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Volume discharges in CO_2–laser mixtures at atmospheric pressure with high energy density

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Introduction

Conditions of significant increase energy density of pumping volume discharge in CO_2–laser mixtures are determined. There are magnification of electron concentration level at the predionization stage and magnification of autoelectron emission current density from cathodes by using of carbon soot on the electrode working surfaces.

Purpose of work:

The purpose of this work was to study the effects of inorganic gas additives (NO, NO_2, I_2) to the CO_2:N_2:He mixture and carbon coatings of the cathodes of small-sized sealed-off TEA-CO_2 lasers on the current density of the volume discharge and the pumping energy density and as a result, on the value of the laser radiation energy per pulse.

I. EXPERIMENTAL SET–UP

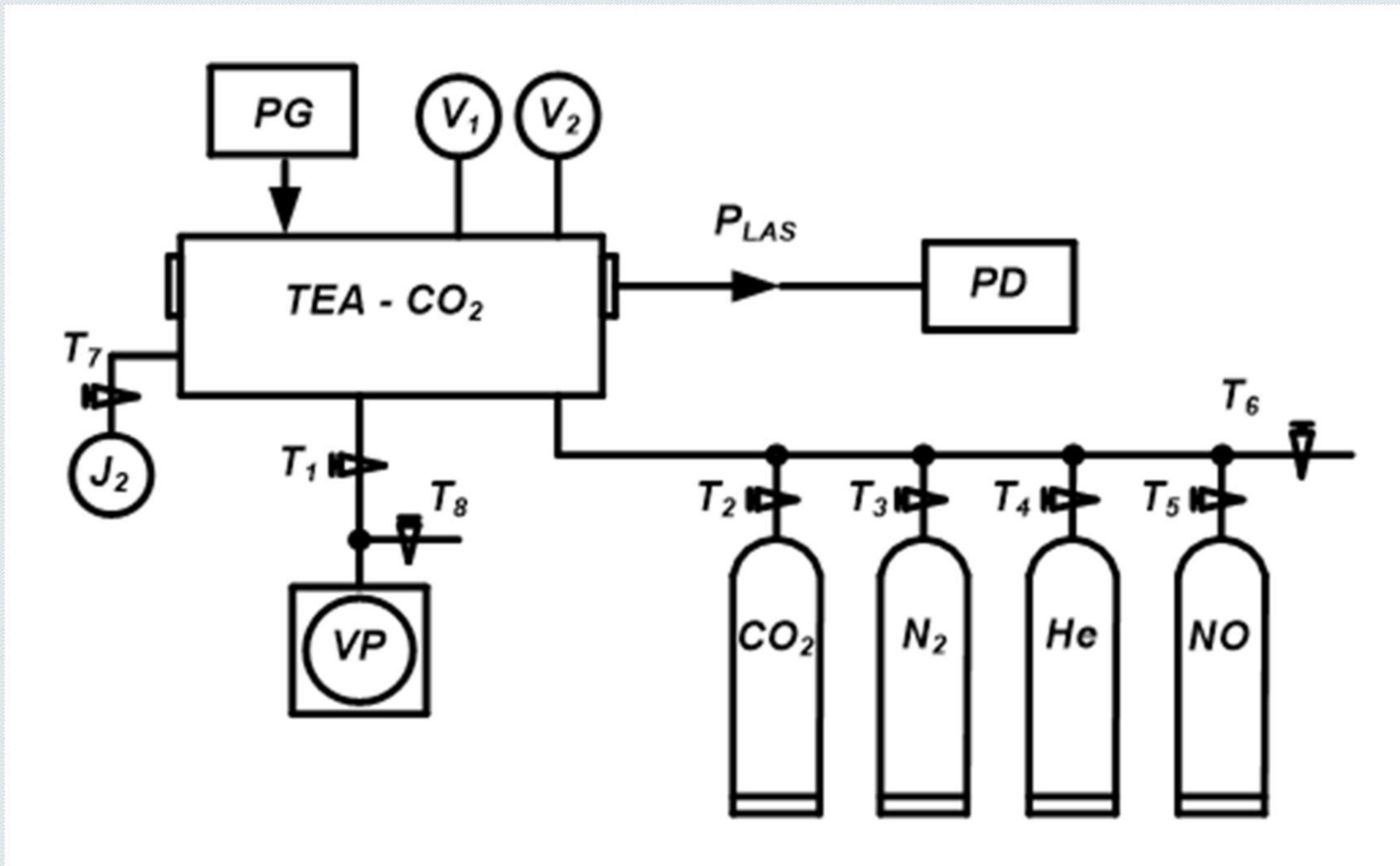


Fig. 1. Functional scheme of the experimental set–up

I. EXPERIMENTAL SET–UP

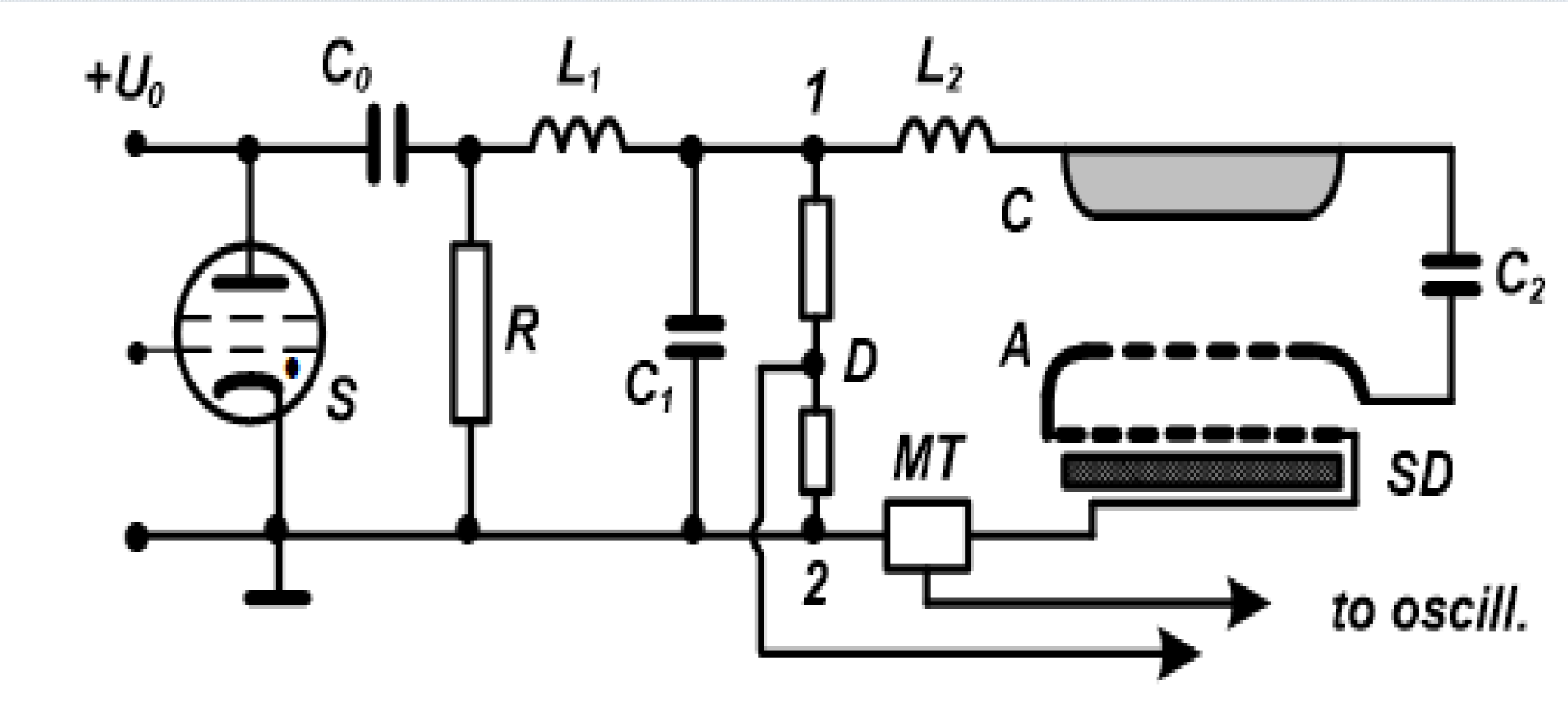


Fig. 2. Electrical scheme of high–voltage pulse generator and discharge gaps for preliminary sliding discharge (SD) and main volume discharge in the gap (A–C).

