LINEAR CHARGED-PARTICLE ACCELERATORS (THEORY AND TECHNOLOGY)

https://doi.org/10.46813/2023-145-084

MAGNETO-OPTICAL STRUCTURE OF THE MULTIFUNCTIONAL ACCELERATOR COMPLEX NSC KIPT

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Optimization of the magneto-optical structure of the multi-functional accelerator complex of the NSC KIPT was carried out. Changing the scheme of injection into the first ring made it possible to obtain a structure symmetrical about the axes of the ring, which had a positive effect on the dynamics of the electron beam movement in the recirculator. The parameters of the beam at the output of the accelerator are given.

PACS: 29.20.-c

INTRODUCTION

In works [1, 2], the conceptual project of creating a multifunctional accelerator complex (Multifunctional Accelerator Complex – MAC) with a continuous beam for research in nuclear physics, neutron physics, physics of free electron lasers was considered and its use for the introduction of radiation technologies in industry, energy, medicine, biology and other fields of science and technology.

The basis of this project was the latest achievements in the development of superconducting accelerator structures, which are recognized as the main direction in the development of electronic accelerators in Europe and the world in the next 5…10 years [3].

The core of this project is a recirculator with a three-fold passage of the beam through the accelerating structure. The linear accelerator consists of seven modules built on the basis of the TESLA superconducting structure [4]. The maximum beam energy at the exit of the recirculator is 559.5 MeV [2].

In the course of further work on the magneto-optical structure, it became necessary to make some changes that ensured the improvement of the parameters of the accelerating and extracted beam.

1. INJECTION

The standard injection zigzag, which ensures the transmission of the beam without loss of characteristics from the injector to the first ring of the recirculator, looks like this (Fig. 1):

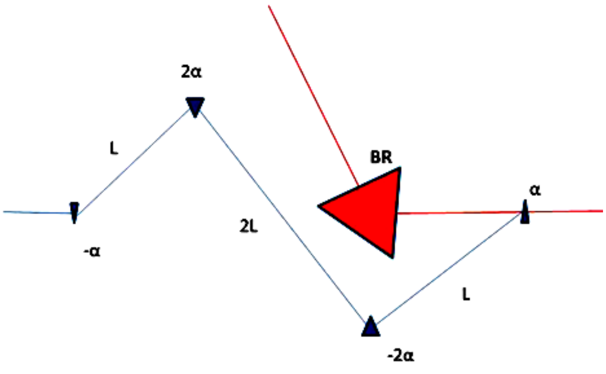

Fig. 1. Injection options. BR is an element of the ring structure, blue triangles are zigzag magnets

For gradientless sector magnets, the conditions of achromatic isochronous beam transfer are shown in the figure. We cannot use such a scheme, since we are going to use an injection beam to generate positrons. In this regard, a combination of injection parallel transfer and a ring structure with a total turn in the arch greater than 180º was used for injection (Fig. 2).

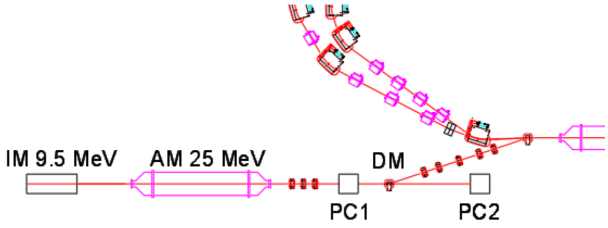

Fig. 2. Injection into the recirculator

The electron beam from the injection module IM will be further accelerated to an energy of 34.5 MeV in the superconducting module AM [4] and will be injected into the recirculator with the help of the DM magnet. To create an intense source of positrons, the PC1 converter will be used, the design of which involves cleaning the target from the trajectory of the electron beam into the recirculator.

When the DM magnet is turned off, the direct beam can be used for radiation treatment of materials, production of isotopes for medicine, creation of a source of slow positrons (PC2) for positron annihilation spectroscopy, etc.

2. RECIRCULATOR

The main disadvantages of the previously considered magneto-optical recirculator structures [1, 2] are as follows:

- Asymmetry of the structure due to the injection chicane. This leads to an increase in the longitudinal harmonics of the perturbation of the fields of the focusing elements and the strengthening of nonlinear effects in the dynamics of the electron beam.
- "Crowding" in the area of beam output with maximum energy (Fig. 3). The angle between the output channel and the channel of the second recirculation ring is 5.85º, due to which the first focusing elements of the channel cannot be located close enough to the exit of the

beam from the SC magnet. The channel becomes long and has poor focus.

