our experiments, the conditions of the reagent mixing were varied by decreasing the diameter of the injection openings. At an opening diameter d = 1 mm, the pressure drop between the injected medium and the reaction volume was ΔP = 10 - 15 Torr, and at d = 0.35 mm and at the same gas flow we obtained $\Delta P \sim 1$ atm. The decrease of the diameter led to an increase of the velocity of the injected jets, improving by the same token the conditions for the mixing of the components. The improvement of the mixing conditions in the second case increased the cw radiation power by approximately 4 times, to 2.1 W.

In conclusion, the authors thank A.V. Pankratov and A. Skachkov for supplying the chemically pure reagents.

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EXPERIMENTAL INVESTIGATION OF THE INTERACTION OF MODULATED RELATIVISTIC BEAMS WITH A PLASMA

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A study of the collective processes of interaction of relativistic electron beams with a plasma is of great interest for plasma physics and for numerous applications. The linear theory of this interaction was considered in [1, 2], and the nonlinear one in [3].

The main conclusion of the linear theory is that the relativistic increase of the longitudinal and transverse masses of the electrons in the beam causes the increments of the excited oscillations to decrease strongly. While this statement is true, it would be incorrect to conclude from it that the efficiency of plasma-beam interaction is lower at relativistic electron-beam energies. The nonlinear theory shows [3] that the beam remains monoenergetic even at the appreciable momentum spread due to the reaction exerted on the beam by the excited oscillations, which are naturally taken into account only in the nonlinear theory.

Owing to the resonant character of the interaction of the monoenergetic beam with the plasma, the "hydrodynamic" phase of this interaction is stretched out, leading to a strong increase of the fraction of energy transferred from the beam to the plasma.

Thus, the interaction efficiency, defined as the relative amount of energy transferred from the beam to the plasma, increases rather than decreases. For an experimental observation of the effects it is necessary to increase either the beam currents or the length of the interaction at not very large currents.

An appreciable enhancement of the effect is obtained under conditions that permit coherent deceleration of the relativistic electron beam by the plasma, which is the inverse of V.I. Veksler's effect of coherent acceleration [4].¹⁾ It is necessary to use for this purpose modulated beams and effects of accumulation of electromagnetic energy [6].

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1) We note that the effect of coherent Cerenkov radiation of nonrelativistic beams in dielectrics was first investigated by V.L. Ginzburg and I.M. Frank [5].

There are still many uninvestigated problems connected with features of the interaction of strong-current relativistic beams with a plasma in experiments with currents 1 - 10 A. At the same time, the physical features of collective interactions in the relativistic stage are easier to investigate experimentally at not very large currents.

We have investigated the interaction of a plasma with a train of relativistic electron bunches obtained from a linear accelerator of an ordinary type, i.e., the interaction of a strongly modulated relativistic electron beam with a plasma. The purpose of the investigation was to observe the coherent energy loss of the electron beam as a result of collective interactions with the plasma. The experiments were performed with a decaying plasma whose density ranged from 10^{14} to 10^{10} cm^{-3}. The phase width of the bunch is 60° [9], so that the intreaction should be coherent for each individual bunch only for densities up to 5×10^{12} cm^{-3}. Coherence between bunches should occur only at a density $\sim 10^{11}$ cm^{-3}, when the electron plasma frequency ω_p is close to the bunch repetition frequency ω_{mod} ($\omega_p \sim \omega_{mod}$). In our case, the length of the system subtends over 20 bunches. For densities at which the bunch dimension exceeds half the plasma wavelength, $L > \lambda_p/2$, interaction between the unmodulated beam and the plasma takes place.

It should be noted that an attempt to observe the collective interaction of a modulated beam with a plasma was made in [7] and led to negative results.