I. EXPERIMENTAL SET–UP

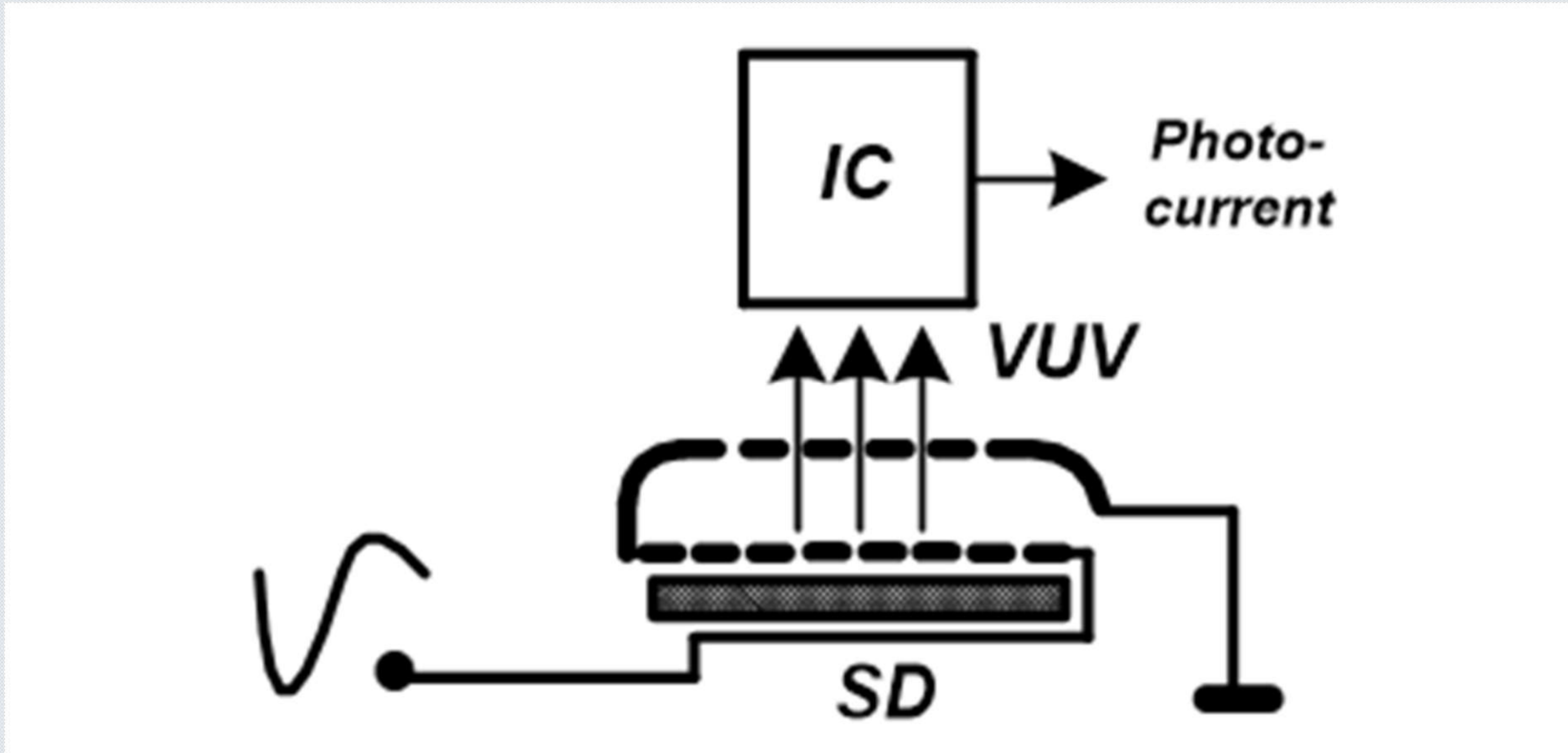


Fig. 3. Relative position of the VUV radiation source and the ionization chamber for measurement of the initial photoelectron concentrations in main discharge gap:

IC - ionization chamber; SD - sliding spark discharge

II. THEORETICAL PART

The photoelectrons concentration in a gas mixture at the predionization stage for fixed distance between source of VUV - radiation and ionization chamber was determined from value of measured photocurrent of ionization chamber as:

$$N_e = \frac{J_e}{e.v_{dr}}$$

where j – current density of the ionization chamber in saturation state; e – electron charge;

v_{dr} –electron drift velocity in the working gas mixture.