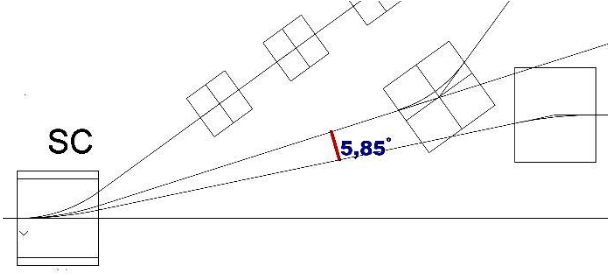

Fig. 3. Structure of the beam output channel with maximum energy

To eliminate the first drawback, a structure with an angle of rotation of the arch is proposed $\psi > 180^\circ$

$$\psi = 180^\circ + 2\varphi,$$

where $\varphi = 3^\circ$ (210 MeV) is the angle of rotation of the additional magnet on long straight sections. Injection into the recirculator is carried out with the help of this magnet (see Fig. 2). The focusing structure becomes symmetrical, which is clearly visible on the phase portraits of the beam. In principle, you could limit yourself to only two additional magnets on the straight-line span of the accelerator, but then the structure of the ring would be symmetrical only in the "left-right" sense and would remain asymmetric in the "top-bottom" sense. For complete symmetry, additional magnets were installed in the spaces opposite to the accelerator. For the same reason, a structure with two chicanes in the accelerator gap was not used.

To eliminate the second drawback, a structure with an additional AM magnet in the output channel is proposed, which allows to separate the paths of the output beam and the beam in the second recirculation ring (the angle between them becomes equal to approximately 8.5°, Fig. 4).

Fig. 5 shows the optimized magneto-optical structure of the complex. The amplitude and dispersion functions of the recirculator are presented in Figs. 6 and 7.

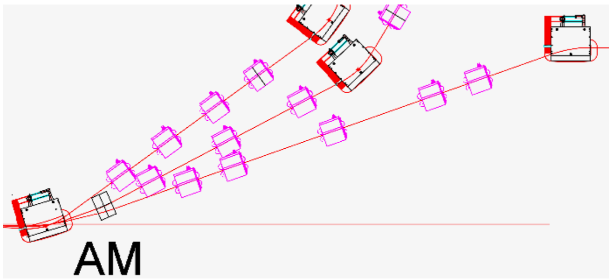

Fig. 4. Structure for the output channel with an energy of 559.5 MeV and the direct beam channel

The phase portraits of the emitted beam at the end of the channel with an energy of 559.5 MeV (see Fig. 4) are shown in Figs. 8, 9. The injection beam is shown in blue, the output beam is shown in red. The cross-section of the beam and the energy spectrum of the extracted beam are shown in Figs. 10, 11, and 12.

