

ent part in beam capture. The values of charge limit accumulated at the injection ($7 \cdot 10^{10}$ el.) and captured at the acceleration ($4 \cdot 10^{10}$ el.) are obtained.

- Possible increase in capture efficiency by means of variation of external magnetic field and beam energy selection of circuital decelerating EMF is investigated. Thus, at the electron energy 40 keV and the

energy selection value 200 eV/rev, capture efficiency increases by the factor of 1,5, which permits the capture at the acceleration $6 \cdot 10^{10}$ el. The maximum capture parameters are obtained at combination of variation of the external magnetic field and decelerating EMF: $N_{\text{cap}} \approx 7,4 \cdot 10^{10}$ el., $K_{\text{cap}} \approx 7,4$ %.

REFERENCES

- Vorobyev A.A., Kononov B.A., Evstigneev V.V. Betatron electron beams. – Moscow: Atomizdat, 1974. – 152 p.
- Moskalev V.A. Betatrons. – Moscow: Energoizdat, 1981. – 282 p.
- Matveev A.N. On the mechanism of capture and limit current in betatrons // Journal of Experimental and Theoretical Physics. – 1958. – V. 35. – № 2. – P. 372–380.
- Kovrizhnykh L.M., Lebedev A.N. Consideration of electron common interaction in cyclic accelerators // Journal of Experimental and Theoretical Physics. – 1958. – V. 34. – № 4. – P. 984–992.
- Antoshkin M.Yu., Grigoriev V.P., Koval T.V., Sablin N.I. Numerical model for investigation of axial-asymmetrical wave excitation in co-axial vircators // Radio Technology and Electronics. – 1995. – № 8. – P. 1300–1305.
- Hokney R., Eastwood J. Numerical simulation by the particle method. – Moscow: Mir, 1987. – 640 p.
- Bruk G. Cyclic accelerators of charged particles. – Moscow: Atomizdat, 1970. – 311 p.
- Ofitserov V.V. Numerical simulation of non-stationary processes in cyclic induction accelerators // Computer Techniques. – 2003. – V. 8. – № 6. – P. 322–330.
- Kasyanov V.A., Shtein M.M., Chakhlov V.L. Formation of focusing point of small-size deceleration radiation // Devices and Technique of Experiment. – 1998. – № 1. – P. 41–42.

Arrived on 11.10.2006

UDC 621.364.634.3

IRON-FREE ELECTRON SYNCHROTRON WITH WEAK FOCUSING

V.A. Moskalev

Tomsk Polytechnic University
E-mail: mva@tpu.ru

A synchrotron construction the magnetic field of which is without steel core is suggested. Acceleration chamber is combined with magnetizing winding. The described version of accelerator is favorably different in small weight, simplified production and assembling technique.

Resonance electron accelerator – synchrotron with weak focusing of electron beam presents a complex electrical-physical device consisting of a number of large units and their supply systems. The basic element of synchrotron is an electric magnet producing progressive magnet field necessary for motion of charged electrons along the orbit of constant radius. It is the so called «control magnet field». Synchrotron magnetic conductor is made of sheet transformer steel and requires high accuracy of electromagnet assembling and mounting made up of four sectors including azimuth angle 90° each. In general this system is the most labour-consuming, technologically complex and expensive part of the accelerator. Thus, the steel weight of the synchrotron «Sirius» electromagnet per 1,5 GeV in Tomsk Polytechnic University is 120 tons [1, 2].

Control magnet field in the suggested synchrotron construction is induced by single-turn winding enclosing an azimuth circle quarter [3].

The winding presents two concentrically located strips of conductive material. The strips are connected

with each other at one end, but at the other one they are connected with alternating power supply. Current flows in both strips in the opposite directions.

In the space between the strips magnet field providing the motion of accelerated particles along the orbit (control synchrotron field) is produced. This field is to possess the property of electron beam axial focusing.

In accelerator with «steel» magnet system focusing is achieved by shaping magnet field in «barrel-like» form by means of increasing the gap between the electromagnet poles as it moves away from the system centre.

To shape magnet field in a necessary form induced between the poles of single-turn winding these poles are to bend in the vertical direction so that the convex part of the strip would present outside from the system centre.

One more labour-consuming element of synchrotron is a vacuum acceleration chamber. It is glued from a large number of ceramic curved sectors forming an arch of quarter circle length, the radius of which corresponds to that of path curve of the accelerated electron beam. Four of such arched sections connected with

each other by straight line sections (without magnet field) form a close circle of racetrack type placed in specific air gap of synchrotron electromagnet.

Single-turn magnetizing winding includes circle space by its turnings – strips, where the motion of accelerated electron beam is to take place. Overlapping the upper and lower winding turns by vacuum-tight dielectric covers makes it possible to use the winding as an accelerating chamber.