II. THEORETICAL PART

The magnitude of the drift velocity for a mixture of gases was determined from the known values of the drift velocity in individual gases CO_2, N_2, He in accordance with the expression:

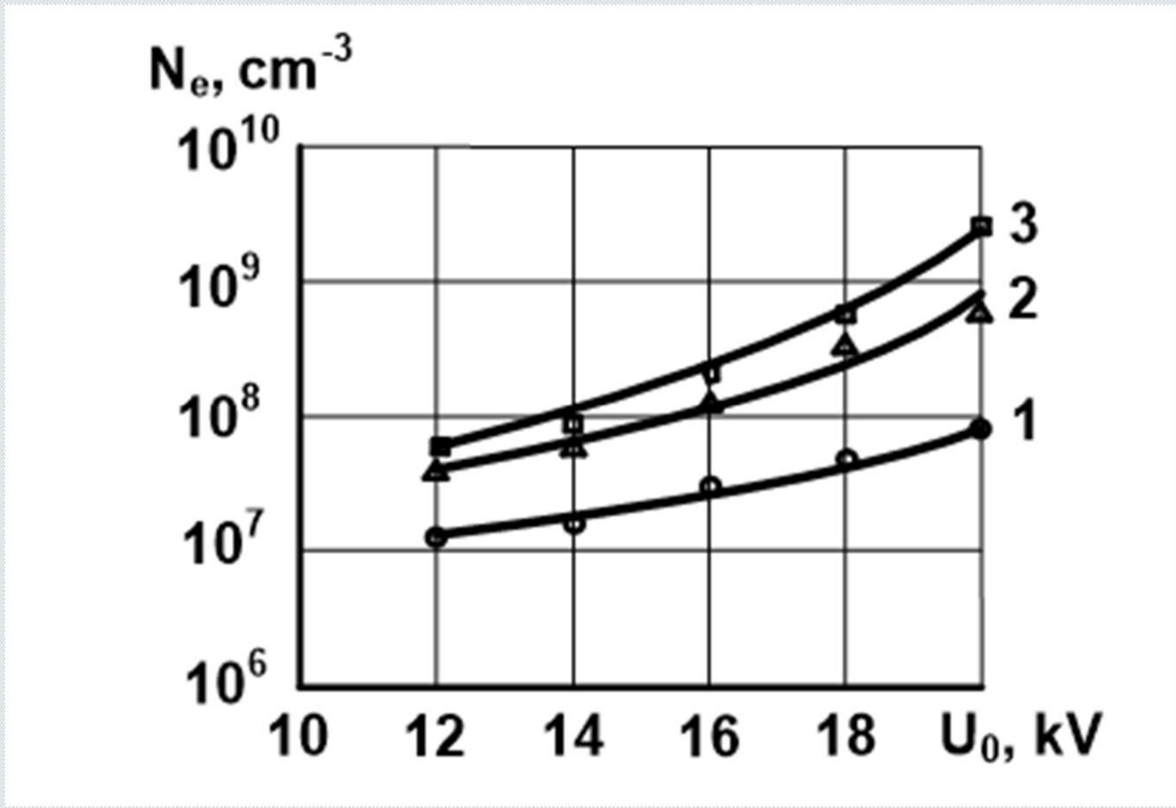
$$\frac{1}{v^{\Sigma}{}_{dr}} = \sum_i \frac{\Psi_i}{v^i_{dr}}$$

Where: $v^i{}_{dr}$ - drift velocity of electron in individual gases.

Ψ_i – partial part of individual gases in mixture;

