indices). Three intense lines whose frequencies are 628, 714, and 781 cm^{-1} and are independent of the scattering angle, correspond to scattering of light by nonpolar vibration of the lattice of symmetry A [2]. The line whose frequency depends on the scattering angle corresponds to scattering of light by a polar lattice vibration for which $\nu_{LO} = 778.5\ cm^{-1}$ and $\nu_{TO} = 736.5\ cm^{-1}$ [2], and the Raman-scattering tensor is of the form $B(Y) = \begin{pmatrix} 0 & 0 & a \\ 0 & 0 & 0 \\ a & 0 & 0 \end{pmatrix}$. Thus, in the case of forward scattering ($\phi = 0°$) one observes light scattering by longitudinal optical phonons. It is seen from the figure that when the scattering angle ϕ varies from 0 to 6° in the YX plane, the angle ψ between the optical-phonon wave vector and the crystallographic axis Y varies from 0 to 72.6°, and the frequency of the optical photon from which the scattering takes place changes from $\nu_{LO} \approx 776$ to $\nu_{LO,TO} \approx 745\ cm^{-1}$. These results are in good agreement with the results obtained by observing Raman scattering of light at 90° [2]. We note that owing to the large birefringence, the wave vector of the phonon at the given scattering geometry amounts to $\sim 10^4\ cm^{-1}$. At such values of the phonon wave vector, the polariton effect makes a negligible contribution to the change of the frequency of scattered light.

It is also seen from the figure that the scattered-radiation line, whose frequency depends on the scattering angle, experiences a "break" near the frequency $\nu' \approx 756\ cm^{-1}$ (at $\phi \approx 3°$). We attribute this "break" to the existence of an optical phonon, of frequency ν', which is very weak in Raman scattering and in infrared absorption, and which interacts strongly with the phonon observed by us in the scattering, in the region of the crossing of their branches. This results in an energy gap (lifting of the degeneracy owing to resonant interaction) and an interchange of the intensities of the light scattered by the strong and weak phonons.

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PRODUCTION OF C AND Al NUCLEI IN A LASER SOURCE OF MULTIPLY-CHARGED IONS

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1. The ionization of atoms in a high-temperature laser plasma is a promising method from the point of view of obtaining multiply-charged ions and their use in accelerator injectors[1)] [1]. Ions with $z > 20$ have already been obtained in a laser plasma [2]. In connection with the realized acceleration of deuterium nuclei in a proton synchrotron [3], the need for obtaining fully ionized atoms with a ratio $A/z = 2$ has already been mentioned in the literature. Acceleration of nuclei of the elements from D to Ca in a proton synchrotron makes it

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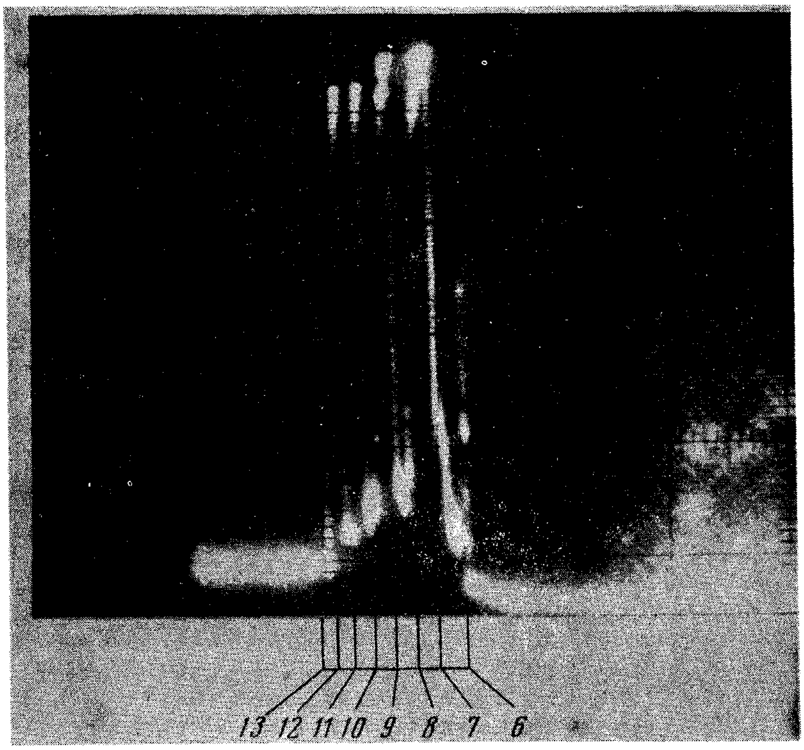
1) Author's certificate (patent) No. 324938, disclosure No. 1337085/26-25 of 8 July 1969, by Yu.A. Bykovskii, Yu.P. Kozyrev, S.V. Ryzhikh, S.M. Sil'nov, V.F. Elesin, and V.I. Dymovich.

