DESIGN OF THE SMALL-SIZED NANOSECOND PULSE-PERIODIC ELECTRON ACCELERATOR

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The design features of high-voltage electron nanosecond accelerators based on the Tesla transformer are considered. The construction of the pulse-periodic accelerator with an energy of $\sim 300\,keV$, a current of $\sim 10\,kA$ and a pulse duration of $\sim 50\,ns$ is given.

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1. INTRODUCTION

Pulse-periodic accelerators are widely used for the needs of nuclear energy, medicine, industry, etc. A special niche among them is occupied by accelerators based on the Tesla transformer. Such accelerators are relatively cheap and easy to manufacture and maintain, they have a great life. The beams parameters vary widely, but there are some parameters that can be called typical: energy 200...2000 keV, current duration 20...50 ns and strength $\sim 10\,kA$. This paper presents a design of compact nanosecond electron pulse-periodic accelerator with an energy of $\sim 300\,keV$, a current of $\sim 10\,kA$ and a pulse duration of $\sim 50\,ns$.

2. NANOSECOND ACCELERATORS BASED ON THE TESLA TRANSFORMER DESIGN FEATURES

The constructions of some native and foreign pulse-periodic nanosecond transformer type accelerators are considered in [1-4]. Let's briefly examine their characteristics:

Metallic chamber. A high-voltage part of the accelerator is placed into a single grounded tank, which is filled with a pressurized gas (nitrogen N_2 or sulfur hexafluoride SF_6), or with a dielectric liquid (oil, water, glycerin) to prevent electrical breakdown between the transformer windings and the chamber.

Transformer coils. The primary coil in such accelerators performed cylindrical or conical with a small taper to increase the coupling coefficient and reduce the accelerator dimensions. The coil is massive, which increases its heat capacity, and reduces the electrical resistance, thereby prolonging the operation time of the accelerator in the periodic mode without overheating. In some constructions the primary coil is formed as a heat exchanger – a flat strip with the tubes at the edges through which coolant runs (such the primary winding should be used when the dielectric medium is a gas). The secondary coil is concentric to the primary one; it has the form of tightly wound cylindrical helix of thin wire. It usually consists of several hundred turns. The magnetic core is not generally used.

Pulse shaping line. It is intended for energy storage and transfer to the vacuum diode. Beam current pulse amplitude and width depends on shaping line's capacitance and inductance. It is electrically connected to the transformer's high voltage output, and often has the form of a cylindrical conductor located inside the frame of a secondary winding.

Sharpening spark gap performs two functions - reducing the current pulse edges and the accelerating voltage value adjustment (if the design of the spark gap provides clearance adjustment). Spark gap can be located in the mutual volume with the transformer or in a separate chamber filled with the gas under the pressure.

Many well-known pulse-periodic accelerators based on Tesla transformer have similar structures, but they can not be considered identical because of some features related to their assignment, working conditions, required parameters [1-4].

3. THE DESIGN OF THE "VGIK -1P" ACCELERATOR

The construction of the "VGIK-1P" accelerator is shown in Fig.1. The generating part is placed into a stainless steel cylindrical chamber 1 filled with transformer oil, and is separated from the vacuum diode 13 with plexiglass insulator 10 that includes aluminum cathode holder 11. Inside the chamber the cylindrical primary coil 4 made of copper bus, and the secondary coil 3 made of the copper wire in the varnish insulation, wound around the dielectric frame are

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placed. The cylindrical pulse shaping line 7 mounted on the bar of the plate capacitor 2 connected to the high voltage output of the transformer and placed inside the secondary coil frame. Sharpening spark gap formed by the pulse shaping line bottom end and a screw 8, turned into the cathode holder 11.

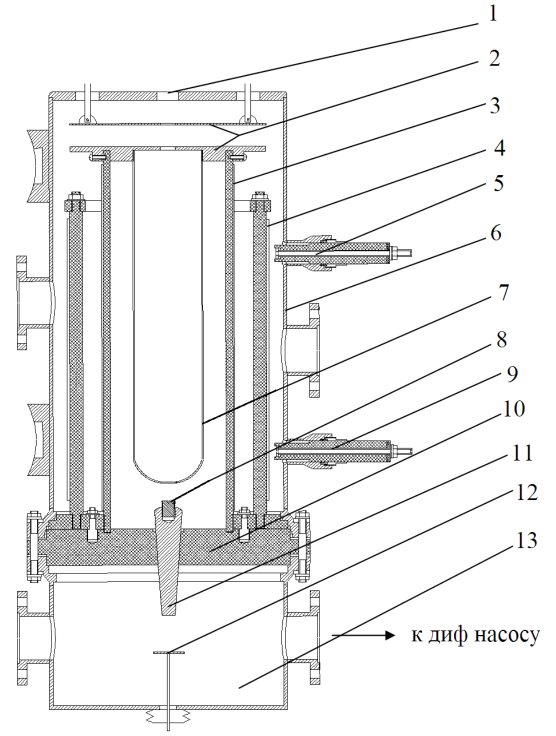

Fig.1. *The construction of the "VGIK-1P" accelerator*

The electrode gap in the sharpening arrester can be adjusted in the range 0...20 mm by turning the screw 8 through the hole in the camera body, the flat capacitor 2 and pulse shaping line 7. Regulated also is the distance between the plates of the plane capacitor – upper (grounded) plate fixed to the movable pins and can be moved in the axial direction, allowing to change the gap width in the range of 0...50 mm.