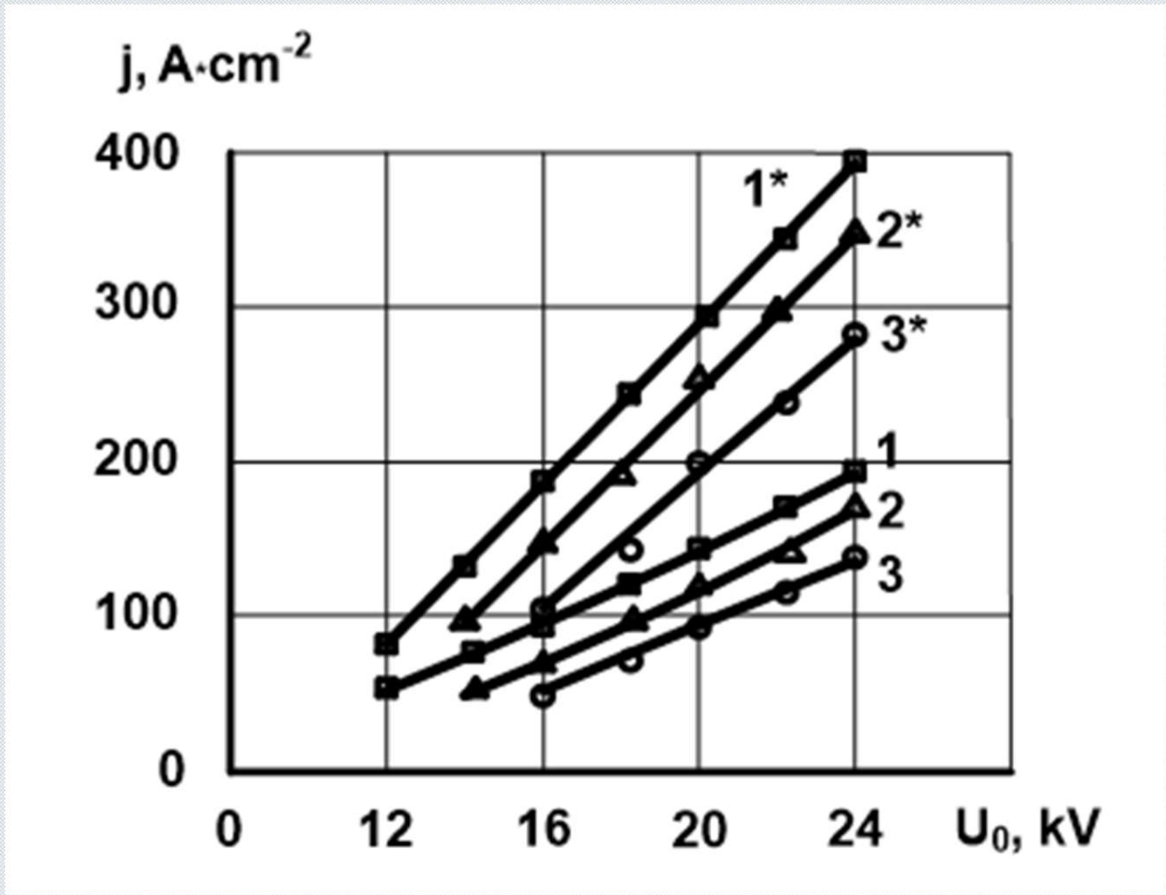
$v^{\Sigma}{}_{dr}$ - electron drift velocity in gas mixture.

III. EXPERIMENTAL RESULTS



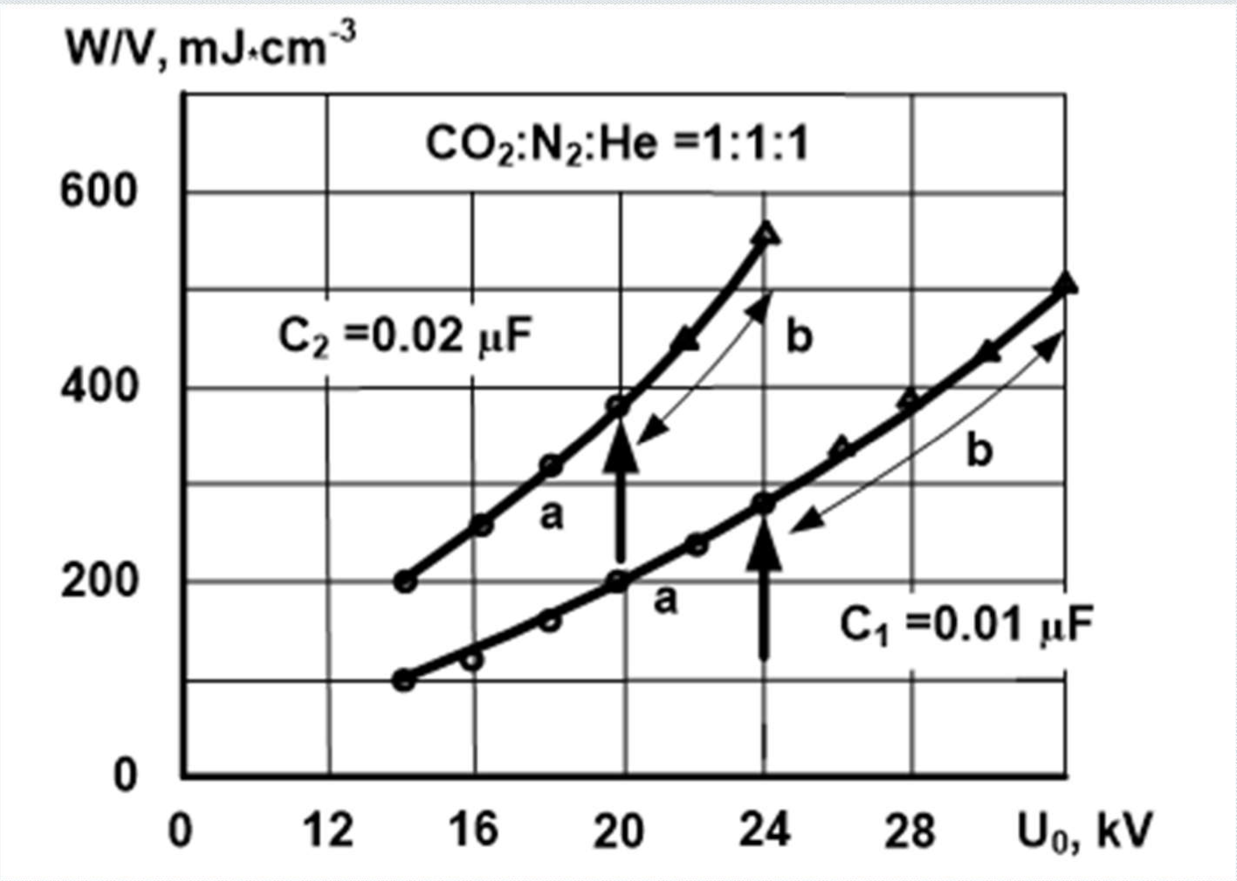
1. Fig. 4. Dependencies of photoelectron concentrations in CO_2-laser mixtures from magnitude of high-voltage pulses. Distance between ionization chamber and grid anode - 2 cm.