Fig. 1. Oscillogram of aluminum ion pulses.



possible not only to increase the energies of the particles at the proton-synchrotron output by z times (compared with protons), but uncovers in principle new possibilities for research in nuclear physics [4].

Earlier investigations [5] have shown that the characteristics of ion emission of multiply-charged ions of a laser plasma are extremely favorable for the introduction of the ions into a linear accelerator (proton-synchrotron injector) because the emission angle of the multiply charged ions decreases with increasing charge number and can amount to only several degrees. To calculate and design an ion source one must also have data on the energy spectra, the relative number, and the total number of ions emitted with a given z.

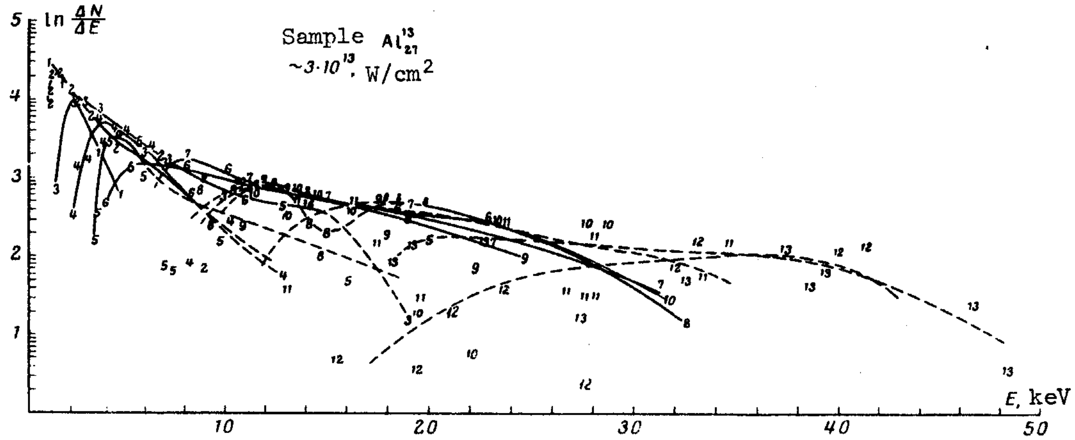


Fig. 2. Energy distributions of aluminum ions.

In the present study[2)] we obtained fully ionized C_{12}^{+6} and Al_{27}^{+13} atoms, investigated their energy spectra and charge characteristics, and estimated the integral number of ions emitted to a target heated by focused laser radiation with a flux density (3 - 5) × 10^{13} W/cm^2.

2. The procedure used to obtain and investigate a laser plasma using time-of-flight mass spectrometry is described in a number of papers [6]. Aluminum and carbon targets were irradiated by a laser system consisting of a neodymium laser and three amplifiers. The pulse duration was 10 - 15 nsec, and the energy 50 - 70 J. The light was focused on the target surface with a lens of focal length 7 cm. The ion-current and receiver signals were time-scanned on the screen of a long-persistence two-beam oscilloscope (SI-42).

A typical oscillogram of the Al ion signal is shown in Fig. 1. The high-charge ions Al^{+11}, $^{+12}$, $^{+13}$ are well resolved by our apparatus.

Figure 2 shows the energy spectra of aluminum and carbon, plotted from oscillograms similar to that in Fig. 1.

The energy interval occupied by the Al^{+13} nuclei corresponds to values from 18 to 30 keV.

