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INVESTIGATIONS OF INSTABILITIES IN A NON-SELF-SUSTAINED REPETITIVELY PULSED DISCHARGE

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Non-self-sustained discharges are known to be unstable. Instabilities which limit the maximum energy input in pulsed modes of operation may develop in different ways. At a sufficiently high discharge voltage an instability which occurs during a current pulse can be observed. The mechanism of this instability has already been studied in detail. At lower discharge voltages instability may develop when the external source of ionization has been turned off. As a result the discharge voltage should be decreased further. This leads to a reduced energy input per pulse in a CO₂ repetitively pulsed laser when the frequency is high or the gas velocity is small [1,2].

This paper reports on the results of experiments on instabilities occurring after turning off the ionization source of a non-self-sustained discharge when a single or two subsequent current pulses of the electron beam current were applied.

The experiments were carried out in pure N₂ or in mixture of gases CO₂:N₂=1:9 at atmospheric pressure. Pulsed 120 keV electron beam having a current density 200 mA/cm² at the anode plane was introduced through an Al-foil into a discharge chamber. Typical oscillograms of current pulse forms without instability are shown in Fig.1a, Fig.1b related to an instability developed after turning off the ionizer and Fig.1c to a case when an instability occurs when the ionizer is active. The instability development time was studied when single pulses τ_p and $2\tau_p$ or sequence of two pulses with a duration τ_p each and a period T were applied.

Dependence of instability development

time τ_a in a discharge plasma for a mixture CO₂:N₂=1:9 upon E/P is given in Fig.2a. It shows the time of instability development relative to the front of the current pulse after the application of a single current pulse. Points related to $\tau_p = 0.3$ ms, are marked (x) and those to $\tau_p = 0.15$ ms - (□). Data obtained in a sequence of two pulses at $\tau_p = 0.15$ ms and T = 0.75ms are identified by (Δ). The same figure also shows the dependence τ_a (E/P) for a case when the instability develops before the end of the current pulse i.e. when $\tau_a < \tau_p$. These experimental points are marked with 0. From the figure it may be seen that the lag of instability development in a sequence of two pulses coincides with the lag observed in a single pulse of double duration if this time is greater than 0.9ms at this value the instability is formed during the second pulse of the sequence. With further increase of E/P the instability development lag reduces slightly. When $\tau_a = 0.75$ ms at E/P = 3.5 kV/cm·atm, τ_a starts again to increase rapidly. When the value τ_a diminishes to 0.15ms, the instability occurs during the first pulse.

Similar dependences were obtained in N₂ (fig.2b) with single 0.1 and 0.2ms pulses (indicated (□) and (x), respectively) and with a sequence of two pulses with $\tau_p = 0.1$ ms and T = 0.9ms (Δ), or with $\tau_p = 0.5$ and $\tau_p = 1.0$ ms (■ and +) and with two pulses $\tau_p = 0.5$ ms and T = 1.5ms (▲).

In our opinion the nature of instability at $\tau_a > \tau_p$ is the same as that observed at $\tau_a < \tau_p$. When the electron beam is interrupted the plasma starts to deionize and the current decreases. However, simultane-

ously with this process the self-sustained ionization continues to increase due to the growth of the mean energy of electrons in the applied field (E/N increases as gas concentration N decreases). Another reason is the increase of the number of fast electrons with ionizing capability. In this case $\partial N_e/\partial t$ (N_e -the electron concentration) may become positive with subsequent current and instability development. The non-self-sustained discharge transforms into a self-sustained mode. The second pulse merely accelerates this process. The time of establishment of a constant gas density after turning off the source of ionization is relatively short. It is of the order of oscillating relaxation time for the mixture of gases and corresponds to the rotational relaxation time for N_2 where the V-T relaxation time is on the contrary very long. Thus the instability will not develop after the first pulse but rather a certain stable density may be established. After the second pulse the density starts again to reduce, $\partial N_e/\partial t$ changes its sign and leads to instability. Thus, the rarefaction of the gas influences essentially the time of instability development.

Discharge voltage in lasers when an external ionizator is used for current modulation should be chosen such that E/P does not exceed the minimum value at which the instability develops, or τ_a should be greater then the time of gas transit through the discharge gap. In both cases this voltage is appreciably lower than the limiting voltage at which $\tau_a = \tau_p$, thus pumping would not be performed in the optimal conditions. It therefore appears that the most promising means of pumping would be provides anode voltage modulation in such a way that the probability of instability development be eliminated.

References

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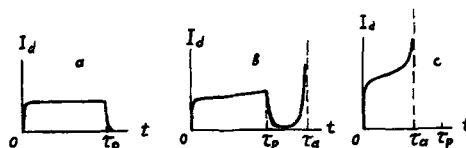


Fig.1

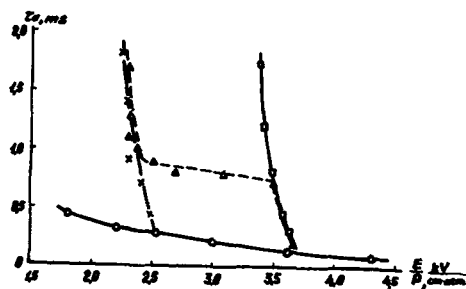


Fig.2a

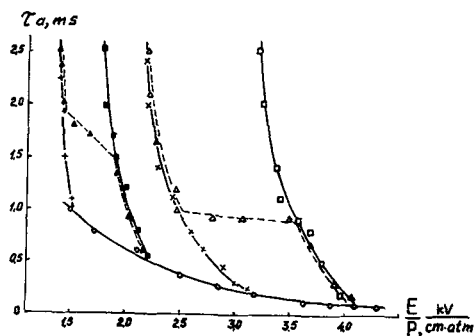


Fig.2b