MAGNETIC STRUCTURE OF THE NSC KIPT NUCLEAR-AND-HIGH-ENERGY-PHYSICS ELECTRON ACCELERATOR AT 400 MeV

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The magnetic structure of the base accelerating facility of NSC KIPT with a continuous electron beam with an energy of 400 MeV is described.

The accelerator represents a recirculator, which is based on two standard TESLA superconducting accelerating sections, accommodated in two straight sections of 5 m long. The energy gain per turn is 2×36,36 MeV.

The magnetic system is based on EUTERPE storage ring magnetic elements. With the use of four spreader magnets and eight EUTERPE bending magnets in arcs, the beam gets an energy about 200 MeV.

In total twenty-four bending magnets ensure that the beam is guided along three turns, with a maximum energy of 400 MeV.

The calculation of beam focusing in the recirculator is carried out. The focusing and dispersion functions in the arcs, which are typical for the given installation, are represented.

Modeling of the beam movement in the accelerator has been carried out; the beam parameters during acceleration and on accelerator output have been calculated.

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1. INTRODUCTION

The basic principle of the base accelerator facility development [1] was creating a source of a continuous electron beam with energy ~400 MeV with minimal material and financial expenses. It was achieved by:

1. choice of a scheme of the accelerator with recirculation, i.e. with multiple passage by the beam of the same superconducting accelerating structure; this essentially reduces capital expenses and operational costs;
2. use of the existing workplace and infrastructure – these factors appreciably determine the general dimensions of the installation;
3. integration in the magnetic structure of the magnetic elements which have been transferred from Eindhoven technical university [2].

2. MAGNETIC STRUCTURE OF BASE ACCELERATING FACILITY

With the purpose of reducing the number of magnetic elements and proceeding from the size of the available workplace a planar arrangement of magnetic elements was chosen with four spreader magnets and two accelerating sections.

In Table 1 the basic parameters of the spreader magnets are given.

In the installation it is supposed to use TESLA superconducting accelerating structures with a frequency of 1.3 GHz (λ_0=23.06 cm). The injection energy in the recirculator equals 10 MeV.

Table 1: Parameters spreading magnets

Magnet type	Pole size	Gap	H-field strength
I type	50×50 cm^2	25 mm	0.6 T
II type	50×30 cm^2		

For the special case of arcs formed with only spreader-magnets, the condition of time synchronism looks like:

$$2S_k+l_k-(2S_m+l_m)=n\lambda\ . \qquad (1)$$

Here S_i and l_i are respectively the lengths of curved and straight sections of i-arc, λ is the wavelength of the RF-field in the accelerating section.

For a case k-m=1 and n=1 the difference of spreader magnets bending radii is equal to:

$$\Delta r = \frac{\lambda}{\pi - 2} \ . \qquad (2)$$

The energy difference is accordingly:

$$\Delta W[MeV]=3B_0[T]*\Delta r[cm] \ . \qquad (3)$$

Here B_0 is the magnetic field strength in the spreader magnets. In case B_0=0.6 T (see Table 1) the energy gain ΔW after passage of the accelerating section gives 36.36 MeV, the distance between the axes of the straight sections is L=593 cm.

In Fig. 1 the bending magnets placing scheme of the base facility is given.

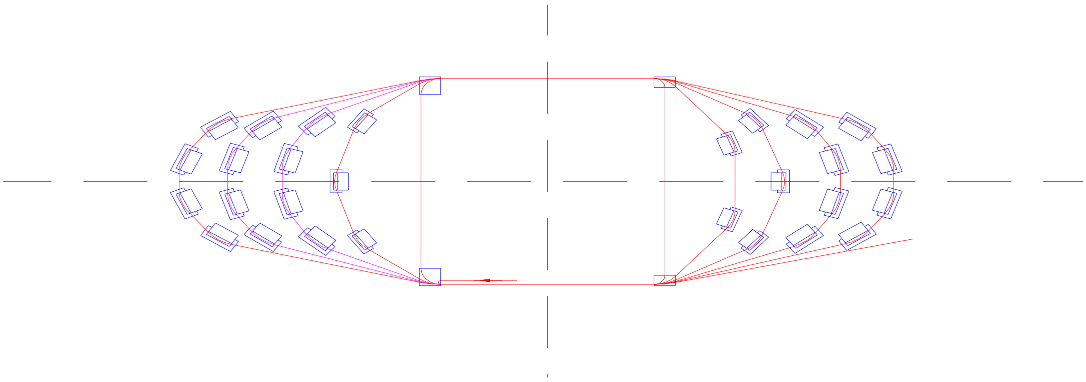

Fig.1: Lay out of the NSC KIPT base facilit.