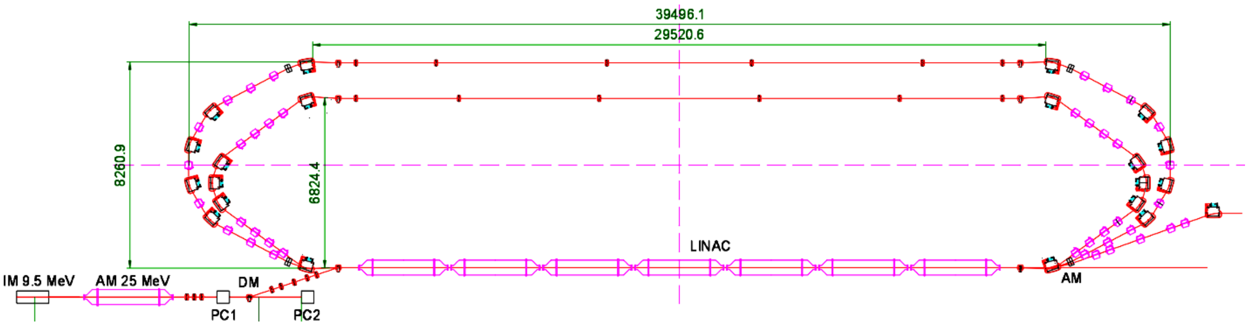

Fig. 5. Optimized magneto-optical structure of the complex

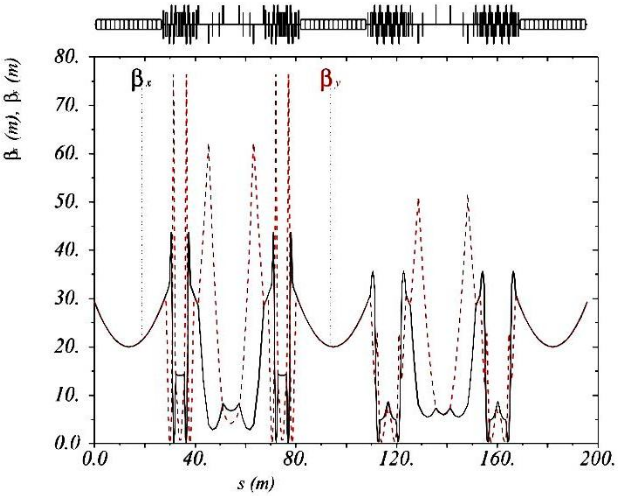

Fig. 6. Amplitude functions of two recirculator rings

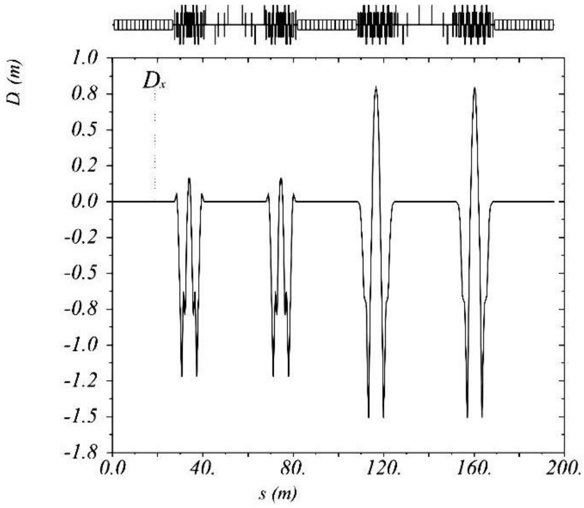

Fig. 7. Dispersion function

The parameters of the injected beam were calculated as follows:

- beam energy E_i = 34.5 MeV;
- normalized transverse emittance $\varepsilon_x = \varepsilon_y = 2\cdot10^{-6}$;
- electron bunch length (rms) l_b = 1.2 mm;
- energy spread (rms) $\delta = 1\cdot10^{-3}$.

The channel with the maximum energy can be used to inject a beam into the storage ring – a source of synchrotron radiation, to create a laser based on free electrons. Compton scattering on an electron beam with a maximum energy of Ee = 559.5 MeV will make it possible to generate gamma quanta with an energy of about 5 MeV. A beam of electrons with an energy of 559.5 MeV is a source for solving many problems in the field of nuclear physics.

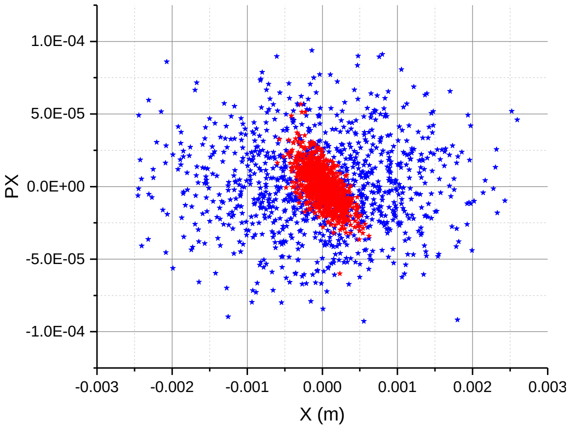

Fig. 8. Radial phase portrait of the beam at the output of the channel with an energy of 559.5 MeV

