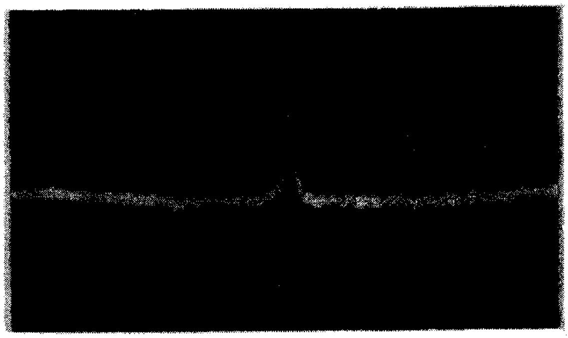

Fig. 2

a flux of (5 - 6) x 10^{18} mol/sec. A typical oscillogram of the laser output intensity is shown in Fig. 2. The total width of the power peak at half-height is about 60 kHz (Q at peak approximately 1.5 x 10^{2}) and is practically independent of the intensity of the molecular beam. In our case, the resonance width was determined by the time of interaction of the molecules with the electromagnetic field.

It must be emphasized that the use of a molecular beam instead of a gaseous medium makes it possible to obtain a much more contrasty power peak, for in the case of a molecular beam the number of molecules resonantly interacting with the field is much larger at the same number of particles per cm^3. The relative magnitude of the power resonance can be greatly increased (compared with the present experiment) by using a more perfect beam source and a vacuum system with greater productivity.

We note that observation of the saturation effect in the absorption line of the molecular beam is possible also with other molecules having small radiative widths and having a transition frequency that falls in the laser generation region, for example saturation of the absorption line of SF_6 molecules with the radiation field of a CO_2 laser.

A laser with a beam-type nonlinearly-absorbing cell, besides its use as an optical frequency standard, also uncovers possibilities of organizing new experiments in the optical band. For example, experiments are possible where ultranarrow lines are obtained by the Ramsay method [4], or the realization of a laser with two resonators in tandem for the study of the emission features of molecules in a mixed energy state, in analogy with the known experiments in the radio band [5].

In conclusion, the authors are deeply grateful to G. A. Elkin for supplying the vacuum equipment and for valuable advice, and to N. I. Golynskii and I. M. Karasev for help in preparing and performing the experiment.

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THRESHOLDS OF TWO-STREAM INSTABILITY OF CURRENT IN A STRAIGHT DISCHARGE

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If conditions for electron runaway are created in a strong-current straight discharge, then an instability is excited and leads to the transport of the entire discharge current by the beams of accelerated electrons and to termination of the discharge [1]. The ASPA setup [1] was used to investigate the excitation of anomalous resistance (R) upon termination of the discharge, and the dependence of R on the initial plasma density n_{e0} and on the discharge voltage U_0 on the capacitor. The parameters of the discharge circuit were: current up to 30 kA, period 1.6 μsec, capacitance 0.2 μF (50 kV), cross section of current channel approximately 80 cm^2, and initial plama density n_{e0} from 1 x 10^{12} to 3 x 10^{13} cm^{-3}. The discharge was excited in a homogeneous magnetic field H_0 at a distance between electrodes L = 5 cm or L = 28 cm. The electron beam passed from the gas-discharge zone through a reticulate anode, and its propagation was investigated along a magnetic field in an equipotential plasma-filled space. The beam-current density and the electron energy were measured at a distance 20 cm from the anode by determining the bremsstrahlung x-rays from the target. The electron-beam parameters were: total current up to 25 kA, electron energy up to 30 kV, beam duration 0.2 - 1.5 μsec, and approximate beam cross section area 100 cm^2.

At low plasma densities, $n_{e0} < 1 \times 10^{13}$ cm^{-3}, the resistance of the plasma gap greatly exceeded the wave impedance of the circuit Z_{wave} = 12 Ω (aperiodic discharge). In the aperiodic regime, the adjustable parameters were the initial plasma density n_{e0} and the discharge voltage U_d, while the discharge current was determined by the plasma resistance. The linear dependence of R on U_d shows (Fig. 1a) that at a specified plasma density n_{e0}, when the

