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ACCELERATION OF IONS IN ELECTRON BEAMS

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The process of acceleration of ions in electron beams was observed in 1960 in experiments on the formation of ion [1] and electron beams from vacuum-spark plasma.

A schematic diagram of the experiments is shown in Fig. 1. Plasma from a spark source [2] (1) proceeds through the emission aperture (2) into the accelerating gap ℓ. An alternating or constant (electron-accelerating) voltage V is applied to the gap. At the instant when the voltage is turned on there may be no plasma in the gap; the plasma may also fill the gap fully or in part. The ion acceleration develops when the electron current is unstable. The gist of the phenomenon is that at the instant when the electron current is interrupted a certain number of plasma ions is accelerated in the direction of motion of the electron beam, i.e., in opposition to the externally applied potential difference. The acceleration is effected in the gap ℓ and in the electrode cavity (3) by the self-consistent fields. The ion energies increase with V and can exceed eV by 10 - 100 times. In particular, at V = 200 - 300 kV we obtained protons with energy up to 4 - 5 MeV and carbon ions with energy up to 15-20 MeV. The average number of accelerated protons or deuterons reached 10^{11} - 10^{12} per pulse.

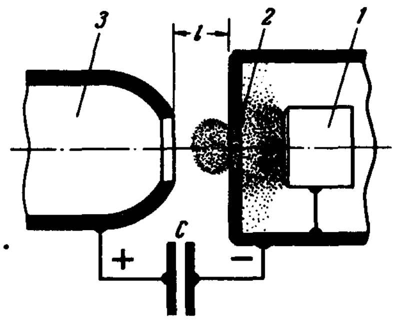

Fig. 1. Schematic diagram of experiment.

It follows from the mass spectrograms of the ions (parabola method) that the averaged energy spectrum of the ions is quite broad (Fig. 2). The maximum ion energies do not depend on the multiplicity of the charge.

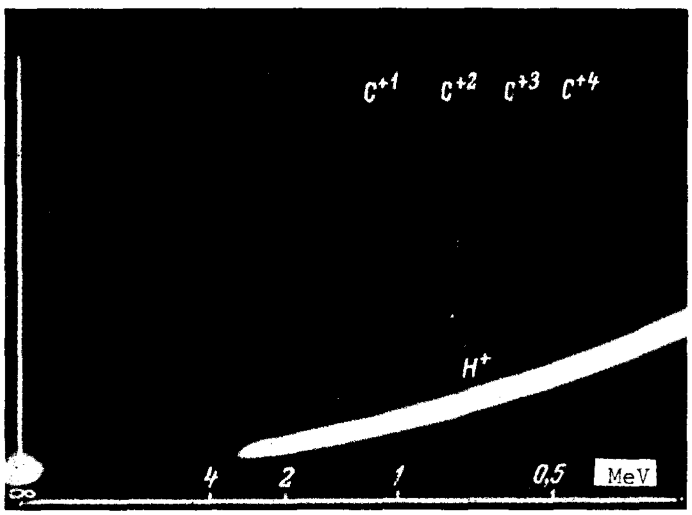

Fig. 2. Mass spectrogram of ions accelerated in electron beam. The indicated energy scale pertains to protons.

Heavy ions (Mg, Cd, etc.) are accelerated in electron beams by using vacuum arcs [3] as the plasma sources. The acceleration process is repeated in this case at the same frequency as the relaxations of the electron current in the nonstationary mode [4]. Relaxation oscillations of this kind were observed also in electron-current separation with a duo-plasmatron.*

The mechanism of ion acceleration in electron beams is not sufficiently understood. The high values of the internal ion-accelerating fields, up to $10^5 - 10^6$ V/cm (for sparks), points to the development of strong collective interactions. This is also evidenced by the smearing of the electron-beam energy and the excitation of a broad oscillation spectrum. The waves that are generated thereby can accelerate the ions.

The experimentally observed energies and numbers of accelerated ions can be explained by starting from the coherent-acceleration mechanism proposed by the late V. I. Veksler [5,6]. The real ion-acceleration picture, however, is more complicated and its elucidation calls for additional experiments.

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PLASMA GAS TEMPERATURES IN THE DISCHARGES USED FOR CO_2 LASERS

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The main physical processes that lead to population inversion and generation in CO_2 lasers were established in [1,2]. However, a quantitative analysis of the phenomena occurring in the discharges used for CO_2 lasers is greatly hindered by the almost complete lack of data on the composition of the plasma and on the temperatures of the components. In particular, there is no information on the gas temperature T_2. Yet the experimental data on the dependence of the generation power on the discharge-tube wall temperature clearly points to the noticeable influence of the gas temperature [3]. The same conclusion follows also from the dedection made in [2] that vibrational relaxation plays a decisive role in the establishment of population inversion between the CO_2 levels. The rate of vibrational relaxation depends in turn on T_2.

The present communication is devoted to the result of an investigation of the dependence of T_2 on different parameters of the discharges used for CO_2 lasers. The experiments were made with a continuous flow of the gas mixtures, at velocities up to 1 m/sec. T_2 was measured by