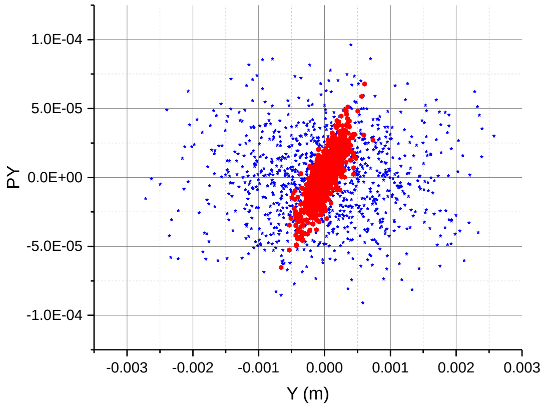

Fig. 9. Phase portrait of the beam in the vertical plane

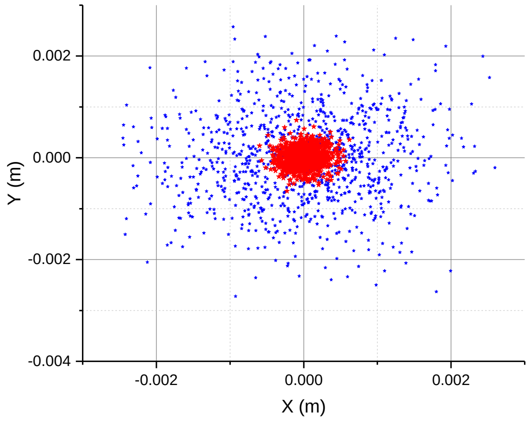

Fig. 10. Cross-section of the beam at the outlet of the channel

A direct beam channel with an electron energy of 209.5 MeV and unique time characteristics allows creating a neutron source on a short flight base, which will not be inferior in its capabilities to the world's leading installations.

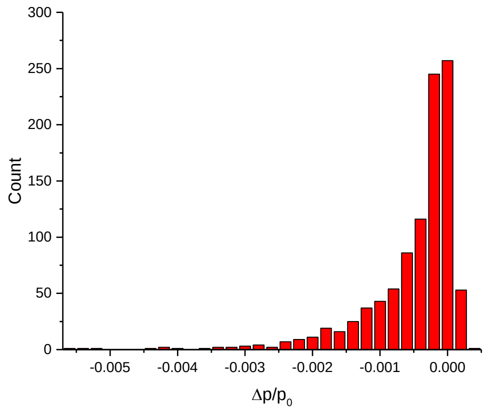

Fig. 11. Energy spectrum of the extracted beam

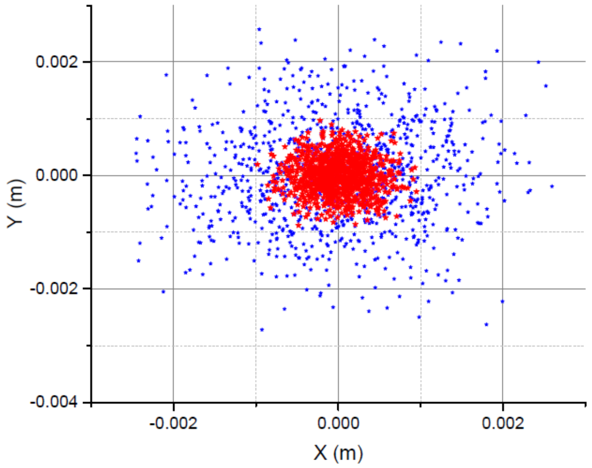

Fig. 12. Cross-section of a beam with an energy of 209.5 MeV at the output of a long gap with a linac

CONCLUSIONS

The work carried out to optimize the magneto-optical structure of the accelerator complex made it possible to improve the system parameters, which significantly affect the dynamics of the beam.

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Article received 08.04.2023

МАГНІТООПТИЧНА СТРУКТУРА БАГАТОФУНКЦІОНАЛЬНОГО ПРИСКОРЮВАЛЬНОГО КОМПЛЕКСУ ННЦ ХФТІ

М.Ф. Шульга, Г.Д. Коваленко, І.С. Гук, П.І. Гладких, Ф.А. Пєєв

Проведена оптимізація магнітооптичної структури багатофункціонального прискорювального комплексу ННЦ ХФТІ МАС. Зміна схеми інжекції в перше кільце дозволила одержати симетричну відносно осей кільця структуру, яка позитивно вплинула на динаміку руху пучка електронів у рециркуляторі. Приведені параметри пучка на виході прискорювача.