

PROJECT OF DESIGNING IN KhTURE HIGH-ENERGY PLASMA ACCELERATOR

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1. INTRODUCTION

The plasma sources of electromagnetic radiation possess the high electrical indexes (exponent) of efficiency. It's well known that the radiation power, density and temperature of plasma in such sources depend on the power put in (inserted in, into) a discharge and therefore on a discharge current [1-5]. Space distribution of the temperature research in the field of discharge allow to optimize parameters of power-plant and construction of radiator for maximum (the highest possible) radiation efficiency obtaining.

Capacity storage-devices are used as power sources in the experimental plants of dense plasma generation and acceleration. In this case the highest possible value of the current is limited by influence inductance of capacitor and parasitic inductance of assembling (bus-bar conducts connected capacitor electrodes and those of the plasma accelerator). The inductance minimize gives the opportunity to realize the conditions close to disperiodic of the storage-device discharge close to aperiodic and approach the highest possible values of the discharge currents of the experimental plants.

In the given work the results of the experimental high-power impulse radiation generator research on the base of coaxial magneto-plasmatic compressor (MPC) of butt-

ending model. Experimental dependence of the parameters of the experimental plant assembled corresponding to beyond the bus-bar type scheme which permits to get high indexes of the radiation efficiency were given. The parameter radiation dependencies and the results of the research of radiation characteristics in the optical wave diapason were listed.

2. EXPERIMENTAL EQUIPMENT

The experimental facility scheme is displayed in the Fig. 1. The coaxial MPC electrodes were placed on the metal plates connected with the corresponding electrodes of storage-device capacitors. The storage-device charge from powered rectifier permitted to obtain voltages in the range of 2 – 3kV.

Facility engaging was made with help of auxiliary plasma generator (for-plasma) the electrode of which placed axially inside the central MPC electrode. In case of the auxiliary capacitor discharging on it $C_{fp} = 60\mu\text{F}$ the for-plasma created inside the chamber and under influence of gas kinetic pressure is discarded as separated streams through the openings in the central MPC electrode into the discharge space. Homogeneous plasma washer was being formed from the separated plasma streams. The MPC electrode polarity had being chosen according to the recommendation [2].

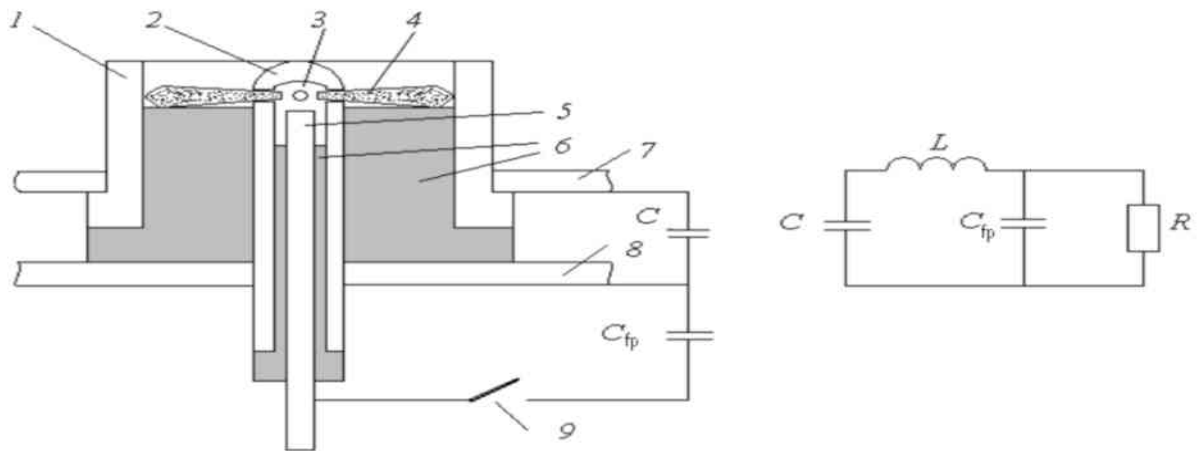


Figure 1: The scheme of MPC with for-plasma leaking-in

1 – the external electrode; 2 – the central electrode; 3 – the switch K1 for for-plasma creation; 4 – plasma streams; 5 – auxiliary electrode; 6 – teflon insulators; 7 — anode; 8 - plate electrode of storage-device – cathode; 9 – the spark gap.

