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INTENSIVE X-RAY GENERATOR ON THE BASIS OF LOW PRESSURE PLASMA DIODE

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Summary. In the paper the pulse X-rays generator on the basis of a high-current plasma diode of low pressure with an extended interelectrode gap is offered. The mechanism of X-rays generation is given and most effective operation mode of a plasma diode is described. On the basis of computer simulation with use of original software « Mode XR » the considerable increase of an X-rays dose per impulse in comparison with systems on the basis of vacuum diodes with an explosive electron emission is shown.

Introduction

Intensive X-ray generators on the basis of high-voltage pulsing vacuum diodes with explosive emission cathodes [1] are widely used in science, technique, medicine, control security systems. However, the pulse duration of radiation in such systems is limited to time of closing of a small accelerating gap of the diode by spreading dense plasma of cathode spots. In this paper the X-ray generator on the basis of plasma diode with an extended interelectrode gap for increasing of pulse duration is offered.

The feature of a plasma diode is that in conditions of low gas pressure at reaching the discharge current of some value of Ic, a double electrical layer of a space charge is formed in a discharge gap [2]. Practically all the voltage supplied to the discharge is concentrated on this layer. In this layer there is an opposing acceleration of electron and ion beams up to energies, defined by a voltage on a layer. From the moment of a double layer formation the current in a plasma diode is transferred in basic ally by an electron beam, which generates intensive X-rays at interaction with the anode atoms [3]. Then in contrast to vacuum diode the current beam value is defined not by a cathode-anode accelerating gap, but a layer thickness, which is much less than a distance between electrodes and which depends on plasma parameters. In these conditions it is possible to derive major electron beam currents and major current pulse duration. It is bound that the closing time of a discharge gap by cathode spot dense plasma at considerable interelectrode distances is rather great.

1. X-ray generator

The schema of an experimental model of the generator is given in fig. 1. The generator consists of a glass discharge tube DT, anode-target A, cathode block with a preliminary plasma supply, voltage divider R_1–R_4. The generator is attached by the anode side to the vacuum device, the pumping-out is yielded through holes near to the anode–target. The high-voltage pulse discharge is initiated in a discharge tube between the cathode C_D and anode–target A after filling a discharge gap by preliminary plasma. The voltage on electrodes yield from the previously charged capacitor *C* through a controllable discharger S.

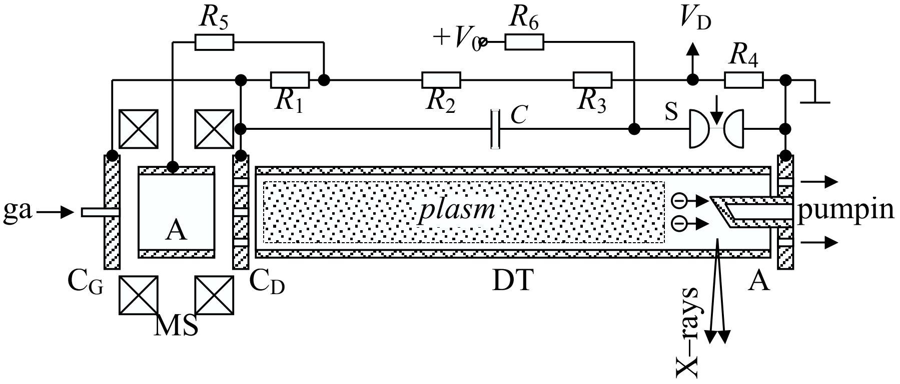

Fig. 1. The X-ray generator schema on the basis of plasma diode.

The preliminary plasma is generated in the cathode block, which is a Penning cell. The block consists of the cathode C_D and opposite cathode C_G, cylindrical anode A_G and magnetic field system MS. The preliminary plasma enters a discharge gap through the holes in the cathode C_D. The cell feeding occurs at the expense of deliver of positive potential with amplitude 0,8-1,5 *kV* from a voltage divider through the resistance R_5.

For initiation and long term existence of a double layer it is necessary, that the peak quantity of a power supply current I_0 in some times exceeds current value I_c, which can be transferred by plasma in the area of a minimum concentration at the expense of a thermal motion. The peak current I_c can be estimated from expression: $I = \int_{S_{pl}} e n_p(\vec{r}) \sqrt{kT_e / 2\pi m_e}\, d\vec{s}$,

where e, m_e and T_e - charge, mass and temperature of plasma electrons correspondingly, S_{pl} - current carrier section of a plasma cord, $n_p(\vec{r})$- the plasma density in a given point depending on a neutral gas concentration. The peak quantity of a current I_0 is defined by expression: $I_0 = V_0 \sqrt{C/L}$, where V_0 - voltage of capacitor charging with capacity C, L - inductance of the whole discharge circuit.