In the arcs two types of bending magnets are used: type A (up to an energy of 191.8 MeV) developed and made at Technische Universiteit Eindhoven; type B (for energy 191.8 MeV < W< 410 MeV), which will be projected specially for the given facility.

In Table 2 the basic parameters of the bending magnets are given.

Table 2: parameters of bending magnets

Magnet type	A	B
Quantity	8	20
Design	C-type, rectangular poles	C-type, rectangular poles
Pole size	120×480 mm^2	120×620 mm^2
Effective length	500 mm	640 mm
Gap	25 mm	25 mm
Magn. field strength	1.35 T	1.2 T

For beam focusing quadrupole magnets are used [2], of which the basic parameters are given in Table 3.

Table 3: Quadrupole parameters

Quantity	stock -32 is necessary-63
Sizes	310×210×210 mm^3
Type	rectangular
Effective length	274 mm
Max. gradient	~15 T/m

For the chosen arrangement of bending magnets, the coordinates and lens strengths which provide straight sections achromaticy and vertical and horizontal beam sizes of no more than ±8 mm at an initial emittance of $\varepsilon \sim 10^{-6}$ m*rad and an initial energy spread of $\Delta E/E \sim 10^{-4}$ have been determined with the codes TRANSPORT and MAD.

In Fig.2,3 and 4 the dispersion and focusing functions are given for the arcs with an energy of 46.36 MeV, 191.8 MeV and 373.6 MeV respectively.

