Production of heavy ions with $Z > 20$

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The emission of multiply charged ($Z > 20$) heavy ($M > 100$ amu) ions from a laser-initiated high-current low-inductance discharge plasma has been detected for the first time.

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A number of papers have reported the discovery, in the vicinity of the discharge column of a low-inductance plasma diode, of "plasma points" with dimensions ranging from a few microns to tens of microns, having an electron temperature $T \sim 10$ keV

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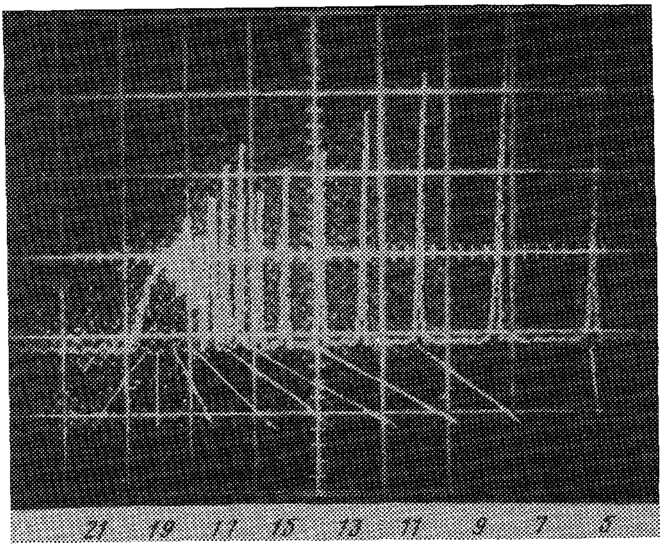

FIG. 1. Ion signal oscillogram. Sweep is 5 μsec/div ($Z = 5-21$).

and a density $n \sim (10^{20} - 10^{21})$ cm^{-3}, which are sources of radiation of the spectral lines of helium- and hydrogen-like ions for elements of the iron group.[1,2] The lifetime of the "plasma points" ($\tau \sim 10^{-9}$ sec) as well as the parameter $n\tau \sim 10^{12}$ cm^{-3}·sec were estimated.[3] The detection of hard x-radiation and microwave radiation from the dense plasma region has been reported. It is of interest to investigate the decay products of the high-temperature "plasma points."

The experimental apparatus consisted of a low-inductance condenser, connected directly to the electrodes located in a vacuum chamber. The discharge was initiated by a laser flash focused on one of the electrodes. The second electrode had a hole to permit free passage of the plasma toward the analyzing apparatus. The amplitude of the discharge current was 100 kA 1.5 μsec after start of the discharge. A time-of-flight mass spectrometer with a resolution of ~ 100 was used to analyze the ionic component. The number of impurity ions was reduced by making the electrodes from especially pure metals. The Z/M (Z, M are the ion charge and mass) values of the corresponding ion signals were measured, and the energy distributions of the observed ions were determined. This made it possible to guarantee the correctness of the investigation of the characteristics of the multiply charged ions of the decaying plasma.

By means of the described apparatus we detected the ions Sn^{+21}, Ta^{+22}, W^{+23}, Pb^{+25}, Bi^{+25}. The separation energies of the ions amounted to 300 keV. The number of ions in high charge states emitted per unit solid angle amounted to $10^{11} - 10^{12}$ particles per flash. Figures 1 and 2 show oscillograms of the signal of the W and Pb ions. In the investigation of the energy distributions of the ions with different charges we detected a shift of the maxima of the distributions toward higher energies as the charge state of the ions increased. It is important to note that this phenomenon of the emission of heavy multiply charged ions from the hot plasma region of a low-inductance discharge can find application in accelerator technology and also in the formation of the high-power ion beams required for pulsed plasma heating in thermonuclear devices.

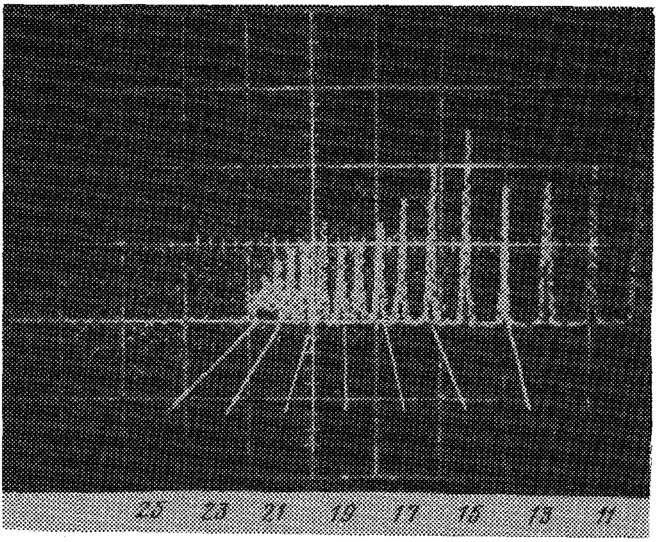

FIG. 2. Ion signal oscillogram. Sweep is 2 μsec/div ($Z = 10 - 25$).

We also investigated the plasma parameters and obtained results close to those given in the above-cited investigations. Figure 3 shows a picture of a plasma jet, containing W ions, taken by a pinhole camera using x-rays with a photon energy greater than 0.8 keV.

Thus, in this work we have detected in plasma devices for the first time the emissions of heavy ($M > 100$ amu) ions with $Z > 20$ and have also detected an increase in the ion charge with an increase in mass, which can apparently be explained by the more efficient ionization during the slower dispersion of the plasma cloud as the mass of the ions increases. The experimentally detected ion emission attests to an ion "quenching" effect during the decay of the high-temperature plasma points of a low-inductance discharge, i.e., a recombination-less dispersion of the plasma bunch in vacuum.

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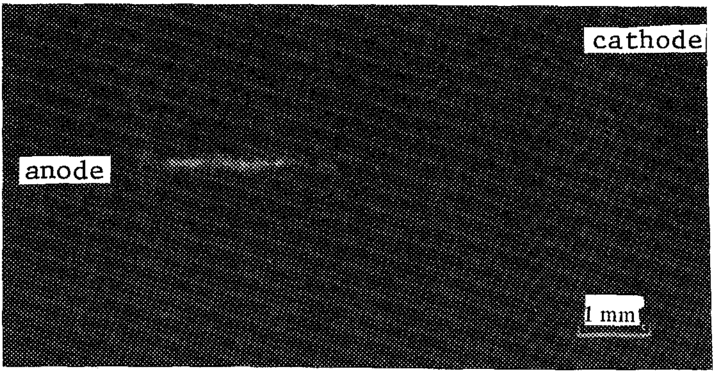

FIG. 3. Pinhole camera recording of plasma jet.

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[3]E. Ya. Kononov, K.N. Koshelev and Yu. V. Sidel'nikov, Fiz. Plazmy **3**, 663 (1977) [Sov. J. Plasma Phys. **3**, 375 (1977)].