19. W. Finkelburg and G. Mekker, Electric Arcs and Thermal Plasmas [Russian translation], IL (1961).
20. B. Ya. Moizhes and V. A. Nemchinskii, "Theory of high-pressure arcs on heat-proof cathodes," Zh. Tekh. Fiz., 42, No. 5, 1001 (1972).
21. D. Gray and T. F. Jacobs, "A cooled electrostatic probe," Raketn. Tekh. Kosmonavt., No. 1, 98 (1967).
22. L. M. Socio and C. V. Boffa, "A new method for measuring the anode fall in arc plasma generators," HTL TR, No. 87, University of Minnesota (1969).
23. R. C. Eberhard and R. A. Seban, "The energy balance for a high current argon arc," Int. J. Heat Mass Transfer, 9, 939 (1966).
24. O. H. Nestor, "Heat intensity and current density distributions at the anode of high-current, inert gas arcs," J. Appl. Phys., 33, No. 5, 1638 (1962).
25. J. B. Wilkenson and D. R. Milner, "Heat transfer from arcs," Brit. Weld. J., 7, 115 (1960).
26. P. Schoeck and F. Maisenhaelder, "Zur Druckabhangigkeit der Anodenfellspannung von Hochdrucklichtbogen," Beitr. Plasmaphys., No. 5/66, 345 (1966).
27. A. M. Dorodnov, N. P. Kozlov, and N. N. Reshetnikov, "Study of the energy characteristics of a radiation-cooled anode," in: Papers of the Second All-Union Conference on Plasma Accelerators [in Russian], Minsk (1973), p. 388.
28. G. V. Babkin and A. V. Potapov, "Influence of surface and volume ionization on near-electrode potential drops," Zh. Prikl. Mekh. Tekh. Fiz., No. 4, 137 (1970).

EXCITATION OF ELECTROMAGNETIC OSCILLATION IN THE PLASMA ZONE OF AN ELECTRON-ION OSCILLATING DISCHARGE

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UDC 533.98

Experimental data are presented on the excitation of electromagnetic oscillations in the plasma of an electron-ion oscillating discharge. The mechanism by which the neutral medium is excited by means of a beam of oscillating electrons and the resulting excitation of electromagnetic radiation are considered. The experimental results reasonably agree with theoretical conclusions for the idealized case of the passage of an electron beam through a neutral medium. A possible mechanism for the acceleration of high-energy electrons by an electromagnetic wave is hypothesized.

It has been demonstrated in a number of works [1-3] that studied an electron-ion oscillating discharge in a magnetic field, that the discharge cavity divides into two mutually connected regions in which the electrons and ions oscillate at low pressures in a system of electrodes whose potential alternates in sign. The electron component of the plasma is continuously populated basically by ionization processes within the discharge. The ion component is continuously populated due to ionization of the atoms of the neutral gas by the oscillating electrons.

The ionization mechanism for a neutral medium by an electron beam was theoretically solved in [4]. It was demonstrated that bremsstrahlung and scattering is accompanied by a disturbance of the medium in some spatial zone, formed due to cascade ionization processes by the electrons of the neutral atoms. Oscillations with a frequency [4]

$$\omega = \left\{\frac{4\pi e^2}{M}\left(\frac{3\pi Z^2 e^4 n_0 \sigma^2 N^3 v_0}{4\alpha E_0 \Delta}\right)^{\frac{1}{2}}\right\}^{\frac{1}{2}},$$

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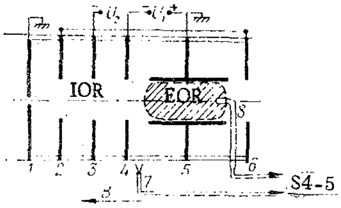

Fig. 1

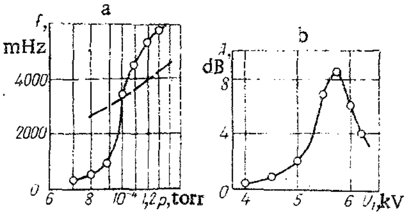

Fig. 2

having the sense of the plasma frequency ω of the zone of maximal concentration, such that the basic contribution to the density of successively emitted electrons is made by electrons with energy E less than the ionization energy Δ, can be excited in the resulting plasma surrounding the beam.

Beam energy oscillates along the electromagnetic field, measured in one direction by multigrid probes, significantly exceeds the transverse kinetic energy of the successively emitted electrons, and is determined by values near the maximum ionization cross section of the neutral gas. It amounts to 80-100 eV for nitrogen.

The recombination coefficent α takes low values, $\alpha \simeq 10^{-13}$ cm^3/sec, for these experimental conditions. The neutral gas density $N = 5 \cdot 10^{12}$ cm^{-3} and the value of $n_0 v_0$ corresponding to a 6 mA current of oscillating electrons is equal to $3.6 \cdot 10^{16}$ sec^{-1}(here n_0 is the linear density of the oscillating electrons).

An estimate of ω for the discharge conditions presented above and the values $E_0 = 80$ eV, $\Delta = 15$ eV, $\sigma = 3 \cdot 10^{-16}$ cm^2 (nitrogen), and Z = 1 (since we are considering electron–electron collisions) yields a value $\approx 2.02 \cdot 10^{10}$ sec^{-1} (f = 3220 MHz).