Figure 1 shows the block diagram of the setup. The relativistic beam was produced by an injector linear accelerator (ILAE) with constant wave phase velocity close to c, developed by A.I. Grishaev, A.I. Zykov, E.K. Ostrovskii, and V.A. Vishnyakov, and similar to that described in [8, 9] but with increased current. The accelerating section is a segment of a diaphragm-loaded waveguide. The beam parameters are: energy 2 MeV, pulsed current 1 A, pulse duration 2 μsec, beam diameter 10 mm, phase width of the bunch $\sim 60°$. The interaction chamber was a glass tube with diameter $d \sim 100$ mm and length $\ell \sim 2$ m, placed in a constant longitudinal magnetic field of intensity up to 2000 Oe. The plasma source was a coaxial plasma gun similar to that described in [10]. The internal electrode of the gun was hollow, with an opening of 20 mm diameter for the admission of the relativistic electron beam into the interaction chamber. The initial pressure in the chamber was 10^{-6} Torr. The plasma density was monitored by microwave sounding with 10 cm, 3 cm, and 8 mm signals.

The energy spectrum of the beam electrons passing through the interaction chamber, both with and without plasma, was measured in the following manner: A magnetic analyzer installed at the exit from the interaction chamber was set for a definite value of the current, corresponding to a specified energy of the

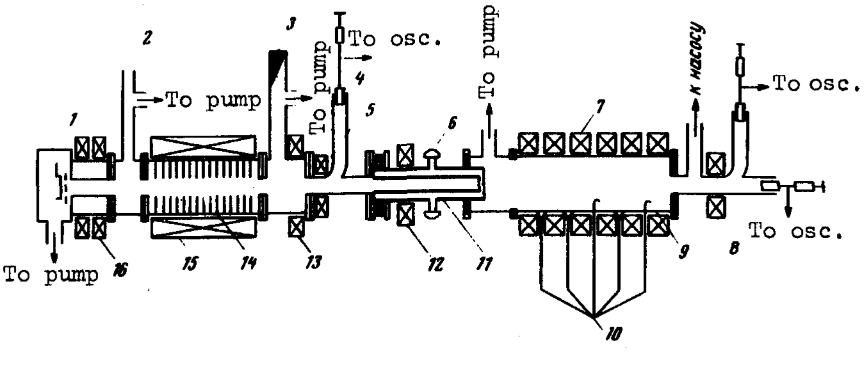

Fig. 1. Block diagram of setup: 1 - electron gun, 2 - evacuated waveguide line, 3 - microwave load, 4 - Faraday cylinder, 5, 8, 12, 13, 16 - systems for correcting and focusing the beam, 6 - electrodynamic valve, 7, 15 - solenoids, 9 - interaction chamber, 10 - microwave diagnostics elements, 11 - plasma gun, 14 - diaphragm-loaded waveguide.

