DEVELOPMENT AND APPLICATION OF ELECTRON LINAC ELECTROMAGNETIC DEVICES FOR RADIOTECHNOLOGIES

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The creation and subsequent service of modern electron linear accelerators at the NSC KIPT have brought evidence for possible successful introduction of radiotechnology processes using electron irradiation. A further extension and complication of physical problems solvable on the basis of radiotechnologies have put forward new and increased requirements for the systems of beam scanning, extraction and formation on the targets and extended irradiated objects. The results of applying our methods developed for prompt measurement of the kinetic energy of the scanned electron beam are presented. For measurement and continuous control of the electron energy the hodoscope magnetic spectrometer technique has been used. The spectrometer includes only one deflecting magnet and has no magnetic focusing. If the real field topography in the magnet is known in detail, then using the input and output coordinates of deflected particles it is possible to determine their energy, and also the chromaticity of electron beam. The step-pulse scanning of the beam is realized through the use of an air-core short-pulse electromagnet. Development and tests of separate units of the device are under way.

To realize a system of discrete-pulsed separation of the electron linac beam it was necessary to develop a series of new devices and units for electro physical equipment. The present paper considers devices of linac excitation and synchronization and a previously developed air-core short-pulse electromagnet magnet (EM). The requirements to the systems of excitation and synchronization impose that at a linac pulse repetition rate in the range from 3.125 to 300 Hz the beam-bending magnet and the accelerator were operating strictly synchronously. This condition is reached when, into the excitation source mounted by the Larionov circuit, the linac pulses of a selected frequency arrive. In the excitation source the rectified voltage transforms into the meander and then into the two-polar current pulses incoming into the bending magnet by the time of beam arrival (Fig.1).

The system of excitation and synchronization operates as is shown in Fig.2. Similarly to the linac synchronization device [1] in the source of EM excitation the positive and negative half-waves of all the three phases of the mains are rectified and fed into the amplifier-converter. At the same time in the triggering generator of the synchronization device the rectangular pulses of 2.5 µs duration are formed and fed into the injector and accelerating sections; here the excitation pulses are delayed and transformed by means of the

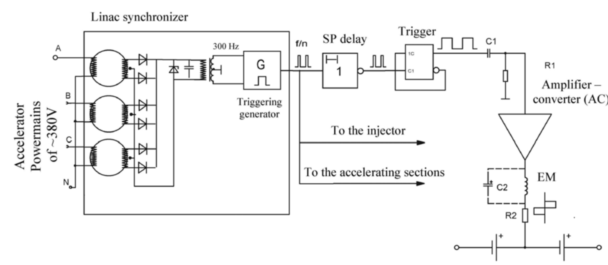

Fig.1. Block diagram of the device of excitation and synchronization

trigger into the meander of a pulse repetition frequency selected for all the linac systems, then they are amplified, transformed into the two-polar ones and enter in the bending EM. Thus, the conditions are created for, by the time of beam entering in the deflecting device (DD), the magnetic field in it be completely formed.

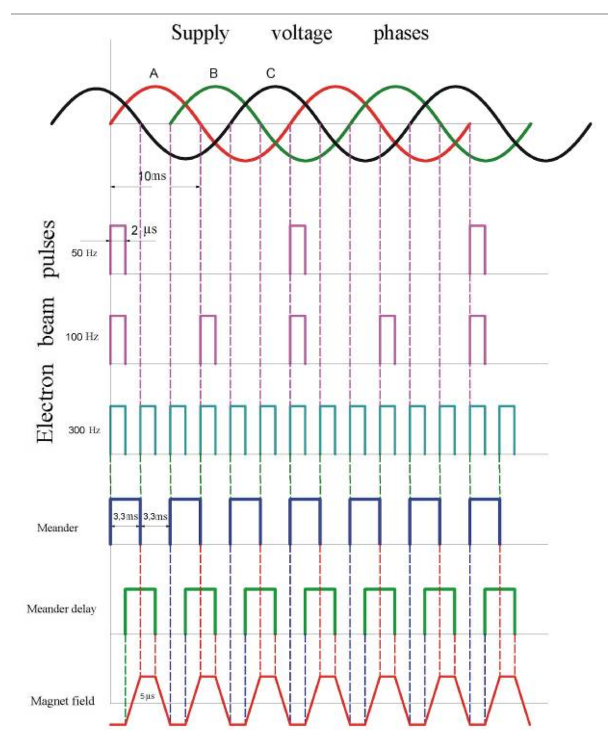

Fig.2. Diagrams of excitation system pulses.

The last state is illustrated by Fig.3 showing the magnetic field diagram in the DD at the linac pulse repetition frequency of 50 Hz.

For the DD one can apply a previously developed air-core electromagnet-transversely flat solenoid (TFS) having the following parameters: L=1.3 μHn, R=0.054 Ohm, rate of rise Iout to 30 A/μs, f =10 Hz …1.25 MHz.

