AN ELECTRON MINIACCELERATOR ON THE BASIS OF TESLA TRANSFORMER FOR NONDESTRUCTIVE TESTING OF CHARGED PARTICLE BEAMS

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An electron miniaccelerator on the basis of Tesla-transformer for nondestructive testing of charged particle beams with operating voltage 120…200 kV, half-wave duration 4 mks and diagnostic beam current within few mA is described. The primary circuit is switched by IGBT. The gun control and filament circuit power supply (impregnated cathode with 1.2 mm diameter) are realized through high frequency isolated transformer. The accelerating tube is made of sectional welded metal ceramics insulator (ceramics 22HS with diameter 95/85 mm).The accelerator test results are presented.

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1. INTRODUCTION

The development of accelerating technology leads to increasing the role of non-destructive diagnostic methods of the electron beams. One of the perspective devices which allows obtaining of spatial charge distribution and does not affect a bunch is a beam monitor. The basic principle of its operations is the interaction of the test low energy electron beam with electro-magnetic field of ultrarelativistic charged particle bunch. The bunch desired parameters are determined from the interaction results [1]. Along with accelerator beam intensity increase, the necessity of testing beam energy raising is appeared. For this purpose miniaccelerator with energy up to 200 kV and high voltage generator based on Tesla transformer was developed [2,3].

2. HIGH VOLTAGE GENERATOR BASED ON TESLA TRANSFORMER

Tesla transformer represents two oscillatory inductive coupled circuits with equal resonance frequencies. The property of the ideal Tesla transformer is full energy transfer from primary circuit to the secondary at fixed magnetic coupling coefficients of the coils equal to 0.6, 0.385, 0.2, etc. The maximum efficiency is obtained at coupling coefficient 0.6 because of dissipation in the circuits. The advantages of the Tesla transformer based generator compared to other types of generators are:

- full energy transfer from the primary circuit to the secondary one at a given time moment;
- good coaxial configuration of the pressure vessel, primary and secondary windings and accelerating tube simplifies high voltage generation at comparatively low operating gradients and small-scale size of the apparatus and provides shielding against external fields on which the testing beam is sensitive;
- there is no closed magnetic core which fabrication is frequently connected with a lot of technological problems;
- an up-to-date semiconductor basis allows comparatively easier realizing of primary circuit switch with recuperation on single module.

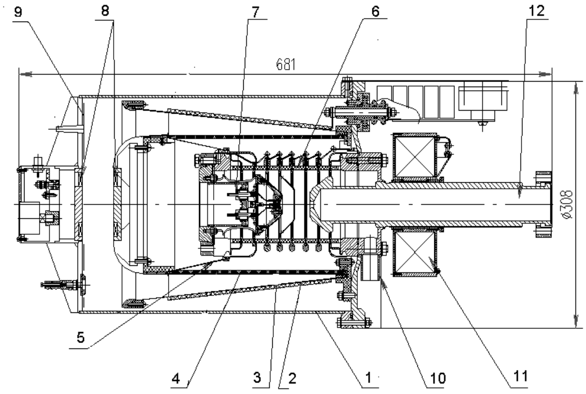

Fig.1. Testing electron miniaccelerator design. 1 pressure vessel; 2 – primary winding; 3 – ferrite core; 4 – secondary winding; 5 – equipotential shield, 6 – accelerating tube; 7 – electron gun with control electrode; 8 – power transfer transformer; 9 – capacitive divider; 10 – vacuum pumping; 11 – magnetic lens; 12 – electron beam line

3. SOURCE DESIGN

The Tesla transformer based accelerator design is presented in Fig.1. The accelerator is placed in SF_6 filled vessel 1 at a pressure 0.17 MPa. For better shielding from external fields the vessel is made of steel ST3. The primary circuit 2 is performed out of double layer foil-clad glass-cloth laminate by printed circuit board technology. The grounded shield is located at the inside of the winding. To be penetrable to magnetic field, the shield represents a set of 0.4 mm width tracks with 0.4 mm spacing between them. To increase the primary winding rigidity it is reinforced by glass tissue and impregnated by epoxy compound outside. At the same location the magnetic core 3 made of ferrite bars providing required coupling coefficient 0.6 is assembled. The secondary winding 4 (glass-epoxy skeleton) is winded by wire PETVLK-0.21 possessing the best insulating performance of Russian small cross-section wires. To provide the stable operation of winding isolation at inevitable breakdowns the special protective shield 5 penetrable to magnetic flux is used. The accelerating tube 6 is made of 22HS ceramics by thermal-compression bonding technology [4]. An impregnated cathode of 1.2 mm diameter is used for the gun emitter. The beam control is realized by diaphragmatic control electrode (“grid”) of 0.6 mm in diameter.

