BEAM DYNAMICS CALCULATION IN THE INDUCTION LINEAR ACCELERATOR

D.S. Bazyl, E.A. Savin, National Research Nuclear University “MEPhI”, Moscow, Russia
A.A. Zavadtsev, D.A. Zavadtsev, OOO “NANO INVEST”, Moscow, Russia

Abstract

The geometry of the linear induction electron accelerator (LIA), which will be used for high current acceleration, has been calculated. For the different currents values the optimum focusing magnetic field and has been obtained. Also a current in the compensative coil near the cathode has been calculated. The cathode electrode geometry was changing to achieve minimum beam oscillations during the acceleration.

INTRODUCION

Electric field which is created by ferromagnetic rings having windings mounted along the beam axis is used for the acceleration of particles in this type of machine. As soon as the accelerating field structure excited in the tubes is similar to the electrostatic field excited by applying a potential difference between the span tubes, to simplify the calculation in this model fields is excited by an electrostatic field.[1] Schematic version of model of the accelerator is shown on the Figure 1. Basic parameters of the accelerator are shown in Table 1.

Injector is a flat grid-controlled cathode, located in the first accelerating gap. Grid voltage is up to 200 V. Voltage on the grid draws electrons which are then accelerated in the first gap. One inductor is connected to each accelerating gap. The pulse duration of the accelerating field is ~10 ns. The modules will contain a delay pulse-matching acceleration. The calculation was carried out in a constant acceleration field.

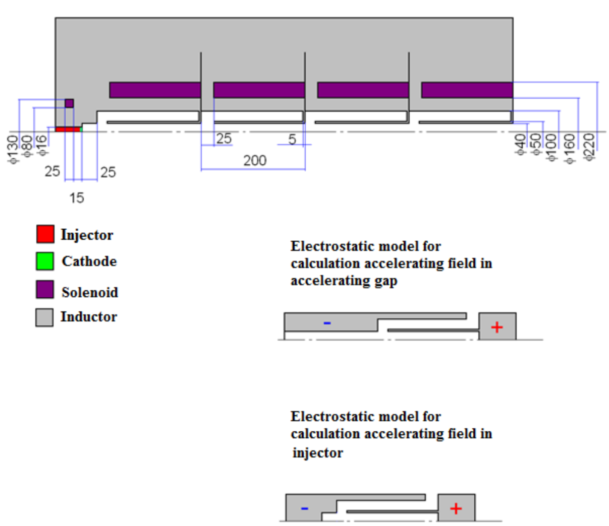

Figure 1: Schematic model for calculating the induction accelerator.

Table 1: Parameters of the accelerator.

Energy of the accelerated electrons, MeV	8
Injection energy, eV	200
The injection current, A	10
The diameter of the injected beam, mm	16
Accelerating voltage in each gap, kV	100

The calculations have started with a small number of modules but with further simulations their number was gradually increased.

Each inductor comprises one focusing coil. The compensating coil is positioned in the injector. The purpose of this coil is to compensate the field at the cathode. Its current is selected so that the total magnetic field at the cathode is zero.

SIMULATIONS

Several electro dynamical parameters were found by using simulations in CST PIC solver.

Simulations of the Electric Fields

When appropriate boundary conditions [2] are installed, the distribution of electric fields in the injector (Figure 2,3), corresponding to reality.

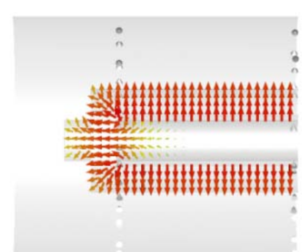

Figure 2: accelerating field in the injector.

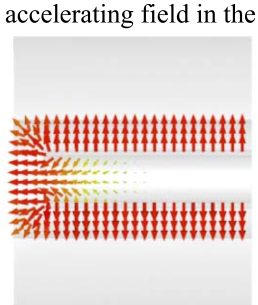

Figure 3: accelerating field in the accelerating gap.

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Further, these fields are imported into the layout, consisting of four gaps (Figure 4) and four coils.