The scheme of the suggested synchrotron is presented in the figure. Single-turn magnetizing winding for induction of control magnet field consisting of four similar sections – 1, is placed in circular sections of accelerated particle path, each of which is performed in the form of concentric circles parts made of copper strips – 2, 3 connected electrically at one end, but at the other one connected to opposite poles of pulse power supply – 4. The strips – 2, 3 are connected with each other by dielectric vacuum seal along the edges 5 and form the four sections of the accelerating chamber.

The chamber sections are connected with each other by straight vacuum electron wires – 6, and forms a closed accelerating chamber of «racetrack» type. To provide the focusing properties of control magnet field («barrel-like» form of the field force lines), conductive strips – 2, 3 are bent in width with convexity outside from the accelerator centre, fig. 1, a). The synchrotron contains also an injector – 7, accelerating resonator or resonators – 8, vacuum pumps – 9, placed in the area of straight parts of the accelerated particle path.

Application of single-turn winding for producing control magnet field and simultaneously forming accelerating chamber permitting refuse completely from steel magnetic conductor, lightens the accelerator several times and simplifies its construction, provides free access to the accelerating chamber along its whole length, simplifies the accelerator production and assembling technology and increases synchrotron serviceability.

At the given connection of single-turn winding current flows in the opposite directions in both strips. As a

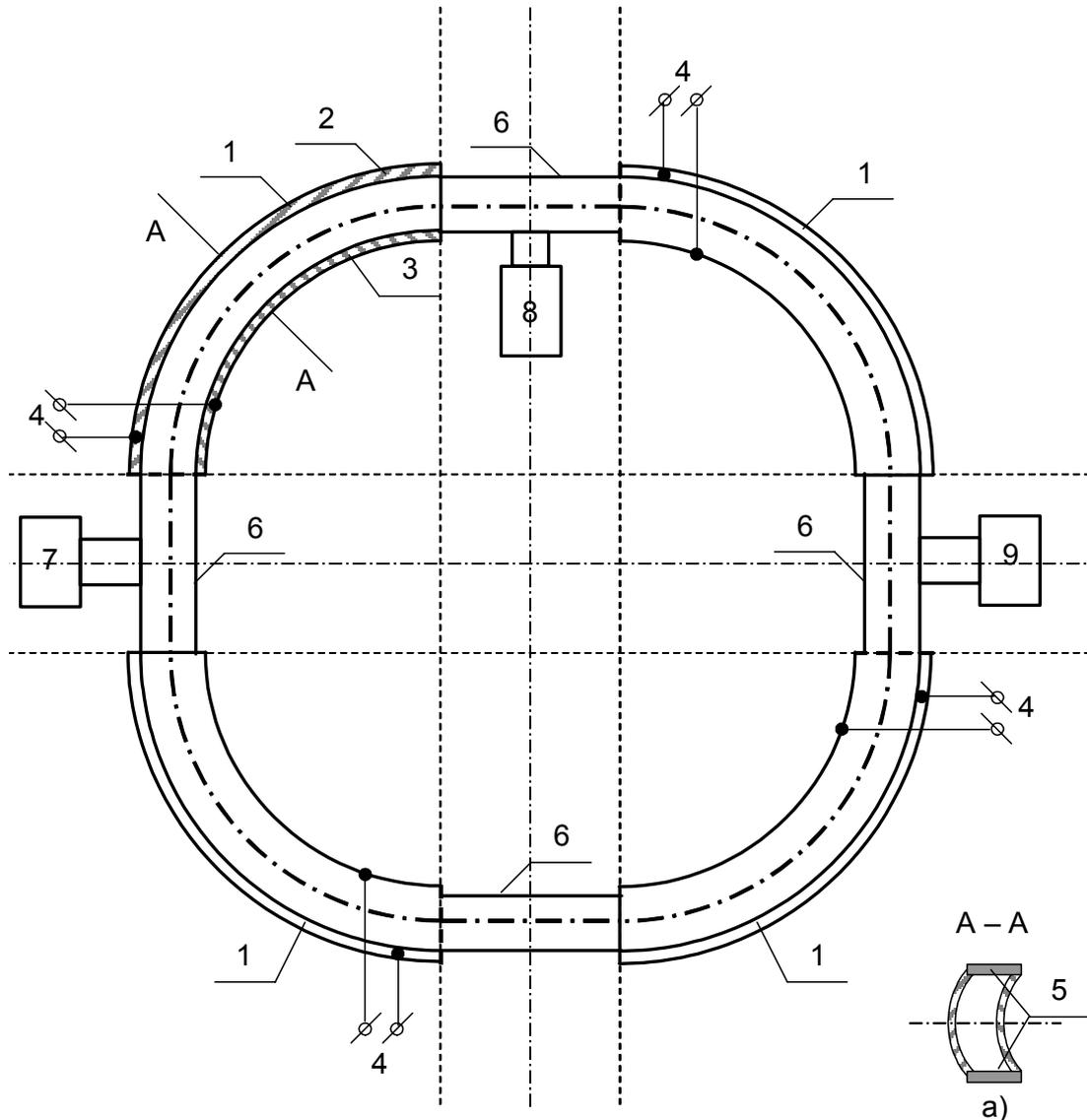


Figure. Synchrotron scheme

result in the space between the strips there is alternating, dying away magnet field along the radius. The strips convexity in width gives the field force lines a «barrel-like» form typical for the focusing («betatron») field.