The cathode heat and grid control unit is supplied by the high voltage isolation transformer 8 [5] based on

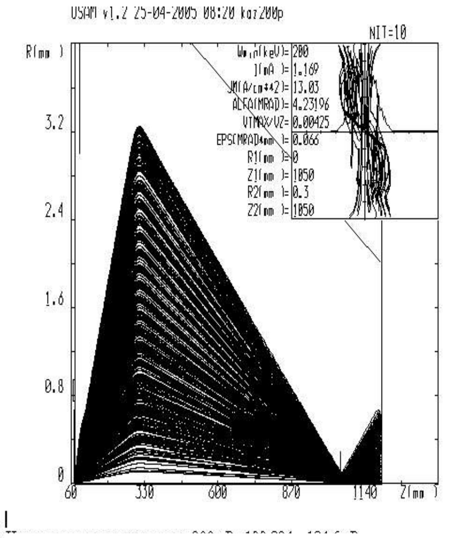

Fig.2. Results of EOS simulation (trajectories of electrons, at the right upper corner – current density distribution and phase portrait of the beam at a distance of 1m from the cathode)

E-shape cores. The unit is controlled by using optic fiber cables laying along the accelerating tube. High voltage pulse measurement is realized with the use of the capacitive divider 9 which is assembled inside the vessel.

The vacuum volume (7) pumping is carried out by ion pump with 7 l/s capability. The magnetic lens 11 focuses the beam up to specified size. For easy maintenance with different beam monitors, a high vacuum gate at the end of the beamline 12 is used.

Simulations performed with the computer codes SAM, ULTRASAM [6] taking into account electron thermal speed finally allow obtaining of an electron beam of 0.15 mm in a radius at the distance 1m from the cathode (see Fig.2).

4. MINIACCELERATOR SUPPLY

A simplified power supply circuit for the miniaccelerator is presented in Fig.3.

The primary circuit capacitance consists of 14 K78-10 capacitors with rated value 0.15mkF each. IGBT module is used as a switch. Primary and secondary voltage and current waveforms are shown in Fig.4.

The gun control electrode is triggered at a moment when the whole energy is concentrated at the secondary circuit capacitance. When a beam current pulse comes to the end, the whole energy is transferred to the primary circuit capacitance through the diode D1 bypassing IGBT. By this time IGBT is switched off and the whole energy except a part took off by the beam and disappeared in the circuits, is concentrated at the capacitance C1.

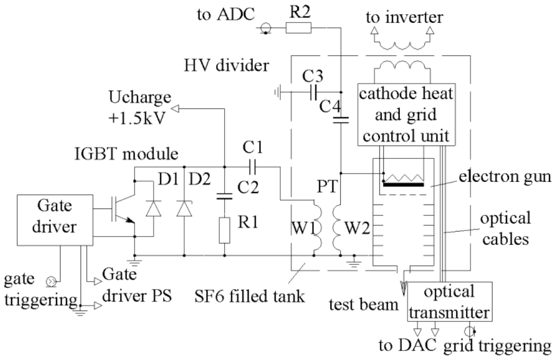

Fig.3. Miniaccelerator power supply simplified circuit

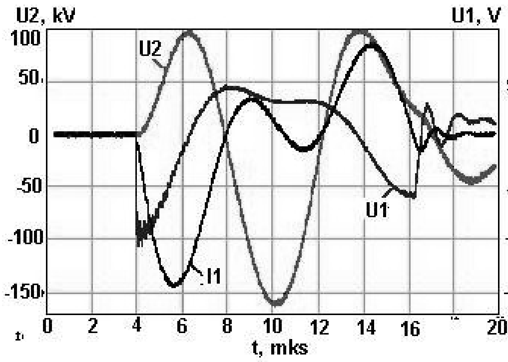

Fig.4. The gun cathode voltage waveform (U2), PT primary voltage waveform (U1), primary circuit current waveform (I1)

5. BEAM DIAGNOSTICS

An electron-optical system composed of a microchannel plate (MCP), a luminophor and CCD camera is used for beam registration. Due to the fact that MCP pulse voltage duration is about 30ns and beam current duration is about 1 mks this system allows observing of a beam part at an arbitrary time moment.