The magnetic field on the axis of each of the four focusing coils power 0.1T = 1000 Oe field in the injector (right on schedule from the "cathode") will nullify the compensating coil.

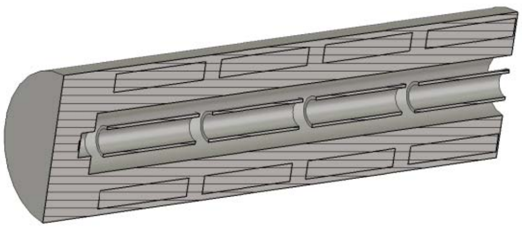

Figure 4: Structure with four accelerating gaps.

Compensating Coil

To compensate the magnetic field at the cathode (Figure 5), the structure was examined with an additional solenoid.

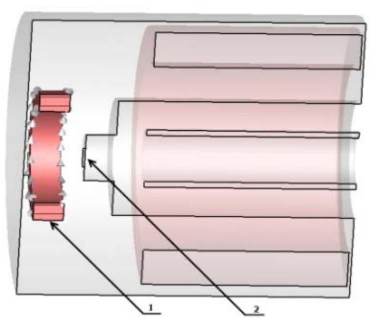

Figure 5: Model with compensating solenoid. (1-compensating coil; 2-cathode).

Direction of the current in the compensating solenoid was chosen the opposite to the direction of the current in the focusing solenoid. During the calculation was obtained the following current value at which the field at the cathode offset: Icomp. = -2900.05A

Table 2: Values of the current and magnetic fields.

The current in the focusing solenoid, A	29500
Current in the compensating solenoid, A	-2900
The magnetic field at the cathode, T	-0,00005
The maximum magnetic field on the axis, T	1
The current in the focusing solenoid, A	29500

Further, three sections with the accelerating gap was added to the structure, the field at the cathode was not changed. Figure 6 represents the distribution of the magnetic field on the axis of propagation of the electron beam

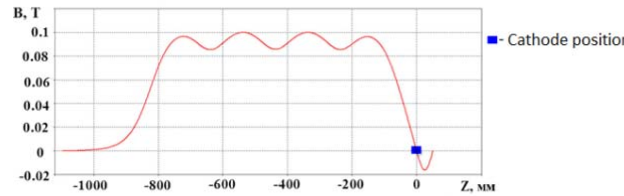

Figure 6: The magnetic field on the central axis of the structure.

Calculation of the Dynamics for Different Currents

LIA was considered with a beam current I = 10 A and a voltage of the first module U = 100 kV. It was further suggested to consider the dynamics of the injected beam at higher current values. However, for example, for the value of the current I = 50 A, using the current values of the magnetic (B = 0.1 T) and electrical (voltage module 100 kV) fields to obtain acceptable beam dynamics in the accelerating structure is not possible, because by increasing the beam current is observed shielding effect near the cathode (Figure 7,8)

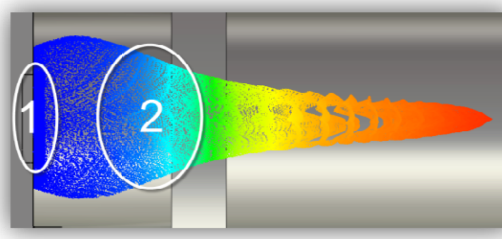

Figure 7: Dynamics of the beam, taking into account the emerging phenomenon.

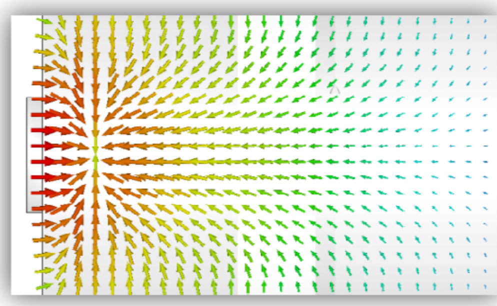

Figure 8: electric field in the event of this effect.

At some point the electric field of electrons from the region 2 (Fig. 7) adopts a configuration as depicted in Fig.11. This prevents subsequent emission of electrons which subsequently accumulates near the cathode (region 1, Fig. 7).

