THE COMPACT INDUCTION ACCELERATOR OF ELECTRONS FOR RADIATION TECHNOLOGIES

G.V. Dolbilov[#], Joint Institute for Nuclear Research, Dubna, 141980, Russia

Abstract

The electron accelerator with energy <10 MEV uses a rectangular pulse of the accelerating induction voltage and a trapezoidal pulse of a leading magnetic field. To preserve the equilibrium orbit radius constant special relationship between the amplitude and temporal characteristics of the magnetic induction and the accelerating voltage inductors are made. It is possible to maintain an orbit close to constant in a constant magnetic field in time. The accelerator contains alternating-sign focusing in dipole magnets and rectilinear accelerator parts.

INTRODUCTION

For receiving electron beams with energy of 0.5-10 MeV the cyclic accelerator in which particles are accelerated by linear induction section can be used [1,2].

For formation of the closed equilibrium orbit of electrons two methods can be used:

1 - a method with the magnetic field growing at acceleration;

2 - a method with a magnetic field, constant on time;

In a both cases the accelerator contains alternating-sign focusing in magnets and rectilinear accelerator parts.

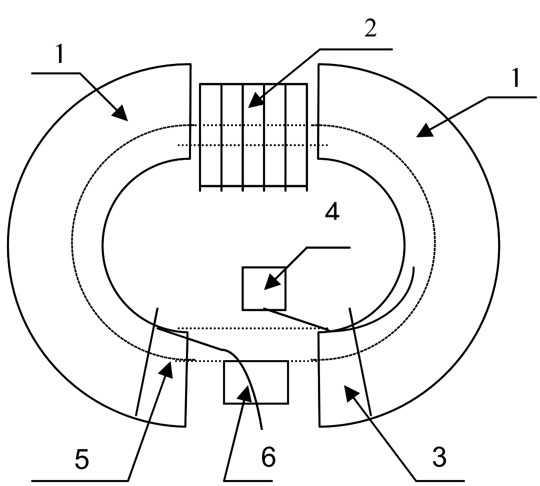

Figure 1: The scheme of the accelerator. 1 - the magnetic system with alternating focusing; 2 - the linear induction accelerating system; 3-6 - systems of input and output of electrons.

THE ELECTRON ACCELERATOR WITH A VARIABLE MAGNETIC FIELD [3]

For $R(t) = R_0$ =Const, the following condition has to be carried out

$$\frac{dB}{dt} = \frac{nU_{ind}}{LR_0}$$

where n – number of inductors; U_{ind} – inductor voltage; L – orbit perimeter.

Energy of electrons 0.5-10MeV can be reached for one pulse T_1 - duration

$$T_1 = 10^{-4} - 10^{-6} s$$

To this end total cross-section of inductors of accelerating section is equal to

$$S = \frac{WL}{\Delta Bc}$$

where W - energy of electrons, L - perimeter of an orbit, $\Delta B \leq 2B_S$, B_S - induction of saturation of inductors, c- velocity of light.

Diagram of magnetic induction, B(t), and the accelerating pulse of induction section, U(t), shown in Fig. 2.

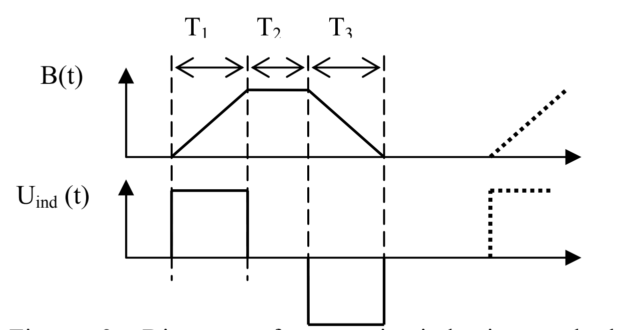

Figure 2: Diagram of magnetic induction and the accelerating pulse of induction section. T_1 – Time of acceleration of electrons, T_2 - Beam extraction time, T_3 - Time of magnetic reversal of inductors of section.

THE ELECTRON ACCELERATOR WITH A CONSTANT MAGNETIC FIELD

The magnetic system of the accelerator is a set of special sections of magnets (Fig.3). The section contains two dipoles. Each dipole deflects the beam at the predetermined angle of ΔΘ/2 which doesn't depend on energy of the accelerated particles.

