we obtain at $\dot{x}(0) = 0$ and $t \gg T$ a residual velocity

$$v_c = - v_0 / \left[ 1 + \left( \frac{1}{\omega T} \right)^2 \right] .$$

A directed current and a quasistationary magnetic field may be produced by incidence of powerful steep microwaves or light pulses on a plasma (in particular, this effect may be one of the causes of the produced spontaneous magnetic fields, in addition to light pressure and thermoelectronic motion) [1 - 2].

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## BEAM HEATING IN A "PLASMA FOCUS"

V. A. Gribkov, O. N. Krokhin, G. V. Sklizkov, N. V. Filippov, and T. I. Filippova
P. N. Lebedev Physics Institute, USSR Academy of Sciences
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High-speed interferometry methods are uded to show that powerful electron beams, subjected to hose instability and focusing in the plasma, are produced during the concluding stage in a plasma focus. The anomalous scattering of the diagnostics laser radiation and the powerful x-radiation of the plasma from the beam-focusing region point to the development of two-stream instability and strong heating of the plasma in this region. This explain the principal neutron pulse produced in the setup.

1. The mechanism whereby the bulk of the neutrons are produced in one of the installations having the largest thermonuclear neutron yields, the "plasma focus" (PF) [1], is still not clear at present [2]. Spectral investigations of the neutron radiation show that up to 80% of the tutal neutron yield can be of thermal origin [3], but the plasma temperature obtained in these measurements ($\sim$20 keV) is frequently doubted, since the density of the plasma in the PF ($\sim 10^{19}$ cm$^{-3}$) does not correspond to the neutron yield.

Various attempts were made to attribute the plasma heating in the "second compression" to two-stream instability [4], macroscopic turbulence [5], ion-acoustic instability [6], and others. There are, however, no experimental data pointing to any one paritcular turbulence mechanism.

2. It was snown in [4] for about 100 nsec after the first compression the plasma density is of the order of $10^{18}$ cm$^{-3}$. Investigations of the subsequent processes occurring in the PF, using the interferometric setup described in [7], have shown that at the instant of the maximum neutron pulse the PF is a "drooping" neck (see Fig. 1), under which one can see a tubular conical formation, the vertex of which points to the anode of the chamber. The density on its axis is less than $10^{16}$ cm$^{-3}$, and in the 'walls' of the cone it is approximately $10^{18}$ cm$^{-3}$. In the base of the cone one sees that the interference fringes vanish and the film is slightly exposed, while at the vertex there is frequently a dark spot showing overexposure of the photgraphic material. The dimension of the spot, which is due to the increased luminosity of the plasma at this point, is about 1 mm.

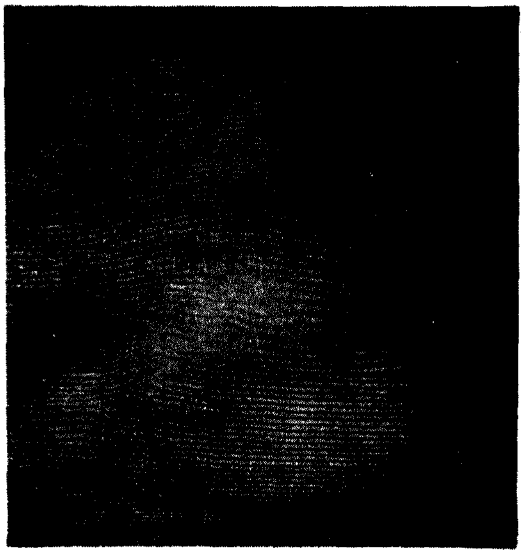

Fig. 1. Interference pattern of plasma waveguide (lower left) and of plasma cathode (bridges top and center)

It is clear from the foregoing that we are dealing here with a typical plasma waveguide made up of the residual plasma by an electron beam drawn from drooping neck (plasma cathode). The vanishing of the interference fringes in the base of the cone is due to the anomalous scattering of the laser radiation when the energy of the Langmuir oscillations excited by the beam as it enters the plasma is partially accumulated, and the increased glow at the vertex of the cone is due to presence of impurities (nitrogen and xenon in our case).

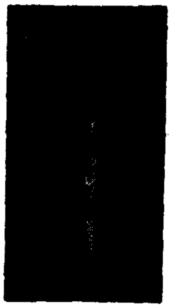

Fig. 2. Obscurogram of beam focusing point, obtained in soft x-rays.