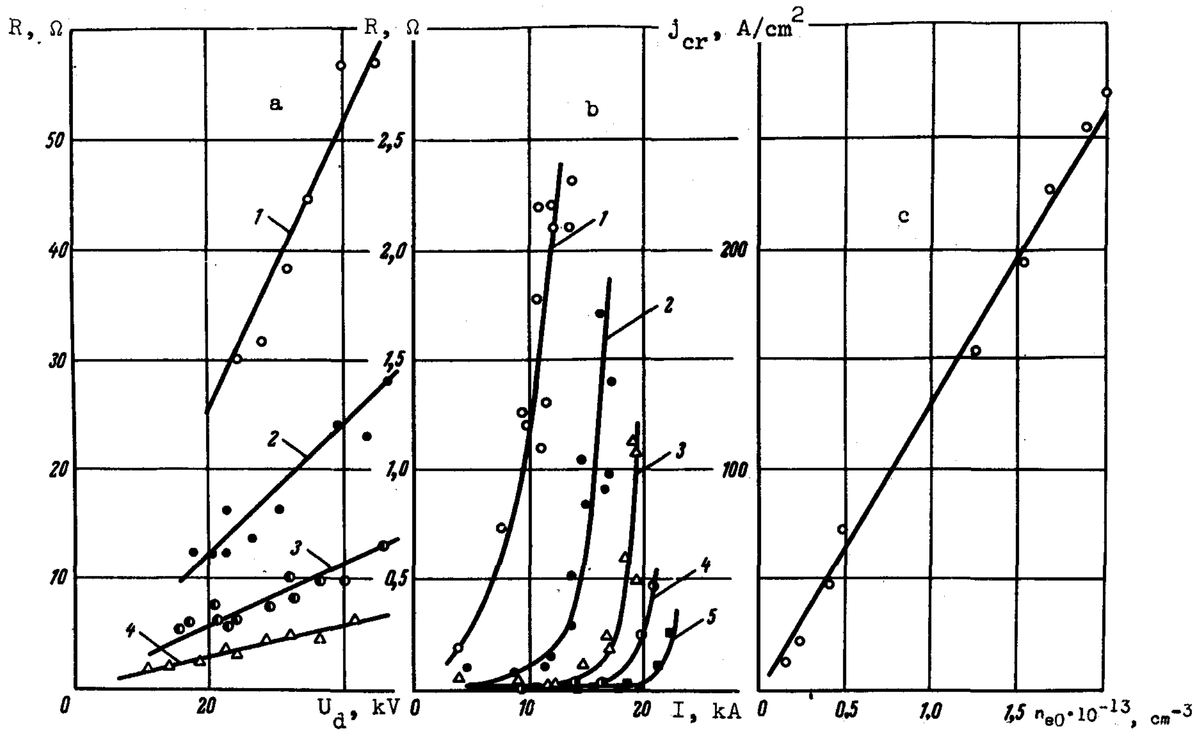

Fig.1. a) Plasma resistance R vs. discharge voltage U_d at instant of instability excitation (aperiodic regime): 1 - 1.5×10^{12} cm^{-3}, 2 - 2.5×10^{12} cm^{-3}, 3 - 4.0×10^{12} cm^{-3}, 4 - 5×10^{12} cm^{-3}. b) Plasma resistance R vs. discharge current amplitude I (oscillatory regime): 1 - 1.2×10^{13} cm^{-3}, 2 - 1.5×10^{13} cm^{-3}, 3 - 1.7×10^{13} cm^{-3}, 4 - 1.9×10^{13} cm^{-3}, 5 - 2.0 x 10^{13} cm^{-3}. c)Critical current density j_{cr} vs. plasma density n_{eo}. Hydrogen, homogeneous magnetic field, H_0 = 600 Oe; distance between reticular electrodes for the presented curves, L = 5 and L = 28 cm.

instability is excited, the current amplitude is limited to a definite critical value and the corresponding critical current density does not depend on the voltage applied to the plasma.

At higher plasma densities $n_{e0} > 1 \times 10^{13}$ cm^{-3} the plasma resistance R is much smaller than Z_{wave} (oscillatory discharge), and the adjustable parameter in the discharge, besides n_{e0}, is the discharge-current amplitude I. When I increases (by increase of U_0), a limitation of I and interruption of the discharge current are observed. Figure 1b can be used to trace the appearance of anomalous resistance in the plasma at a definite current density j_{cr}. The data of curves 1a and 1b, recalculated in terms of the critical current density j_{cr} and its dependence on n_{e0}, are shown in Fig. 1b. The critical drift velocity at which instability is excited is approximately 2 eV and agrees well with the thermal energy of the electrons of the gas-discharge plasma. The linear dependence of j_{cr} on n_{e0} in the aperiodic and in the oscillatory regimes indicates that the observed instability has the same physical natures in the different regimes.