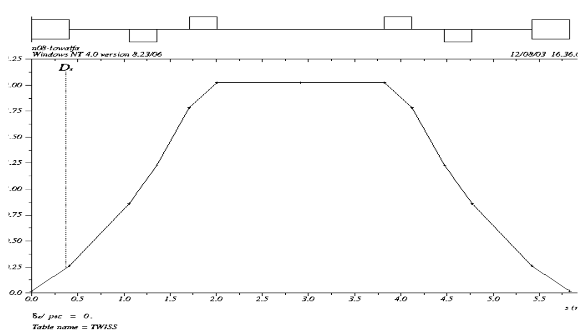

Fig. 2,a

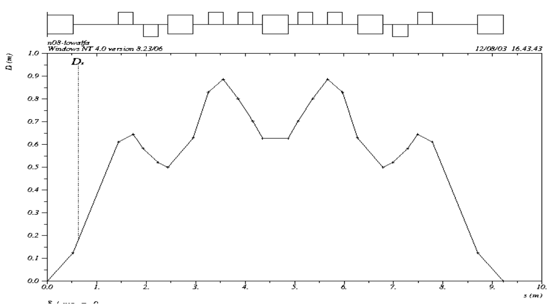

Fig. 3,a

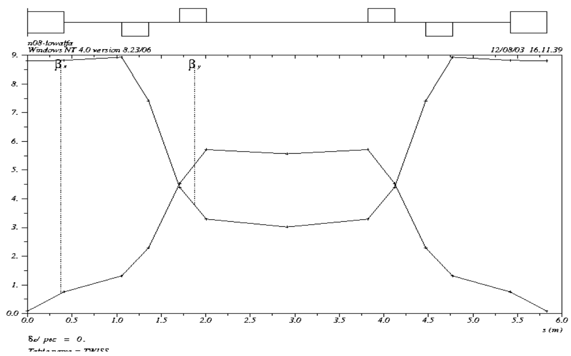

Fig. 2,b

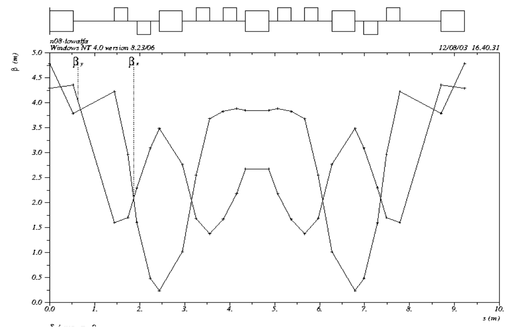

Fig. 3,b

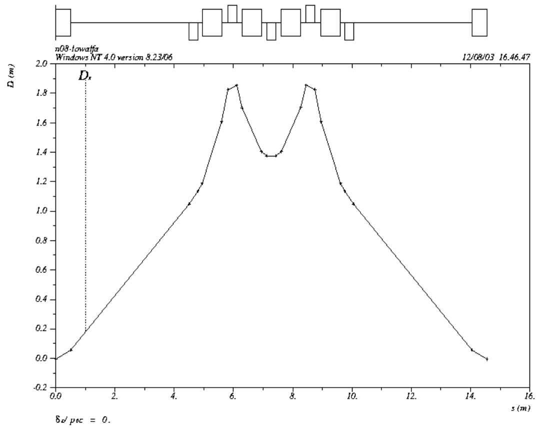

Fig.4,a (Figure caption for figures 2,a to 4,b)

3. CONCLUSIONS

The results of numerical modeling show, that the presented magnetic structure takes care of proper passage of the electron beam which is accelerated up to 410 MeV at a maximum injection beam emittance of ε ~10^{-6} m·rad. The accelerated beam has the following parameters: E=410 MeV, e~$3\cdot10^{-8}$ m·rad., $\Delta E/E\sim3\cdot10^{-5}$.

1.
2.

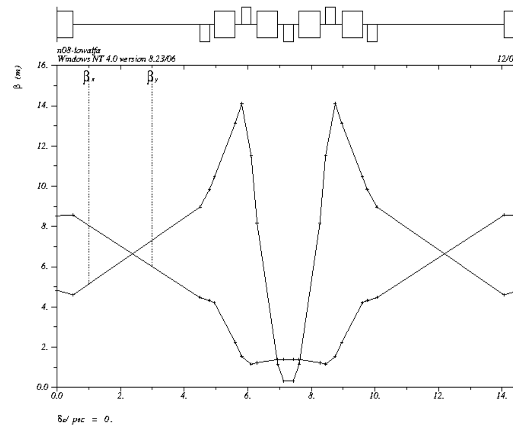

Fig. 4,b

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МАГНИТНАЯ СТРУКТУРА БАЗОВОЙ УСКОРИТЕЛЬНОЙ УСТАНОВКИ ННЦ ХФТИ

ПО ЯДЕРНОЙ И ФИЗИКЕ ВЫСОКИХ ЭНЕРГИЙ НА 400 МэВ

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Рассмотрена магнитооптическая структура базовой ускорительной установки ННЦ ХФТИ с непрерывным пучком электронов энергией 400 МэВ. Ускоритель представляет собой рециркулятор на основе двух стандартных сверхпроводящих секций TESLA, установленных в двух больших прямолинейных промежутках рециркулятора длиной 5 метров. Прирост энергии за полный оборот составляет около 72 МэВ. Магнитооптическая система спроектирована на основе магнитных элементов накопителя EUTERPE. С использованием этих магнитов и четырёх новых магнитов, пучок набирает энергию около 200 МэВ. Двадцать четыре дипольных магнита, обеспечивающих поворот пучка на три оборота, позволят получить максимальную энергию 400 МэВ. Приведены амплитудные и дисперсионные функции фокусировки на дугах рециркулятора. Проведено моделирование движения пучка в ускорителе, рассчитаны параметры пучка в процессе ускорения и на выходе ускорителя.

МАГНІТНА СТРУКТУРА БАЗОВОЇ ПРИСКОРЮВАЛЬНОЇ УСТАНОВКИ ННЦ ХФТІ ПО ЯДЕРНІЙ ТА ФІЗИЦІ ВИСОКИХ ЕНЕРГІЙ НА 400 МеВ

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Розглянута магнітооптична структура базової прискорювальної установки ННЦ ХФТІ з безперервним пучком електронів з енергією 400 МеВ. Прискорювач являє собою рециркулятор на основі двох стандартних надпровідних секцій TESLA, які розташовані в двох великих прямих відрізках рециркулятора довжиною 5 метрів. Приріст енергії за повний оберт електронів близько 72 МеВ. Магнітооптична система спроектована з використанням магнітних елементів накопичувача EUTERPE. Ці магніти та чотири нових магніти дадуть змогу одержати енергію близько 200 МеВ. Двадцять чотири дипольні магніти, які забезпечують три оберта пучка, дозволять одержати максимальну енергію 400 МеВ. В роботі приведені амплітудні і дисперсійні функції фокусування на дугах рециркулятора. Проведено моделювання руху пучка в прискорювачі, обчислені параметри пучка в процесі прискорення і на виході прискорювача.