From experimental data one can estimate the beam focusing length [8], when the magnetic-compression force is balanced by the beam-pressure force:

$$\ell \approx R\left(\frac{\sigma_o p_o}{i_o^2 t}\right)^{1/5}\left(\frac{N_{e_b} m_e c^2}{p_o}\right)^{1/2} \approx 3 \text{ mm} , \qquad (1)$$

where T is the plasma temperature, $p_0$ is the plasma pressure $N_{e_b} = 3\times10^{15}$ cm$^{-3}$ is the beam density, $\sigma_0$ is the plasma conductivity, $I \simeq 10^6$ A is the beam current, $N_{e_{pl}} \simeq 10^{18}$ cm$^{-3}$ is the plasma density, R = 1.5 mm is the initial beam radius, and $t \simeq 10^{-7}$ sec is the injection time.

From the dimensions of the minmal radius (r) of the focused beam and from the focusing length $\ell$ we can estimate the average initial angular scatter of the electrons in the beam $<\theta_0>$, and the increment of the hose instability to which, as seen from Fig. 1, the beam is susceptible [8]:

$$<\theta_o> \sim \frac{r}{\ell} \sim 0{,}07 \qquad (2)$$

$$\tau = \frac{1}{\gamma} = \left(\frac{N_{e_{p\ell}} M_i}{N_{e_b} m}\right)^{1/2} \frac{r}{c<\theta>} \sim 2{,}4\cdot 10^{-8} \text{ sec} \qquad (3)$$

The order of magnitude of (1) and (3) corresponds to the experimental values.

3. When an electron beam passes through a plasma having a density higher than the beam, longitudinal Langmuir oscillations are the first to build up in the plasma [9]. Evidence of the strong heating of the plasma at the beam focusing point is seen in the obscurograms of the (Fig. 2) observed by us in soft x-rays. These obscurograms show small formations ("beads") that have usually a tubular structure. It is interesting that these "beads" frequently followed one another, making the electron-beam focusing picture similar to the case of the so-called "banana" self-focusing of a laser beam [10].

4. The mechanism whereby powerful electron beams were produced during the concluding stage of the PF was different for the different additives (nitrogen and xenon) introduced into the deuterium. In the former case, the analysis of the anomalous scattering of the sounding laser radiation in the skin layer has shown that plasma oscillations develop in it before the first compression; the estimated ratio of the oscillation energy density to the thermal-energy density is of the order of 0.2. The oscillation energy density apparently continues to increase during that period until the amplitude of the electron oscillations in these longitudinal oscillations becomes comparable with the current velocity of the electrons in the sheath ("strong turbulence"). This interrupts the current in the skin layer and leads to the production of strong electric fields [4] on the periphery of the PF near the skin layer, and subsequently the current in the PF is carried by the tubular electron beam produced in the induced electric fields.

In the case of the xenon additive, no breaks in the current sheath were observed as a rule. The interference patterns show, however, that when the sheath converges to the axis in these discharges, the shock wave is practically not detached from the sheath, so that the density near the axis is quite low. This makes it possible to satisfy the Dreicer criterion for "runaway" electrons in the plasma on the PF axis in this case.

5. The conditions of beam "passage" vary strongly from discharge to discharge. Most frequently the beam breaks up into several filaments, which are susceptible to hose instability (Fig. 3). In some cases, however (as a rule in the case of xenon additive), the beam reaches the anode without being distorted (Fig. 4) ("overcompensated beam passing through a Z-pinch").

The discharges were accompanied by an anomalously large x-ray flash.

The results thus demonstrate the important role played by the beam heating mechanism during the last stage of development of the PF.

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Fig. 3. Hose instability of beam.

Fig. 4. Case of good beam transport.

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# QUASISTATIONARY ATMOSPHERIC-PRESSURE $CO_2$ LASER WITH NON-MAINTAINING DISCHARGE CONTROLLED BY A NEUTRON FLUX

V.M. Andriyakhin, E. P. Velikhov, A. S. Kovalev, V. D. Pis'mennyi, A. T. Rakhimov, and V. E. Khvostionov
Nuclear Physics Institute of the Moscow State University

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An atmospheric-pressure $CO_2$ laser with non-maintaining discharge controlled by a neutron beam is investigated. Lasing is obtained with a pulse duration from tens to hundreds of microseconds and with energy up to 40 J/l.

In a 1968 paper [1] there was described a strong increase in the generation power of a cw electric-discharge $CO_2$ laser of low pressure ($\sim$10 Torr) under the action of an ionizer (beam of fast protons) that made the discharge non-self-maintaining. The discharge current under condition of non-self-maintenance (several dozen milliamperes at a proton beam current of several microamperes) had a value indicating that it is transported by the electrons, while the current-voltage characteristics [2, 3] indicated that the beam ensures a high degree of ionization of the gas ($\sim 10^{-7}$ at $N_0 \sim 10^{17}$ cm$^{-3}$).