- The beam trajectory with the maximum energy is r_{max} radius circle;
- The beam trajectory with energy of injection is $\Delta\Theta$ angle chord.

$$\Delta r = r_{max} - r_{min} = r_{max}(1 - \cos\frac{\Delta\Theta}{2})$$

$$\Delta r \approx R_{max}\frac{1}{2}\left(\frac{\Delta\Theta}{2}\right)^2$$

ISBN 978-3-95450-170-0

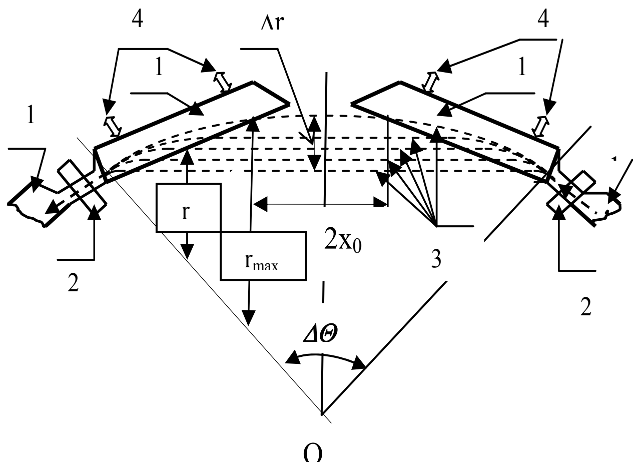

Figure 3: Special section of magnetic system. 1 - Magnetic dipoles with a uniform field, 2 - combination of quadrupole and symmetric lenses, 3 - Beam trajectories with various energy of particles, 4 - System tuning the beam trafctores.

- Amplitude and duration of pulses of the accelerating voltage is

$$U_{acc}T_1 = \Delta BnS$$

U_{acc} – accelerating voltage,
T_1 – pulse duration,
ΔB < 2Bs, Bs - induction of saturation of the inductor core,
n - number of inductors, S - cross-sectional area inductor

- Total cross section of the inductors

$$nS = \frac{WL}{\Delta B v_a}$$

W - the final energy of the electrons;
L - периметр равновесной орбиты;
v_a - the average velocity of the electrons, $v_a \simeq$ c

- The radial cross-sectional size of inductors is

$$\Delta r_S = \frac{W}{\Delta Bc}\frac{L_p}{L_{ind}}$$

where L_p and L_{ind} - the perimeter of the equilibrium orbit and length of the induction section.

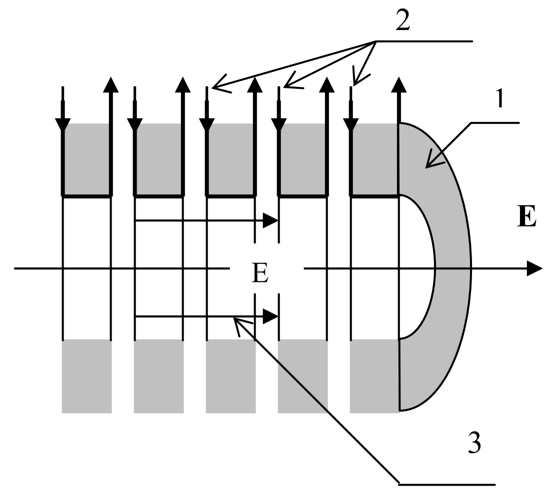

Figure 4: Shematic diagram of induction accelerating section. 1 – Ferromagnetic cores of inductors, 2 – Exciting loops of inductors, 3 - The accelerating electric field.

CONCLUSION

- The maximum energy of the electrons, which can be achieved in the excitation inductors single rectangular pulse, depends only on:
  1. $\Delta B \le 2Bs$, Bs - Saturation induction inductors;
  2. Δr_s - Radial dimension of the cross section of inductors
  3. $Lp / Lind$ - The ratio of the perimeter of the orbit to the length of the induction section.
- When W = 5 MeV, $\boldsymbol{\Delta B}$ = 0.5 T and $Lp/Lind$ = 2 parameters of the accelerator is:
  1. $\Delta r_s \simeq 6$ sm
  2. $U_{ind} = 10^2 - 10^4$ V
  3. $T_1 = 10^{-4} - 10^{-6}$ s
- When a magnetic field on the orbit equal to 0.1T and $W = 5MeV$

  $r_{max} = 17$ cm
- If $B(t)$ = Const, $\boldsymbol{\Delta\Theta = 30^0}$

  $r_{max} - r_{min} = 0.6$ cm

REFERENCES

[1] G.V. Dolbilov, «The Compact Iduction Circular Accelerator for Radiation Technologies», Proceedings of APAC 2007, Raja Ramanna Centre for Advanced Technology(RRCAT), Indore, India, p.p. 628-629
[2] G.V. Dolbilov, "Induction cyclic electron accelerator", Patent JINR, №2524571б, 2014.
[3] G.V. Dolbilov, "Method for induction accelerating of electrons", Patent JINR №2513034, 2014.

ISBN 978-3-95450-170-0