This phenomenon can be eliminated in two ways:

1) Increase the value of the electric field gradient in the accelerating gap

2) Reduce the distance from the cathode to the first accelerating module.

The first way worked out well but high voltage was required. Fine beam dynamics appeared when the voltage on each accelerating gap was U=1 MV, which is quite a lot, as soon it's proposed to have 80 sections. So we can say that first way showed to be impossible to make it practically by economical and practically.

Due to the fact that an increase in the voltage at the first accelerating module is irrational solution to the problem of screening near the cathode, it was decided to study the behaviour of the particle dynamics depending on the position of the cathode ΔL relative to the first accelerating module.

To eliminate these effects, a series of calculations, the results of which were set to the optimal value of the magnetic field at the center of the first module, the value of which was: B = 0.2 Tesla.

Figure 9 shows the dynamic of the beam for the above parameters of the magnetic field B = 0.2 T; the voltage at the first module U = 100 kV, the distance between the cathode and accelerating gap ΔL = 28.39 mm, and the beam current I = 50 A.

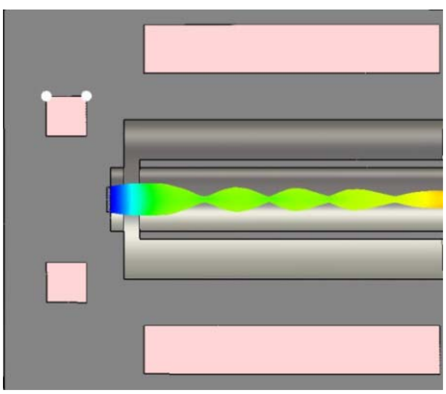

Figure 9: Dynamics of the beam at ΔL = 28.39 mm, I = 50A, U = 100 kV, B = 0.2 Tesla.

THE ENERGY OF THE OUTPUT BEAM FOR THE EIGHT ACCELERATING MODULES

Besides the beam dynamics, output energy of the electrons was also calculated. The results are shown in Table 3, also this table presents other settings that allow to present an complete picture of the dependencies between the different parameters:

Table 3: Results of the calculations.

I, A	E, eV*10^5	B, T	ΔL, mm
10	8,11	0,1	28.39
20	8,16	0,1	28.39
50	8,32	0,2	28.39

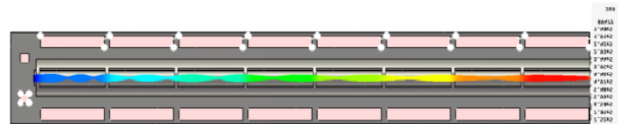

Figure 10: Beam dynamics for eight accelerating gaps.

CONCLUSION

Accelerating structure has been optimized, taking into account any adverse events. While increasing the value of the beam current, at some point there was an effect of screening in the vicinity of the cathode. It was proposed to solve the problem in two ways: to change the distance between the cathode and the first module or increase the voltage. Increased tension in the first gap proved unsustainable way. The problem was solved by approaching the cathode to the first module. The optimal distance between the cathode and the first accelerating module was found and was ΔL = 28.39 mm. For a beam with a current I = 10 A and I = 20 A, the value of the magnetic field was B = 0.1 T (based on previous calculations). For a beam with a current I = 50 A, the value of the magnetic field was chosen B = 0.2 T. With the parameters described above, there is an acceptable beam dynamics in the accelerating structure.

The energy of the output beam of the structure is linearly dependent on the number of modules and to the accelerating voltage. This report described the dynamics of the beam in the structure of the eight modules. For a beam with a current of I = 50 A value of the output energy was E = 8,32 * 105 eV, and hence for the module 80 is equal to the energy E ~ 8 MeV and 100 units - E ~ 10 MeV.

REFERENCES

[1] A.N. Lebedev, A.V. Shalnov, "Basic physics and accelerator technology. Linear accelerators" Moscow, Energoatomizdat, (1983).

[2] N.P. Sobenin, O.S. Mylovanov "RF technics". Moscow, Energoatomizdat, (2007)

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