Table 1: Experimental plant parameters

$C, \mu\text{F}$	U_{ss}, kV	I_m, kA	L, nH	P_r, MW	$\tau_1, \mu\text{s}$
1400	2 – 3.6	200 - 400	8.75	55	22

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3. EXPERIMENTAL RESULTS

The discharge has fluctuate character with great decrement of attenuation which value $\ln(I_m(t)/I_m(t+T)) \cong 1.39$. On the base of the time diagrams $i(t)$ and $u(t)$ one can build the dependencies of immediate power $p(t)=u(t)i(t)$ and those of the resistance $r(t)=u(t)/i(t)$. Its time constant is $10 \mu s$ is comparable with the duration of research processes. The immediate power remains positive, consequently the resistance during discharging possesses has an active character.

The dependencies of discharge current on the voltage of charge of the storage-device U_s and from the value of stored power $W_s = 1/2CU_s^2$ show that the current grows linear with the voltage, i. e. it can be said that the integral resistance of discharge circuit $R=\Delta U/\Delta I \cong 9.4 \cdot 10^3 \text{ Ohm}$ and the medium power of losses in the researched diapason of energies remain constant. The current value also can be measured by integrating the first semi-period of oscillogram of the current and comparing the result with the charge stored in capacitor. From this

$$i_m = \frac{CU_s^2}{\int_0^{\tau_1} f(t)dt}$$

where τ_1 is the duration of the first semi-period of current, $f(t)$ is the function describing the time dependence of current. The values calculated for the chosen values of charge voltage in assumption that the first semi-period of the current has a next form $i(t) = I_m \sin \omega t$.

The dependence of radiation power density flux measured on the distance of 1 m from the source on charging voltage and on stored power was obtained. The extreme of this dependence and lowering of the degree of radiation power growth can be explained by the displacement of maximum of temperature distribution curve (the Plank's curve) radiating plasma formation in the ultraviolet area and by coming out of the limits of the admission zone of the instrument when the power applied to the charge grows. It results in the corresponding

growth of plasma temperature. The value of discharging current then is $I_m \cong 260 \text{ kA}$. With this current the magnetic pressure $\mu H^2/2$ (where H – magnetic intensity produced) considerably exceed gas kinetic pressure of plasma column $\sim 2nkT$ (n –electron density in the discharge column, k – Boltzman constant, T – temperature) and it results in constriction and instability and formation of plasma focus (PF) [1 - 4]. The temperature estimate one can get using Bennet relation for equal case taking into consideration only azimuth magnetic field created by discharging current $\mu H^2/2 = 2nkT$, where the uniform distribution of charged particles density along plasma column section is supposed, $H = I_m/2\pi r$ – the magnetic field on the border of plasma column with the radius r . Using $r = 1 \text{ cm}$, $n = 5 \cdot 10^{18} \text{ cm}^3$ we'll get $T = 7.8 \cdot 10^4 \text{ K}$

The energy of radiation of high-temperature area for given temperature and density of a flow makes size about 102 J . The estimation of complete energy of radiation turns out by integration of density of a flow diagram of an orientation of radiator and $W_{\text{ful max}}$ is equal $1,744 \text{ kJ}$ thus efficiency of radiator is equal $0,19$. Thus it was supposed, the spatial distribution of radiation is proportional to the area of section of PF in an azimuth and meridional planes in 2π space.

The spatial distribution of temperature in the field of the discharge and effects accompanying MPC high current discharge can be estimated on the basis of photos, executed with application, of an optical filters. As it is visible (Fig. 2a) the most high-temperature area of the discharge is located near to an end face of the central electrode and has the sprinkle form, characteristic for PF formation [2,3]. The top border of a passband of the filter UFS-6 is equal 390 nm , therefore realization of PF is represented rather probable. Besides the discharge is accompanied by a powerful shock wave on an output of the plasma accelerator.

Use of filters with more low-frequency characteristic of passing shows, that the areas with smaller temperature have the large sizes and in red area of a spectrum the discharge has character of diffusion.

