electrons on an exit of an injector — 9.5 MeV.

As a prototype injector of the polarized electrons we select an injector developed for SEBAF accelerator [6]. As energy of electrons in it does not exceed 100 keV, for accelerating electrons up to 9.5 MeV it is supposed to use one more module. It will be situated after the electron-emitting source.

In Fig. 1 the plan of recirculator arrangement in target hall of accelerating complex LU2000 with channels of transportation beams and adjoining premises is shown.

2. MAGNETOOPTICAL STRUCTURE OF SALO RECIRCULATOR

Optimization of all chosen magnetooptical systems with the purpose of diminution of energy straggling of a beam [4] has been led. The minimization of the beam energy spread has been reached by isochronicity of all sections of the beam line, since injection beam line and including two sites of beam recirculation.

The plan of injection allowing promptly enough transferring from operation with one injector before operation with another [4] is chosen. The peak energy of injection is equal to 9.5 MeV.

For injection the magnet which is a part of a chicane from three magnets is used. Three dipole magnets located before accelerating section cause a feeble arcuation of a trajectory for the basic beam and allow yielding injection of a beam with energy 9.5 MeV passing magnets of arches. Such a system of injection allows one to regulate energy of the accelerated electrons smoothly. In Fig. 2 the site of injection of a beam in structure of recycling is shown.

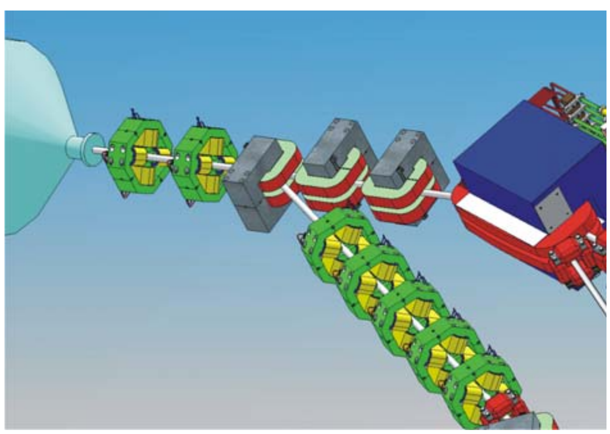

Fig. 2. Injection of a beam in accelerating structure

Into a composition of magnetooptical system of the first ring enter 10 dipole magnets and 12 quadrupole lenses of EUTERPE storage ring transmitted NSC KIPT by Eindhoven Technical University [5].

Because of necessity to turn out beam in existing SP-103 hall [2] the initiating structure of the second turn of recycling [4] has been changed — two quadrupole lenses are removed. In Figs. 3, 4 functions of focusing of the second turn of recycling after this operation are given.

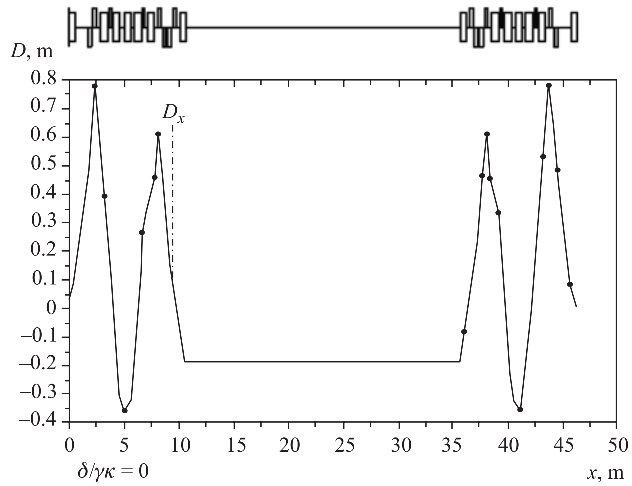

Fig. 3. Structure of the second turn of recycling and dispersion function of focusing