All four sections of the single-turn winding form a synchrotron single magnet system. Sections of the single-turn winding connected with vacuum seals – 5 along the strip edges – 2, 3 form four curvilinear sections of accelerating chamber combined with magnetizing single-turn winding.

These curvilinear sections are connected with each other by straight electron wires and form a closed chamber as it is done in the known synchrotrons of «racetrack» type. The straight sections of the accelerating chamber free from magnet field are used to assemble the attendant equipment – resonators, vacuum pumps etc.

The value of control magnet field strength in the accelerator orbit depends on energy of the accelerated particles; the maximum field strength is determined by setting value of particle energy that is desired to obtain.

Injection of the charged particles into accelerating chamber is made by the injector – 7, particle acceleration – by means of resonator or resonators – 8, vacuum in the chamber is provided by the pumps – 9.

Thus, the use of single-turn winding concept for induction of control magnet field (similar to single-turn winding used in miniature induction cyclic accelerator [4]) in the form of four similar sections located in circular sectors of the accelerated particle path, at simultaneous performing of the winding the function of accelerating chamber results in creation of charged particle accelerator of new type, i.e. iron-free synchrotron having a number of new technical and engineering-economical parameters, such as small weight of the accelerator and the accelerating chamber, combination of magnetizing winding and accelerating chamber functions in a single system, simplified technology of the accelerator production and assembling and etc. Therefore, the suggested iron-free synchrotron is favourably distinguished from all the known accelerators of such type.

REFERENCE

1. Electron synchrotron «Sirius» // Formation and Development of Scientific Schools in Tomsk Polytechnic University / Edited by Yu.P. Pokholkov, V.Ya. Ushakov. – Tomsk, 1996. – P. 158–160.
2. Vorobyev A.A., Chuchalin I.P., Vlasov A.G. et al. TPI Synchrotron per 1,5 GeV. – Moscow: Atomizdat, 1968. – 160 p.
3. Pat. 2265974 RF. IPC H05H 13/04. Iron-free synchrotron / V.A. Moskalev. Published 10.02.2005, Bull. № 34.
4. Pat. 2193829 RF. IPC H05H 11/00. Induction charged particle accelerator / V.A. Moskalev. Published 27.11.2002, Bull. № 33.

Arrived on 21.04.2006

UDC 621.384.647

RESEARCH OF CHARGE BALANCE IN DIODE UNIT OF PULSED ELECTRON ACCELERATOR

A.I. Pushkarev, R.V. Sazonov

High Voltage Research Institute, Tomsk
E-mail: aipush@mail.ru

The results of experimental research of charge balance in the diode unit of high-current pulsed electron accelerator TEU-500 (350...500 keV, 60 ns, 250 J per pulse) at the operation of electron beam generation are presented. The investigations are performed for the planar diode as with the cathodes made of graphite, copper, carbon fiber 43...60 mm in diameter so with the multi-edge cathode. It is shown that the main source of parasite losses of electrons in the planar diode is their scattering in the anode-cathode gap induced by the electron field distortion at the cathode periphery. In the matching mode of diode impedance to the output resistance of nanosecond generator (gap of 10...12 mm) the charge losses value does not exceed 12 %. The half of electron scattering angle is 68° at small anode-cathode gaps and it decreases with the gap increase down to 60°.

Introduction

The application of pulsed electron beam for the initiation of plasmachemical processes, gas laser injection, microwave radiation generation and other fields requires the development of efficient electron accelerator which would possess long operation life time and high stability of operation parameters. Any nonproductive energy losses lead to the heating and premature destruction of construction units of the accelerator. The experimental investigations performed by us and the analysis of work of other authors [1, 2] showed that the accelerator operation life time is mainly determined by the diode unit.

The presence of nonproductive losses in the diode unit can be calculated by the current balance. The total current introduced to the diode unit from the nanosecond generator is equal to the sum of extracted electron beam current, current of capacity charge exchange of the diode unit and parasite losses current. The losses during the electron beam generation can be conditioned either by the electron beam scattering while going from the cathode to the Faraday cup collector or by the charge escape along the isolator surface, or by the parasite discharges in the vacuum volume of the diode chamber. One of the principal loss sources in the diode