THE UTILIZATION OF STANDARD DC ACCELERATOR ELV FOR THE TOMOGRAPHY

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Abstract

ELV accelerators have been developed at the Institute of Nuclear Physics, Siberian Branch of the Russian Academy of Sciences and occupy a special place in the spectrum of the equipment produced by the Institute. These machines are widely used for radiation modification of polymers and worked well in a variety of processes in many countries of the Eurasian continent. Using serial ELV accelerators for industrial tomography opens up new possibilities for industrial technologies. This increases the requirements on the stability parameters of the injected electron beam.

The article formulates the requirements for electron accelerator ELV for tomographic studies, pulsation energy and beam current. Described Schottky effect affects to the shape and size of the ripple current, and the method for increasing the stability of the beam parameters. These machines are unified with conventional accelerators ELV and expand the scope of their utilization.

INTRODUCTION

Budker Institute of Nuclear Physics of the Siberian Branch of Russian Academy of Sciences is one of the world leaders in the development, design, production and delivery to the industry of electron accelerators based on high-voltage rectifier, covering the energy range from 0.3 to 2.5 MeV, maximum beam power for separate machines from 20 to 100 kW and maximum beam current up to 100 mA. These properties, as well as compact dimensions and high operational qualities have allowed BINP take a leading position in the market of industrial accelerators, both in Russia and abroad. But if the application of ELV accelerators for radiation modification of materials is related with ensuring the required level of uniformity of the radiation dose [1], the use of ELV accelerators for the tasks of industrial tomography is associated with the need to fulfill the following requirements on the parameters of the injected beam:

- energy pulsing at the level E = 1,0 MeV ≤±5%;
- current ripple at the level Ibeam = 100 mA ≤±2%.

These conditions were formulated as a result of a number of experiments on the industrial 100-kW accelerator of the ELV type, whose special features are the high electron energy (1.4 MeV) and the possibility of extracting the focused electron beam directly into atmosphere.

The Design of the Accelerator

To conform to these requirements and to take to account specific requirements of design, ELV4-based accelerator has been developed (Figure 1).

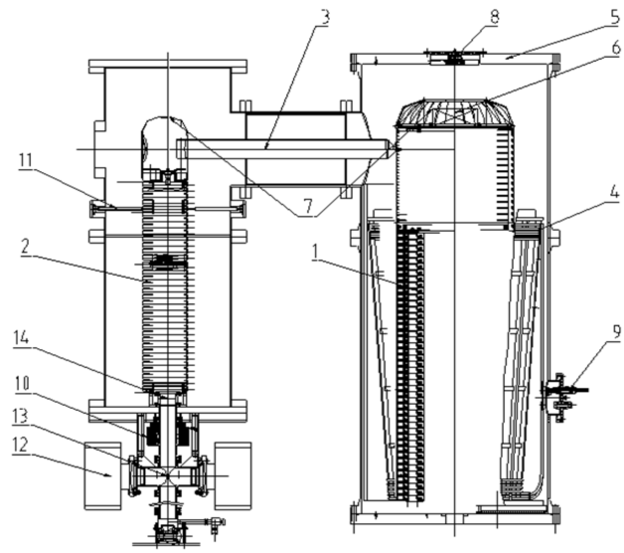

Figure 1: Common design of accelerator: Common design of accelerator: 1 - column rectifying sections; 2 - accelerating tube; 3 - gas feeder; 4 - the primary winding; 5 - the case of the pressure vessel; 6 -block injector control; 7, high voltage electrodes; 8 - the optical elements of the beam current control system; 9 entries of the primary winding; 10 - lens; 11 - supports to support tube; 12 - ion pump vacuum system; 13 - docking port of the vacuum system; 14 - bellows for fixing the accelerating tube.

Energy Pulsing

To reduce the energy pulsing, the series of experiments was carried out on a standard accelerator ELV-4. Energy was measured by the sensor circuit shown on Figure 2.