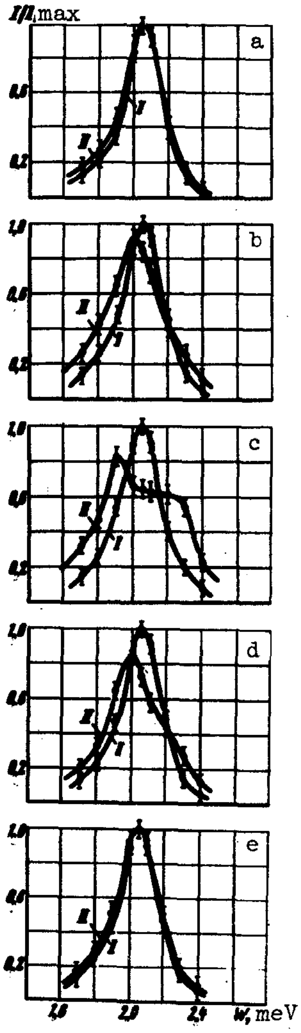

Fig. 2

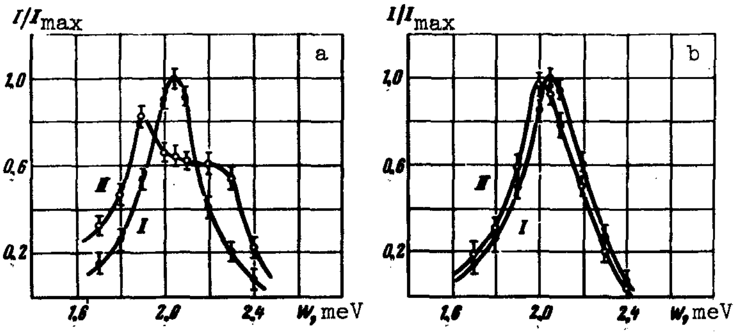

Fig. 2. Energy spectrum of electrons at a beam current of 1 A. I - without plasma, II - with plasma: a - $n_p \sim 5 \times 10^{12}$ cm^{-3}, b - $n_p \sim 10^{12}$ cm^{-3}, c - $n_p \sim 10^{11}$ cm^{-3}, d - $n_p \sim 10^{10}$ cm^{-3}, e - $n_p \sim 5 \times 10^{10}$ cm^{-3}.

Fig. 3. Energy spectra of electrons: a - for a current 1 A and b - for a current 0.5 A, $n_p \sim 10^{11}$ cm^{-3}. Curve I - without plasma, curve II - with plasma.

particles passing through the analyzer. At this value of the energy, numerous measurements of the particle current were made with and without the plasma. The rms error of the current measurement at a given energy was 2 - 3% (see Figs. 2 and 3). By varying the setting of the analyzer, we determined the energy distribution function of the beam electrons for different values of the beam current and plasma density.

Typical distribution functions are shown in Fig. 2. As seen from the drawings, there is a collective interaction between the relativistic electron beam and the plasma; this interaction has a resonant dependence on the plasma density. The maximum interaction is observed at a plasma density $n_p \sim 10^{11}$ cm^{-3} (Fig. 2c). The maxima in the spectra are shifted by approximately 150 - 250 keV. A noticeable fraction of the electrons is accelerated by 100 keV. We note that incoherent Bohr energy losses for the case in question amount to only 10^{-6} eV. For plasma densities $n_p \sim 5 \times 10^{12}$ and 5×10^{10} cm^{-3}, no interaction is observed (Figs. 2a and 2e). At densities $\sim 5 \times 10^{12}$ and 5×10^{10} cm^{-3}, the interaction is greatly weakened (Figs. 2b and 2d).

Consequently, the maximal interaction is observed at a plasma density such that the length of the excited plasma wave λ_p is equal to the difference between the bunches, i.e., when $\omega_p \sim \omega_{mod}$.

The interaction efficiency depends strongly on the beam current. Figure 3 shows the distribution function of the beam electron energies for a current 0.5 A and a plasma density $n_p \sim 10^{11}$ cm^{-3} (curve II). As seen from Fig. 3, when the beam current decreases, the interaction is greatly reduced even at the optimal value of the plasma density.

The large values of the energy lost and acquired by the particles, and the resonant character of the dependence of the loss on the plasma density (Fig. 2c), offer undisputed evidence of the coherent collective character of the interaction of the relativistic electron beams with the plasma.

We note that the negative result of [7] may be due to the fact that the condition for coherent interaction ($\omega_p \sim \omega_{mod}$) was not satisfied and the beam current was too small (∿0.15 A).

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MAGNETOOPTICAL PROPERTIES OF THE BIELECTRON IN THE BiI_3 CRYSTAL

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The absorption spectrum of the BiI_3 crystal at 4.2°K revealed a number of sharp absorption lines with longer wavelengths than the intrinsic absorption edge, in the spectral interval 6150 - 6250 Å. These lines converge in the long-wave region of the spectrum (see Fig. 2a) and their position is well described by the hydrogen-like relation

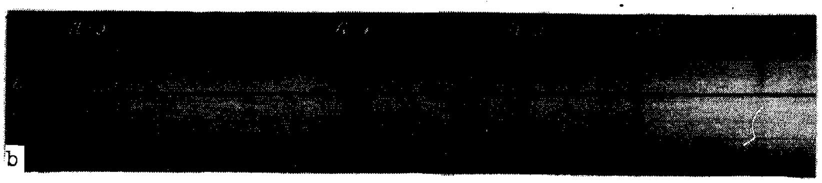

Fig. 2. Absorption spectrum of inverse hydrogen-like series in a magnetic field perpendicular to the crystal axis: a - H = 0, b - H = 34 kG.