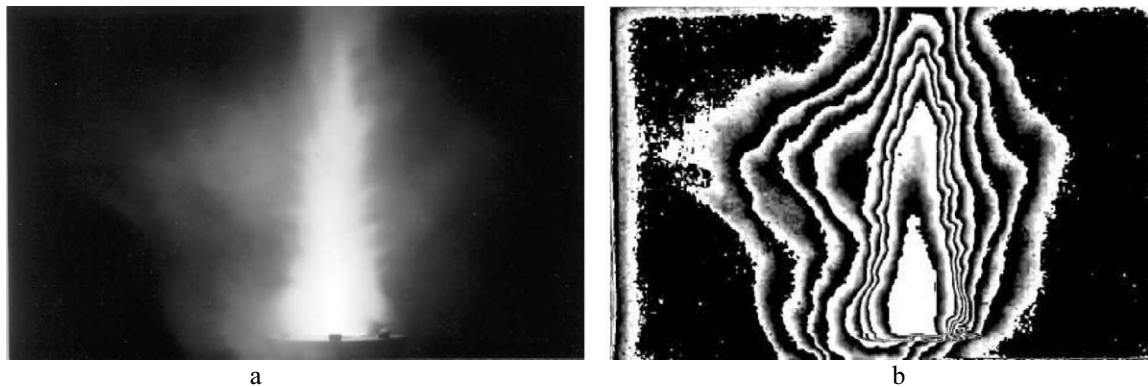


Figure 2: Photo of high current discharge of MPC, executed with application of the HC-10 optical filter (a) and spatial distribution of temperature (b)

The detailed picture of spatial distribution of temperature is given in Fig. 2b. For visualization of areas of the discharge with various temperature the algorithm of search of lines of equal brightness of the image and subsequent processing of photos with the help of personal computer (software package Corel PhotoPaint) was applied. With the help of such processing it is possible to allocate wide enough spectrum of brightness gradation of the discharge, which actually represent isotherms of temperature distribution.

It is possible to allocate two directions among ways of increasing of radiation optical pulse power. The first one concerns with the expense increasing of capacity of a storage-device C_{s-d} and / or increasing of a charge voltage U_{s-d} on a storage-device (i.e. the increases of energy of an impulse). The second one concerns with providing reduce of pulse duration at constant energy put-in the discharge. These ways include the reduce of parasitic inductance of a storage-device and current conductor parts by the constructive decisions, in particular, by application of the capacitors with small inductance and of current conductor parts executed as metal sheets; selection of the form and material of electrodes ensuring the minimal resistance of plasma in the field of the discharge; application of forcing capacities in the storage-devise (see Fig. 3).

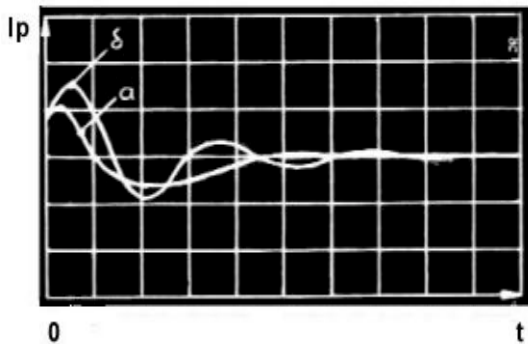


Figure 3: Oscillograms of discharge current with forcing capacities (a – aperiodic process, δ - oscillatory process).

4. CONCLUSION

The developed and created source of bandwidth optical radiation of plasma at high current discharge in the atmosphere allows to receive impulses by power up to 55 MW. The efficiency of a source makes size about 19 % of energy put in the discharge. The application of the busless circuit of connection of MPC with condensers of the store has allowed to realize short pulses of a current $\sim 20 \mu s$ and to increase power of radiation. The results of photographic researches of the high current discharge radiation in various areas of an optical spectrum are received. That allows to carry out the analysis of spatial distribution of radiation of the discharge area and to estimate spatial distribution of temperature. Received results can serve to form the basis the simple technique of a qualitative estimation of distribution of temperature of plasma at the high current high-voltage impulse discharges.

REFERENCES

- [1] I.S. Shostko, S.N. Shostko, Yu.F. Lonin., et all "Experimental Researches of the Powerful Broadband Optical Radiation on the Optical-Electrical Devices", The 7-th International Crimean Meeting "Microwaves devices and broadcasting technologies" (KryMiKo97) materials of the Meeting. Sevastopol, Crimea, Ukraine, September 15 – 18, 1997 V.1, p.271-274.
- [2] A.S. Kamrukov, N.I.Kozlov, Yu.S. Protasov, Letters to Technology Physics Journal 1975, v.1 no. 9 p.419-422 (in Russian)
- [3] N.I. Kozlov "Plasma Focus as a source of dense plasma", TBT, 1973, issue 11, no. 1 p.191-193
- [4] V.D. Zvorykin, A.S. Kamrukov, A.D.Klementov et all "The Researches of Plasma Focus Radiation in the Field by Ionization Chambers", Quantum Electronics, 1977, v.4, no. 2 p.290-300. (in Russian)
- [5] I.P.Kozlov, A.I. Morozov Plasma Accelerators and Ionic Injectors edited M.:1984 p.271. (in Russian)