The density of the electron beam formed when the discharge current is interrupted agrees with the density of the gas-discharge current, and the energy of the electrons in the beam is in good agreement with the voltage U_d applied to the plasma. When the discharge voltage U_d and the current in the discharge I are changed, a change takes place also in the intensity of the x-ray flash J_x from the target introduced into the region of beam propagation (Fig. 2). Points 1 and 2 of Fig. 2 have an absolute calibration of the x-ray itensity, for the determination of the enefgy and current density of thebeam electrons. Point 1 was calibrated by the photographic-dosimetry method. The method of absorption in aluminum foils was used to determine the energy of the x-rays, 9.0 ± 1.0 keV at $\overline{U}_d$ equal to 24 kV. Comparison with the density of a film produced by irradiation with an x-ray tube on which the voltage was maintained equal to $\overline{U}_d$ has shown that the density of the current of accelerated electrons to the target amounts for point 1 to 125 A/cm^2 at a total discharge current I = 8.3 kA, a current density in the discharge ∿100 A/cm^2, and $\overline{U}_d$ = 24 kV. The second point 2 (Fig. 2) was calibrated against the x-ray intensity J_x measured with a photomultiplier. The light yield of the plastic scintillator was determined for three gamma lines: 122 and 14.4 keV of Fe^{57} and 23.8 keV of Sn^{119}.

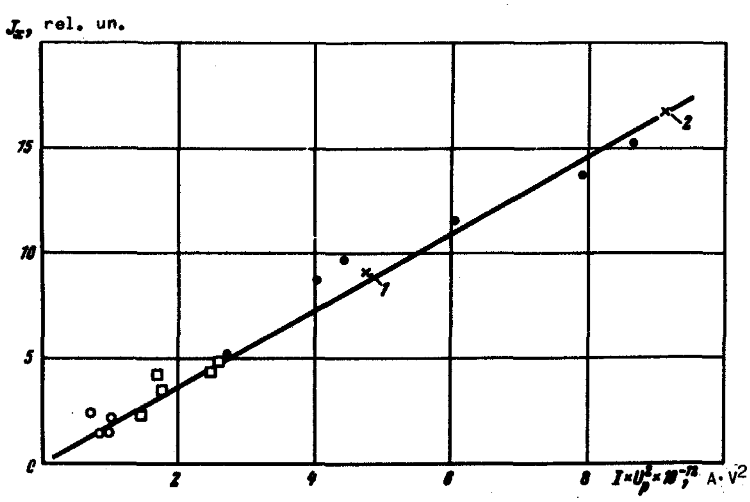

Fig. 2. Intensity of bremsstrahlung x-rays J_x from target vs. product of total discharge current I (ampleres) and square of the voltage U_d (volts) at instant of x-ray flash: o - U_0 = 22 kV, □ - 33 kV, ● - 45 kV. Hydrogen, plasma density n_{e0} varied from 3×10^{12} to 1.8×10^{13} cm^{-3}, uniform magnetic field, H_0 = 600 Oe.

The maximum value of U_d was used in the calculation of the beam-current density. The density of the beam current to the target was 110 A/cm^2 at the discharge parameters I = 10.5 kA. $\overline{U}_d$ = 29.5 ± 1.5 keV, and j_{disch} = 130 A/cm^2; the effective x-radiation intensity, measured with a photomultiplier and determined from the half-absorption layers, was 10.5 ± 1.5 keV.

The agreement between the results of two different methods of absolute calibration of a stream of accelerated electrons, and the good agreement between these data and those obtained with thermal probes [1], give grounds for stating that the entire energy dissipated by the anomalous discharge resistance goes to acceleration of the electrons, and is carried out through the anode by beams of accelerated electrons. Thus, in a straight discharge, when n_{e0} changes from 1 x 10^{12} to 2.5 x 10^{13} cm^{-3} there is excited a current instability at an electron drift velocity close to the thermal velocity. The result of the development of this instability is an interruption of the discharge current and a transition into a regime wherein the entire current discharge is transported by accelerated electrons with energy close to the active voltage drop across the discharge gap. An appreciable fraction of the energy of the discharge circuit (20 - 80%) is consumed during a short time interval, 0.2 - 1.5 μsec in the production of a powerful pulsed electron beam. The threshold of this instability agrees with the calculations of Buneman [2], but the result of its development and the processes of energy dissipation and current transport agree more readily with the hypothesis of B. B. Kadomtsev [3] that the effective density of the carriers in the plasma is decreased. Ion-acoustic instability cannot explain the observed anomalous resistance, since the electric field in the plasma exceeds the critical field of Field and Fried [4]. An instability of the interruption type is observed also in the discharge current in toroidal system (see the bibliography in [1]).

It is very important to observe such an instability at much higher plasma densities in discharges of the plasma-focus type [5, 6]. As shown by experiment [5, 6], the energy in these discharges is also transformed with very high efficiency (20 - 30%) into the energy of a beam of accelerated electrons that transport the entire discharge current. One cannot therefore exclude the possibility that in these systems the ions and electrons of the plasma are heated by the beam, and that this heating plays a decisive role in the energy balance of the heated plasma and makes a large contribution to the effect of subsequent production of the flash of neutron radiation.

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