To amplify image brightness MCP is located close to cathodoluminescent screen so that an electron image transfer from MCP to the screen occurs in a uniform electric field. In spite of large dispersion of initial electron energy leaving the channels, a spot on the luminophor is weakly diffused. Camera converts the luminophor image to the array of numbers and sends it to a program which transforms this array into the image on a PC monitor.

A tantalum plate loaded on 50 Ohm is used to measure the beam current value.

While source testing, the following results were obtained:

1. Operational voltage 150 kV is defined by vacuum isolation electrical strength. At this voltage and control electrode voltage 120 V operational current about 1 mA was achieved.

2. The beam autograph measured by the procedure stated above is shown in Fig.5. According to the spot

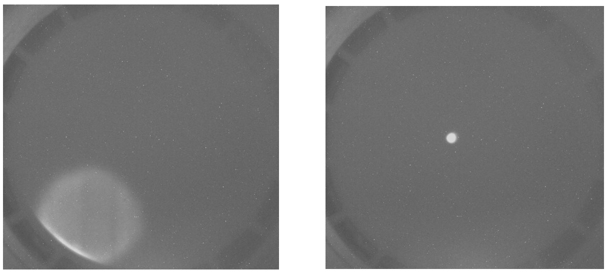

Fig. 5 Beam image with and without focusing (energy 80 kV, control electrode voltage 20 V). Focusing consists in lens (short solenoid) current selection at which the spot size is minimum

size one can judge that the beam size with halo does not exceed 1 mm.

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МИНИУСКОРИТЕЛЬ ЭЛЕКТРОНОВ НА ОСНОВЕ ТРАНСФОРМАТОРА ТЕСЛА ДЛЯ НЕРАЗРУШАЮЩЕЙ ДИАГНОСТИКИ ПУЧКОВ ЗАРЯЖЕННЫХ ЧАСТИЦ

В.Е. Акимов, А.В. Булатов, П.В. Логачев, И.В. Казарезов, А.А. Корепанов, Д.А. Малютин, А.А. Старостенко

Описан миниускоритель электронов на основе трансформатора Тесла с рабочей амплитудой напряжения 120…200 кВ при длительности полуволны 4 мкс и током диагностического пучка в пределах нескольких мА. В качестве ключа первичного контура используется IGBT. Питание накала и цепей управления пушки (импрегнированный катод диаметром 1.2 мм) ускорителя осуществляется с помощью высокочастотного разделительного трансформатора броневого типа. Металлокерамический узел выполнен на базе керамики 22ХС диаметром 95/85 мм, соединяемой с электродами термокомпрессионной сваркой. Приведены результаты испытаний миниускорителя.

МІНІПРИСКОРЮВАЧ ЕЛЕКТРОНІВ НА ОСНОВІ ТРАНСФОРМАТОРА ТЕСЛА ДЛЯ НЕРУЙНУЮЧОЇ ДІАГНОСТИКИ ПУЧКІВ ЗАРЯДЖЕНИХ ЧАСТОК

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Описано мініприскорювач електронів на основі трансформатора Тесла з робочою амплітудою напруги 120...200 кВ при тривалості напівхвилі 4 мкс і струмом діагностичного пучка в межах декількох мА. Як ключ первинного контуру використається IGBT. Живлення розжарення й ланцюгів керування пушки (імпрегнований катод діаметром 1.2 мм) прискорювача здійснюється за допомогою високочастотного розділового трансформатора броньового типу. Металокерамічний вузол виконаний на базі кераміки 22ХС діаметром 95/85 мм, що з'єднує з електродами термокомпресіонним зварюванням. Наведено результати випробувань мініприскорювача.