Electromagnetic radiation from the discharge plasma was received by a telescope antenna mounted outside the discharge. The spectral composition of the electromagnetic radiation was determined by the S4-5 spectrum analyzer. The antenna was oriented and adjusted to the maximal signal and its position was a function of the discharge conditions. Moreover, electrostatic plasma oscillations were registered by a high-frequency probe. The high-frequency probe and its calibration were as in [5]. The probe was mounted in the plasma of the electron oscillating region (in its center) or near the plasma boundary and could shift in the axial and radial directions of the discharge (Fig. 1, where 1-4 and 6 are the electrodes, 5 is a cylindrical anode, 7 is the telescopic antenna, 8 is the high-frequency probe, and IOR and EOR are the ion and electron oscillating regions).

Values of frequencies fixed in the experiment by the high-frequency probe and antenna at $U_2 = 10$ kV and D = 600 G basically coincide and amount to 3280-3400 MHz as a function of pressure and voltage U_1 on the electrodes of the electron oscillating region.

The experimental dependence of the plasma frequencies on pressure (Fig. 2a, $U_1 = 5$ kV) is close to that previously presented [4] (broken curve), but is somewhat steeper. The growth in the frequency of radiation of maximal amplitude with increasing pressure is explained by the increase in the number of electron–electron collision events.

The amplitude maximum of electromagnetic radiation increases with increasing electric field strength within the volume of electron oscillations (Fig. 2b, $p = 1.4 \cdot 10^{-4}$ torr). An amplitude oscillation peak (A increases to 9 dB) is observed with a voltage U_1 across the electrodes of between 5.5 kV and 6 kV, this peak exceeding the mean value by a factor between 4 and 6. This is explained in the readjustment of the topography of the electric field of the ion and electron oscillating regions, when excitation is complemented by the secondary electrons of the ion region. These electrons as they approach the anode, additionally disturb the neutral medium as well as its ionization.

A stable value for the frequency of electromagnetic radiation is most likely at primary beam energies close to the values of mΔ in the ionization cross-section maximum (for a given gas). Maximal values of the oscillation amplitudes also correspond to these conditions.

The influence of a magnetic field (in the range of B between 230 G and 600 G) is insignificant, and it can be seen that the amplitude of electromagnetic oscillations linearly increases with increasing inductance of the applied magnetic field.

Such electromagnetic radiation accompanies ionization processes of the neutral atoms and ion recombination in an oscillating electron discharge and is apparently the source of energy for fast electrons in the course of their self-resonance acceleration within the volume of a cylindrical anode (oscillating electron region) [6].

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LITERATURE CITED

1. V. P. Demutskii and N. A. Khizhnyak, "Particle distribution function of a plasma in a system of alternating electrodes," in: Interaction between Charged Particles and a Plasma [in Russian], Naukova Dumka, Kiev (1967), pp. 178-193.
2. M. I. Korsunskii and É. M. Gorbenko, "Determination of certain parameters of an oscillating electron discharge," Zh. Tekh. Fiz., 35, 1193-1202 (1965): "Certain properties of an oscillating electron–ion discharge," Zh. Tekh. Fiz., 35, 1265-1273 (1965).
3. V. M. Rashkovan, V. P. Demutskii, and N. A. Khizhnyak, "Study of an oscillating electron–ion discharge in a longitudinal magnetic field," Zh. Tekh. Fiz., 39, 452-457 (1969).
4. A. S. Dolgov, "Ionization of a neutral medium by an electron beam," Zh. Prikl. Mekh. Tekh. Fiz., No. 3, 24-28 (1973).
5. A. N. Kharkhov, "The use of B4 probes for studying the natural modes of a plasma," in: Plasma Diagnostics [in Russian], Atomizdat, Moscow (1973), pp. 371-375.
6. A. A. Vorob'ev, A. N. Didenko, A. P. Ishkov, A. A. Kolomenskii, A. N. Lebedev, and Yu. G. Yushkov, "Study of self-resonance particle acceleration by an electromagnetic wave," Atom. Énerg. 22, No. 1, 3-6 (1967).

SUPERHEATING INSTABILITY IN A PULSED XENON DISCHARGE

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It is shown that previously obtained conditions for superheating instability substantially vary if we take into account secondary xenon ionization. Instability completely vanishes if the density of heavy particles in the discharge is kept constant and whenever a discontinuous time variation of temperature T in a restricted region between 15 · 10^3°K and 20 · 10^3°K is possible for a constant effective pressure. The development of instability is studied numerically by a ranging method. Stationary temperature distributions possessing a high contrast as a local temperature passes through a given range of instability with constant pressure are presented.

The possibility of discontinuously varying the temperature in a strongly radiating pulsed discharge under the effect of superheating instability has recently been widely discussed [1-4], such instability arising when the relative increment of plasma emissivity φ (T) becomes less than the relative increment in electric conductivity σ(T). The reliability of the theoretical prediction of this difference effect substantially depends on correctly taking into account details in calculating σ and φ and thus requires experimental verification. For example, such instability has been detected experimentally [5] for a discharge in a vapor plasma in the range of temperatures T between 16 · 10^3°K and 24 · 10^3°K and also in [6] for a discharge occurring in erosion products from quartz glass.

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