For elimination of energy losses of an electron beam in plasma, the localization of a double layer at an effective surface of the anode–target is the most favourable. Then the accelerated electrons get on the anode at once. Such mode corresponds to M–discharge with at near-anode voltage drop [4]. As the localization of a double layer at M–discharge happens in the area of the least plasma density [5], which in this case should be at the anode, for making a gradient of plasma concentration along a discharge tube the gradient of working gas pressure is formed at the expense of vacuum resistance of system devices at gas filling in the cathode block.

The generator works as follows. After delivery of a high voltage on electrodes there is an excitation of a Penning discharge in the cathode block and through holes in the cathode C_D the preliminary plasma flows out in to a discharge tube DT. Under influence of an electric field between the cathode C_D and anode–target A this plasma is polarized and redistributes all the voltage in to a near-cathode area. At the expense of a near-cathode potential drop the cathode spots are formed on the cathode, that leads to sharp current increasing in a discharge tube DT and excitation of the inductive discharge. When a discharge current reached I_c the formation of a double layer at the near-anode area happens. The electron beam, formed in a layer, interacts with a anode–target surface and generates X-rays. It lasts until at a target surface the dense plasma is formed at the expense of a bombardment and the discharge current does not becomes less then I_c. The period of X-rays generation is inversely proportional to electron beam power.

2. Computer simulating of X-rays generation.

For optimization of generator construction the software of Mode XR was specially designed. The performances of electron beam, generated in a double layer, are calculated in magnetohydrodynamic approach. The analytical model of the program contains the specially introduce free parameters, which values are determined by matching of calculation results to experimental data.

The electron trajectories in the anode–target are simulated by a Monte Carlo method. The energy losses of electrons on ionization and process of photons formation are calculated under the schema of catastrophic collisions. In calculation of a bremsstrahlung the weight schema on each step of electron trajectory build-up is used. The formation of fluorescent photons is simulated as the result of photoelectric sorbtion of a bremsstrahlung in a target. The loosing of X-rays in the generator construction is calculated with use of the weight schema. The window of an X-rays output is set as restricted cylindrical multilayer structure.

The results are submitted as X-rays spectra and spatial distribution of a dose behind an output window of the device. The integrated performances of an electron beam and conversion coefficients of electron radiation in X-rays are also calculated.

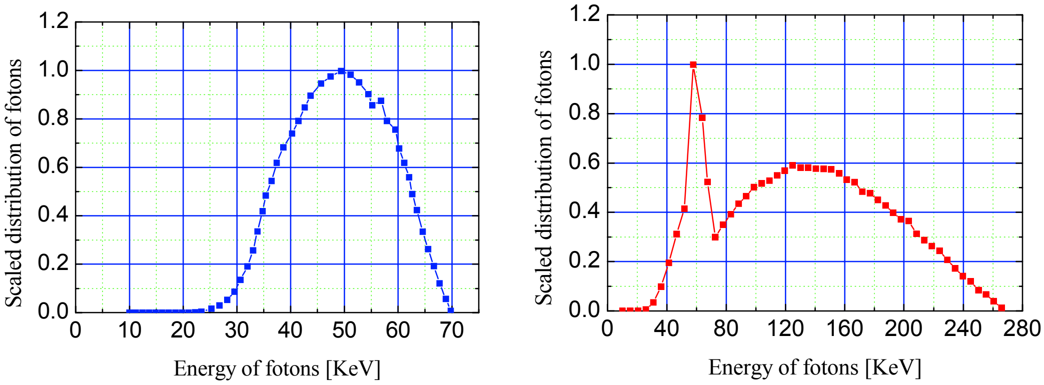

Fig. 2. Spectral dependences of normalized energy distributions of photons for a tungsten target. (a - beam energy 70 *keV*, b - beam energy 270 *keV*).

The discharge parameters and X-rays doses are given in the table.

Figure	Beam energy, *kV*	Beam current,	Impulse time, µ*s*	Radiation dose for an impulse, (roentgen) apart from a tube	
				0,5 *м*	50 *м*
2	70	1600	10	28,22	0,095
2b	270	1600	1	77,37	0,239

Thus the comparison of the obtained data with the performances of X-ray generators on the basis of vacuum diodes with an explosive electron emission with equivalent mass and dimensional parameters shows considerable increasing of an X-rays dose per impulse. It makes this direction perspective in development and making of X-ray tubes of new generation.

Acknowledgments

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