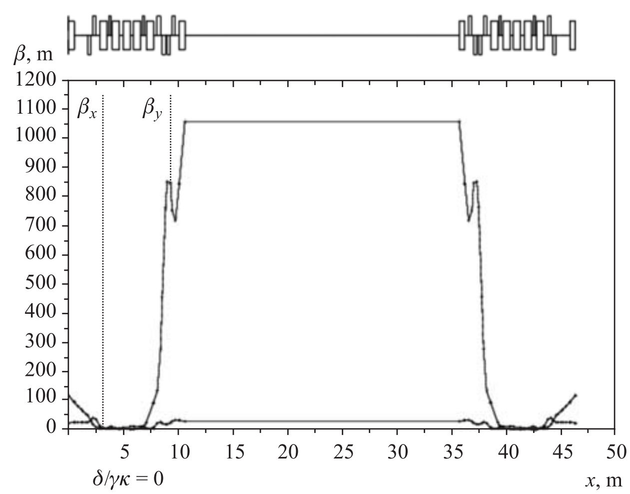

Fig. 4. Structure of the second turn of recycling and peak functions of focusing

Dipole magnets and the strong quadrupoles enter into magnetooptical structure of the second turn except for magnetic devices of EUTERPE storage ring. The construction of these magnetic devices is developed specially for SALO recirculator (see Figs. 5, 6).

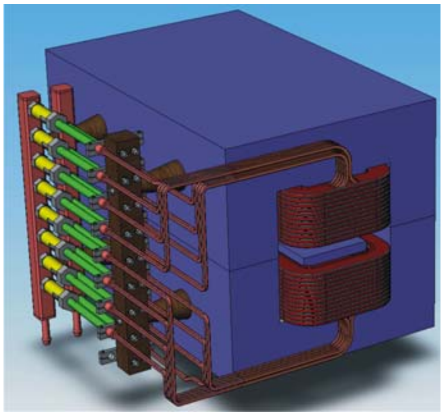

Fig. 5. General view of a dipole magnet of the second turn of recycling

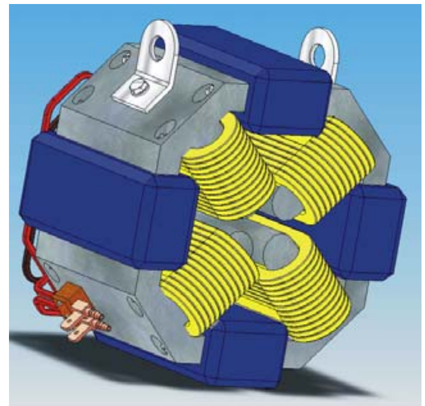

Fig. 6. General view of a quadrupole magnet of the second turn of recycling

For the peak energy of electrons 730 MeV the beam emittance on a recirculator exit will be equal to 0.004 $\pi \cdot \mathrm{mm} \cdot \mathrm{mrad}$ and energy straggling — $2 \cdot 10^{-5}$.

3. THE ELECTRON BEAM LINES FROM SALO RECIRCULATOR TO PHYSICAL INSTALLATION

For operation on the physical program [5] developing of five beam lines A, B, C, D and E (see Fig. 1) is provided. The maximum energy of electrons on lines A, B, C is equal to 730 MeV, and on lines D and E — 490 MeV. The lines magnetooptical structure is chosen from the reasons of satisfaction of experiment requirements: the cross sizes of a beam — ± 0.02 cm; divergence — ± 0.05 mrad.

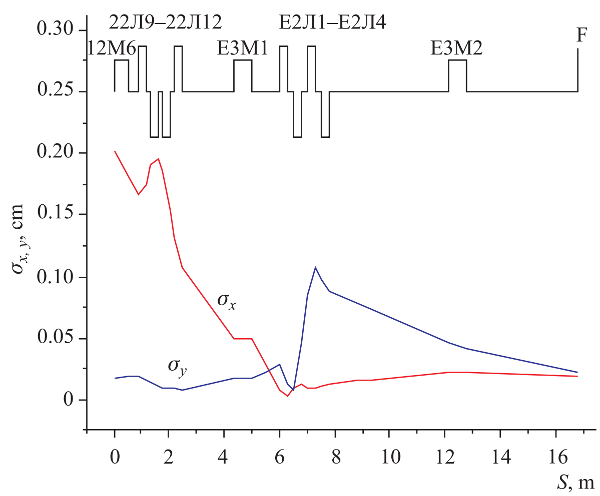

Fig. 7. The sizes of electron beam along line E

In Fig. 7, for example, the vertical and horizontal sizes of a beam of electrons lengthways for E line are given. Point F corresponds to a standing of a target.