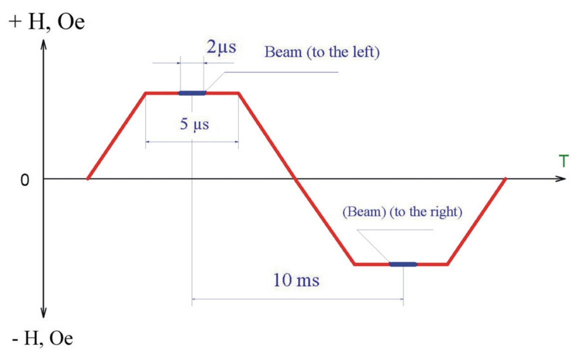

Fig.3. Excitation current signal form in the deflection magnet

By carrying out an experiment in the field of high-energy physics one uses different types of electromagnetic spectrometers. Each of elements in the magnetic circuit of the spectrometer (with iron) has the so-called operating point. It is determined by the defined value of the magnetic induction and magnetizing force in coordinates of the BH hysteresis loop (Fig.4). The operation points can be in any position inside the main hysteresis loop or on the loop itself. Therefore, before carrying out spectroscopic measurements, in particular, the precision ones, it is necessary to eliminate a residual magnetization by the outer magnetic force required for ferromagnetic domains be returned to the initial conditions of a zero equilibrium that corresponds to H= 0

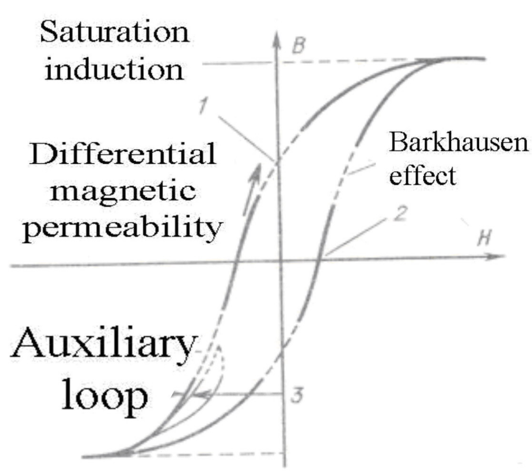

Fig.4. Hysteresis loop: 1 – residual magnetization, 2-coercive force, 3 – displacement of the operating point

Undesired magnetization can be eliminated by means of the changing magnetic field with continuously decreasing amplitude [2]. The initial field amplitude should be taken sufficiently large (two-three times more than the value of coercive force). The changing field frequency should be chosen so that the penetration depth can extend throughout the specimen. For iron at 50 Hz this depth lies between 1 and 2 mm depending on μ. Besides, the attention should be given to the fact that because of the constant influence of the Earth the demagnetization really can take place. Therefore, to exclude the earth magnetic field influence, demagnetizing coils should be arranged in the East-West direction.

In the case of chick specimens it is recommended to perform demagnetization using, at first, the commutated direct current with decreasing amplitude and, then, the alternating current [3,4]. To perform successfully and with assurance the work upon electromagnet-analyzer demagnetization under conditions of the constantly operating linac the following requirements should be fulfilled:

- knowledge of real magnetic characteristics of the magnet used, preliminary read "on the bench" before setting it in the linac: gauge function H_0=f(I_{excit}) on the line of mean beam turning radius (ρ_0) in the center of magnetic track; function H=f(s, ρ) along the beam trajectory for s≈±∞ and ρ_0 ±1.5 cm; range of operating magnetic field strength H_0…H_{max};
- additional (auxiliary) exciting winding with a number of ampere-turns of ≈10…15% of the main one is used for demagnetization at the direct and alternating current (via the switch) from the independent supply source. The winding serves also as a "zero adjuster" in the process of demagnetization and during operation with the beam towards the linac exit.
- it is necessarily to have "a null indicator" with a permalloy control pickup (others do not suite). Such a device, for example, has been successfully applied at the KIPT storage ring H100 [5];
- in the magnet working gap (or at the end) one should provide for an area where a remote field control pickup can be placed in case of need during the linac operation.
- in the 'long" high-energy linacs usually one provided intermediate channels for beam extraction with the help of direct-current electromagnets. After completing the deflection process, the electromagnet is switched off and there the residual field arises distorting the rectilinear beam trajectory. Consequently, the beam cannot to hit strictly the target at the linac exit. In this case, along with the above-described demagnetization, an effective method of trajectory correction is continuous auxiliary winding current adjustment with simultaneous control of a signal from the current-and-beam position sensor being usually available at the linac exit.

REFERENCES

[1] N.V.Demidov. Synchronization system of linear accelerators. Moscow, 1984, p.29 (in Russian).

[2] E.Angerer. Physical experiment technique. Translated from German p.208. Gos.izdat.fiz.-mat lit. Moscow, 1962 (in Russian).

[3] I.A.Radkevich et al., Device for magnetic field measurement by means of permalloy sensors and its use for proton synchrotron adjustment. Pribory i Tekhnika Ehksperimenta, No 4, p.229 (1962) (in Russian).

[4] L.L. Goldin, S.V. Skachkov, K.N. Shorin. Magnetic measurements in charged-particle accelerators. p.36. Gosatomizdat, Moscow, 1962(in Russian).

[5] Tolstoj A.E. Dissertation, p. 41, Kharkov, KFTI, 1967