III. EXPERIMENTAL RESULTS



1. Fig. 5. Dependencies of current density from charging voltage of pulse generator capacitor C_0 for cathodes from Ni (1-3) and Ni with carbon soot (1*-3*). The working mixtures – CO_2:N_2:He = 1:1:8 (1, 1*); 1:1:6 (2, 2*); 1:1:4 (3, 3*).

III. EXPERIMENTAL RESULTS



1. **Fig. 6.** Dependencies of the volume discharge energy density from charging voltage of pulse generator for storage capacitors C_1 = 0.01 μF and C_2 = 0.02 μF and cathodes from Ni (a) and Ni with carbon soot (b). Laser mixture $CO_2:N_2:He$ = 1:1:1, P_Σ = 1 Atm.

CONCLUSION:

- Investigation results indicate main directions of increase energy density at ignition of self–sustained volume discharges in CO_2 laser mixtures with maximal energy densities up to 2000 $mJ \cdot cm^{-3}$. There are introduction in working mixture nonorganical gas impurities with ionization potential in the range $9.2 \div 9.8$ eV. Priority of them - nitric oxides such as NO and NO_2 and with simultaneous application high-current sliding discharge.
- The introduction into the working mixture of easily ionized gaseous impurities of an inorganic nature (NO, NO_2, I_2) provides an increase in the concentration of initial electrons predionization stage of volume discharge by more than an order of magnitude from 10^7 cm^{-3} to $10^8 \div 3 \cdot 10^9$ cm^{-3}.
- Application iodine vapour in working mixtures of sealed-off TEA-CO_2 laser is not advisable by reason of its very big chemical activity. Effective interaction of iodine vapour with the inner construction elements made from nickel and stainless-steel significant decrease the partial pressure of iodine vapour in laser container during some hours and not provide high level of photoelectron concentrations.

CONCLUSION:

- Covering of the electrode working surfaces by the carbon soot with micro- and nanostructure components leads to an increase of field emission currents from these surfaces by a factor of $2 \div 10$ compared to "pure" metal surfaces.
- The presence of carbon soot on the surface of the electrodes contributes to an increase in current density to a level of $500 \div 600$ $A \cdot cm^{-2}$ and an increase in the pump energy density from $250 \div 400$ $mJ \cdot cm^{-3}$ to $800 \div 1200$ $mJ \cdot cm^{-3}$.
- The presence in the working mixture of easily ionizable additives and the deposition of carbon coatings on the working surfaces of the cathodes makes it possible to form volume discharges in CO_2+N_2 mixtures without helium and to achieve a pump energy density in such mixtures of up to 2000 $mJ \cdot cm^{-3}$.

THANKS FOR YOUR ATTENTION!