The accelerator design provides an opportunity of its operation as driver of subcritical reactor [10]. For this purpose making of special line, which possible directions in Fig. 1 are designated No. 1–No. 3, is supposed. At designing of this line the basic attention should be given to minimization of beam losses, which mean power will be close to 130 kW. With this purpose the beam sizes on all path of transportation should be minimum.

However, at the end of a line the requirement to the sizes of a beam essentially changes. On the neutron generating target, the power density should be the least for improvement of target cooling. The beam size should be the closest to the size of a target. At diameter of a target of 6 cm, diameter of a beam on it should be equal to 5 cm in our case. Therefore, after rotational displacement of an axis of a beam from a horizontal plane in vertical, the size of a beam apart about 1.9 m from edge of the last rotary magnet should increase

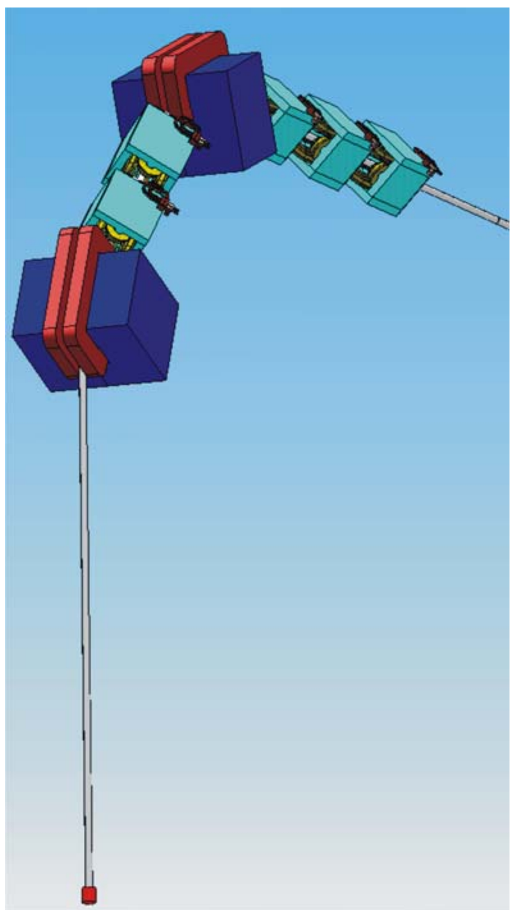

Fig. 8. Turn of a beam on a target

sharply. This problem can be carried out with the help of magnetic structure which general view is given in Fig. 8. Change of the beam sizes in this structure is shown in Fig. 9.

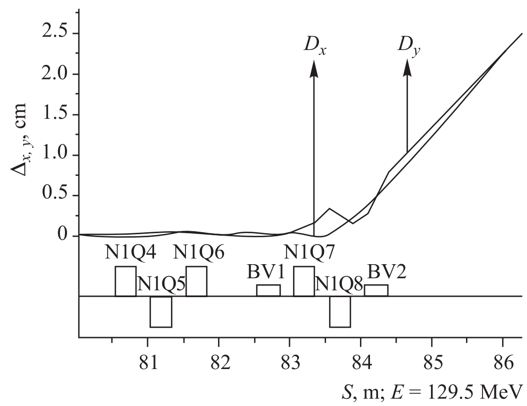

Fig. 9. The beam sizes on a terminal site of transportation of electrons on a target

The free electron laser (FEL) can be disposed in the free rectilinear recirculator gap, and radiation can be output in a direction of channel E. The second place for arrangement of the laser — channel C.

CONCLUSION

The design allows allocating two possible stages in recirculator start. The first stage guesses the use of available constructions and inventories. It is necessary to buy serially released modules of accelerating structures and a high-frequency injector. This stage guesses the start of the accelerator on energy 490 MeV.

At the second stage it is necessary to develop and make magnetic system of the second ring and an injector of a polarized electron beam.

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