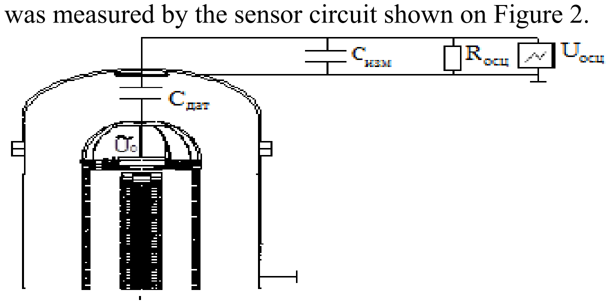

Figure 2: Sensor circuit for measuring pulsation energy.

The pulsing of energy measured by this sensor and the spectral decomposition of the signal is shown in Figure 3.

It shows three distinct peaks:

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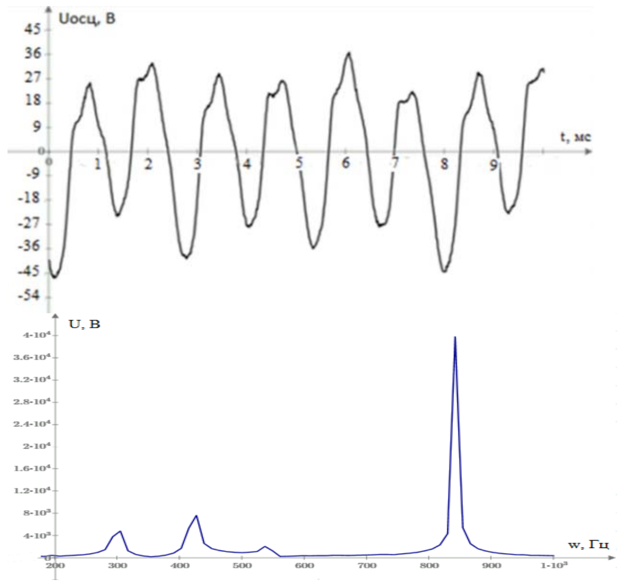

Figure 3: Waveform pulses with energy(up) and the spectrum of the signal pulses(down), E = 1 MeV IBeam = 100 mA.

- The peak frequency of 300 Hz is due to ripple voltage mains rectifier inverter. At the input of the inverter is installed six-phase rectifier with the filter capacitance $C_ф$. Ripple voltage of the rectifier with a frequency of 300 Hz will contribute to accelerating voltage ripple. Increasing the filter capacitance at the input of the frequency converter giving energy to further reduce ripple of ± 5% when a beam current of 100 mA at an energy of 1 MeV (Figure 4).

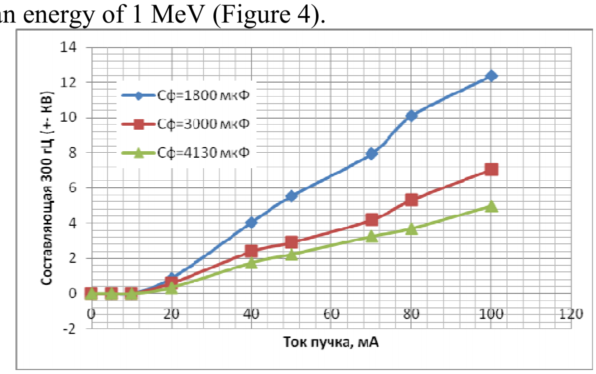

Figure 4: 300 Hz ripple component at different $C_ф$ depending on the beam current

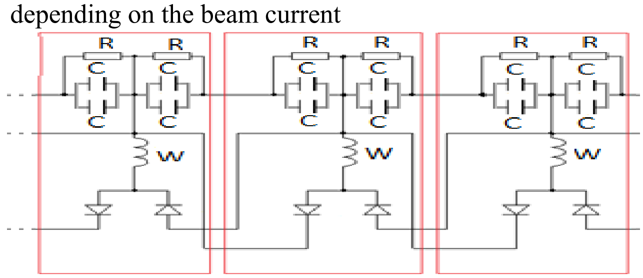

Figure 5: Series-parallel circuit connection rectifying sections.