Using the transformer oil as a dielectric medium makes it possible to make the generating part of accelerator small-sized (diameter of chamber is 350 mm, height of the cylindrical part is 650 mm, the gaps between the coils of the transformer 45 mm, between the chamber wall and the edge of a plane capacitor 25 mm) with an operating voltage up to 400 kV because of relatively high electric strength of oil ($\sim 45\,kV$, after multiple breakdowns increases to 60 kV across the gap 2.5 mm) [3]. Furthermore, transformer oil has $\varepsilon \approx 4$, which increases the capacity of the secondary circuit and provides a more uniform distribution of the electric field near the secondary coil through the close values of permittivity of oil and varnish insulation of the wire.

The vacuum chamber is pumped out with a diffusion pump with a nitrogen trap to a pressure of $10^{-5}\,Torr$.

4. THE POWER SUPPLY CIRCUIT AND ELECTRICAL PARAMETERS OF THE ACCELERATOR

Electrical scheme of the "VGIK-1P" power supply system is shown in Fig.2, where T1 – autotransformer (voltage regulator); T2 – high-voltage transformer; VD – diode bridge; L1 – reactor that limits primary circuit capacity charging current; C1 – primary circuit capacitor; Cf, Lf – filter capacitance and inductance, that obstructs the HF influences in the supply network; FV1 – multigap rotary spark gap; T3 – Tesla transformer; C2 and C3 – capacitance of the plane capacitor and of the pulse shaping line, respectively (in conjunction they make up the capacity of the secondary circuit); L2, L3 – inductance of the pulse shaping line and of the cathode holder; FV2 – sharpening spark gap; VL – vacuum diode.

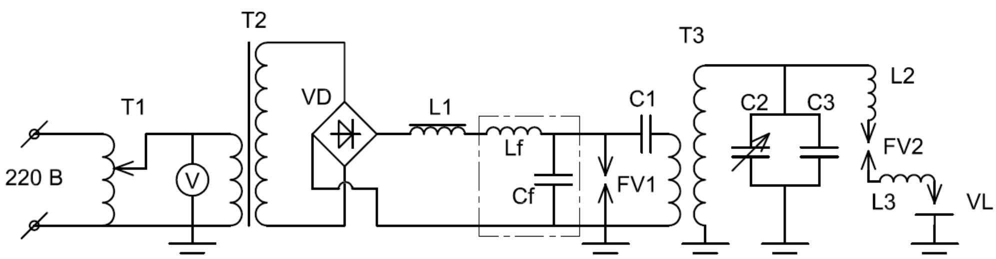

Fig.2. *The power supply system of the "VGIK-1P" accelerator*

For efficient energy transfer between the circuits of the transformer is necessary that the natural frequency of them were equal to each other ($f1 = f2$), which can also be written as

$$L1C1 = L2C2, \qquad (1)$$

where L1, L2 – inductances and C1, C2 – capacities of the primary and secondary circuits respectively. The calculated values of the natural frequencies in "VGIK-1P" accelerator are equal up to 1%, $f_{1,2} \approx 86\,kHz$, which corresponds to period $T_{1,2} \approx 11.6\,\mu s$. To ensure the fulfillment of the condition (1) there is a possibility of smooth adjustment of the secondary circuit capacity within 300...450 pF by capacitor C2 plate movement.

Electron beam parameters were calculated based on the values of the secondary circuit capacitance C2 and the discharge circuit inductance L_P that consists of inductances of pulse shaping line, sharpening arrester and vacuum diode. With $C2 = 350\,pF$, $L_P = 180\,nH$ and the voltage across the secondary coil of the Tesla transformer $U_2 = 300\,kV$ electron beam has a length of $\sim 50\,ns$, current $\sim 10\,kA$ and energy of $300\,keV$. Rotating multigap arrester is used for energy commutation in the primary circuit; it can provide the pulse repetition rate up to $320\,Hz$. The amplitude of the voltage pulse on the vacuum diode depends on the primary circuit arrester gap length, and the repetition rate of pulses - on the frequency of rotation of the rotating multigap, the number of electrodes in it, and the amperage in the charging loop of the primary capacitor.

5. CONCLUSIONS

The design of the pulse-periodic electron accelerator with an energy of $\sim 300\,keV$ electron beam current of $\sim 10\,kA$, a pulse duration of $\sim 50\,ns$ and a pulse repetition frequency up to $320\,Hz$ is developed.

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ПРОЕКТ МАЛОГАБАРИТНОГО НАНОСЕКУНДНОГО ЭЛЕКТРОННОГО УСКОРИТЕЛЯ ЧАСТОТНО-ПЕРИОДИЧЕСКОГО РЕЖИМА ДЕЙСТВИЯ

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Рассмотрены особенности конструкций высоковольтных электронных наносекундных ускорителей на основе трансформатора Тесла. Предлагается конструкция ускорителя частотно-периодического режима действия с энергией ∼ 300 кэВ, током ∼ 10 кА и длительностью импульса ∼ 50 нс.

ПРОЕКТ МАЛОГАБАРИТНОГО НАНОСЕКУНДНОГО ЕЛЕКТРОННОГО ПРИСКОРЮВАЧА ЧАСТОТНО-ПЕРІОДИЧНОГО РЕЖИМУ ДІЇ

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Розглянуто особливості конструкцій високовольтних електронних прискорювачів на основі трансформатора Тесла. Пропонується конструкція прискорювача частотно-періодичного режиму дії з енергією ∼ 300 кеВ, струмом ∼ 10 кА і тривалістю імпульсу ∼ 50 нс.