An important characteristic of the energy spectra are the positions of the distribution maxima. Figure 3 illustrates the energy positions of these maxima and the half-heights as functions of z. With increasing z, the maxima of the distribution shift monotonically into the region of high energies. A comparison of such plots for Al and C (at equal ion charges) shows that the ion energy ratio is approximately equal to 2.

Figure 4 shows a plot of the number of ions N = f(z) with different charges, registered within the aperture solid angle ~5 × 10^{-7} rad of the experimental setup. An estimate of the number of Al_{27}^{+13} ions, based on the experimental data, yields a value ~10^6; the number of registered singly-charged ions is larger by one order of magnitude.

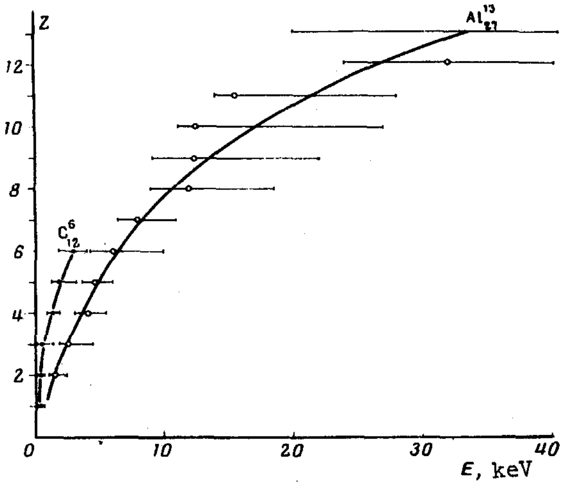


Fig. 3

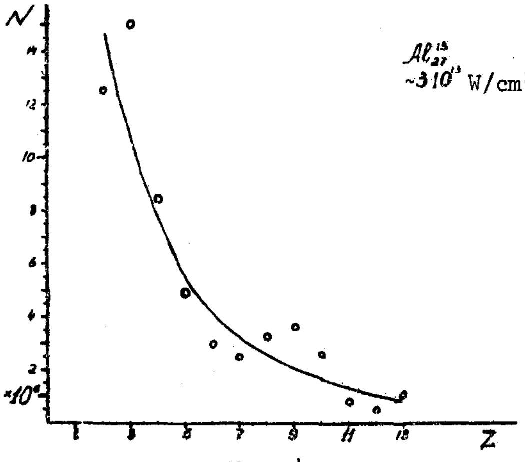


Fig. 4

Fig. 3. Positions of energy maxima of multiply-charged aluminum and carbon ions.

Fig. 4. Plot of the number of aluminum ions.

[2)] The results were reported at the Second All-union Conference on the Physics of the Effect of Optical Radiation on Condensed Media, Leningrad, April 1972.

The measurement results agree with those of [7], in which it is reported that Al_{27}^{+11} ions with 15 keV energy were obtained, and that their number was smaller by two orders of magnitude than the number of singly-charged ions at an approximate laser radiation flux density 2×10^{12} W/cm^2.

Assuming that the ions with $z = 1$ are emitted mainly isotropically [8], we find that $\sim 10^{14}$ ions are emitted by the plasma. At the same time, the number of atoms ejected from the target is 10^{18} (estimated from the volume of the produced crater). The relative yield of the ion emission is thus $\sim 10^{-4}$. This is in satisfactory agreement with the ion emission estimated in [9]. Recalculation in terms of the total emission angle shows that the lower limit of the number of Al_{27}^{+13} ions is $10^9 - 10^{10}$ per laser pulse. This number of bare Al_{27}^{+13} nuclei can be greatly increased by using more powerful lasers [10].

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NEW CW CRYSTAL LASERS

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Searches for new active crystalline media for high-power cw lasers have recently acquired a particular importance. This is fully evidenced by the

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1) This work was performed in collaboration with members of the Crystallography Institute of the USSR Academy of Sciences, the Institute of General and Inorganic Chemistry of the Siberian Division of the USSR Academy of Sciences, the Physics Research Institute of the Armenian Academy of Sciences, and the M.D. Mendeleev Moscow Chemical Technology Institute.