- peak at a frequency of 840 hertz (main) is due to a full-wave mode of operation of high-voltage rectifier. Using an electric circuit with a series-parallel connection rectifying sections (Fig.5), allowing to limit the ripple HV column.

- third peak has a frequency of 420 Hz voltage. His appearance associated with fact that capacitors rectifying sections in different half-lives are fed from different windings. The voltage distribution on the secondary windings is not entirely uniform, it slightly decreases from the center of the column to its upper end. Therefore the half cycle when the capacitors are charged from the upper winding, they get smaller charge and, conversely, when charged from an underlying winding, produced a larger amount, i.e. appears with frequency ripple voltage.

Current Pulsing and Schottky Effect

Measurement beam current ripple produced by a special discharge device used for generating x-rays radiation, which fully absorbs the electron beam (Figure 7).

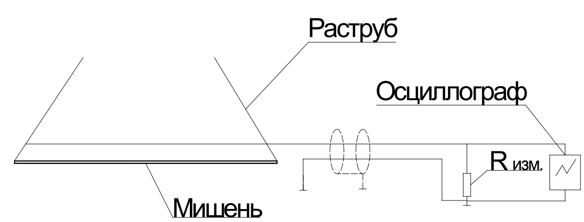

Figure 7: Scheme of the measurement current ripple.

Measurements of beam current showed the presence of pulsations correlated with the ripple voltage on the upper rectifying sections. Schottky effect is that when the electric field around the cathode current changes its saturation. If the electric field will have a variable component, the saturation current will also pulsate with the same frequency. Figure 8 shows the appearance of the variable component of the electric field near the cathode in the accelerator.

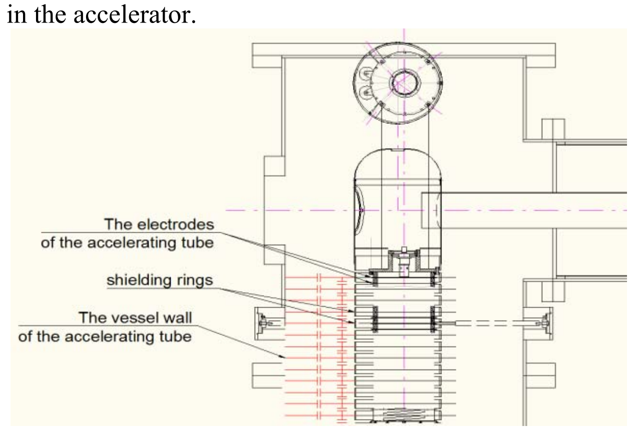

Figure 8: The upper part of the accelerator.

All capacitance shown in Fig. 8 form a complex capacitive divider, so there is a variable voltage component in the capacitance between the cathode and the first electrode to the accelerating tube. Increasing the capacitance (Fig. 9) causing it to fall the value of the variable component, thereby reducing the pulsation of the beam current.

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The table 1 shows the results of measurements of different plug to the electrodes of the tube containers, where 30 pF is standard capacitance between the electrodes without additional connections.

Figure 9: Modified accelerating tube.

As a result, has reduced volatility in energy of up to ± 5% at a beam current of 100 mA. To reduce the ripple current the additional capacity were placed in parallel the divider resistances of tube. It reduces the instability of current to ± 0.14%.

Figure 10: Assembled accelerator for tomography.

CURRENT STATUS

Currently the accelerator for industrial tomography has been assembled at the customer's site and is subjected to adjustment tests (Fig. 10).

ELV accelerators continuously adapted for use in a variety of processes of radiation in industry and can be used for research into and development of new techniques and materials by electron irradiation.

Table 1.The dependence of the pulsation energy and beam current from the interelectrode capacitance.

The capacitance between electrodes	30 pF	310 pF	590 pF
Ripple of the beam current	± 6%	± 1.3%	± 0.8%
Pulsation of the electric field near the cathode	± 21%	± 1.2%	± 0.7%
$(\frac{\delta I}{I})/(\frac{\delta E}{E})$	0,29	1,08	1,14

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