PRODUCTION OF SPECTRA OF MULTIPLY CHARGED IONS BY FOCUSING LASER RADIATION ON A SOLID TARGET

N. G. Basov, V. A. Boiko, Yu. P. Voinov, E. Ya. Kononov, S. L. Mandel'shtam, and G. V. Sklizkov
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 21 December 1966
ZhETF Pis'ma 5, No. 6, 177-180, 15 March 1967

When the radiation from a Q-switched laser is focused on the surface of a solid target, a dense high-temperature plasma of the target material is produced. When such a plasma is scattered, ions are registered with energy of several kV [1,2]. As shown in [3], the radiation from such a plasma contains lines of multiply ionized atoms. We present in this communication some results of an investigation of such a plasmoid.

The flash of a neodymium-glass laser was focused by a lens (F = 100 mm) on a target placed in vacuum $\sim 10^{-5}$ mm Hg. The laser consisted of a generator controlled by a Kerr cell and two amplifiers. The total length of the neodymium rods (15 mm dia) was 720 mm. A second Kerr cell was placed between the generator and the amplifier to sharpen the leading front of the pulse to 4 nsec. The pulse duration at half-height was 15 nsec at an energy of 10 J.

The plasma scattering was recorded by photographing its glow with a high-speed camera. The scattering velocity, using an aluminum target, was $\sim 10^7$ cm/sec, corresponding to an aluminum ion energy of ~1000 eV at the edge of the plasma. According to shadow-method measurements, the plasma dimension in a laser beam is ~1.5 mm at the end of the pulse. The estimated density of the heated plasma, averaged over the volume, estimated from the absorption coefficient of the laser emission under the assumption that the thermal energy is comparable in order of magnitude with the laser-emission pulse energy, is $N_e \sim 10^{20}$.

The plasmoid radiation in the vacuum-ultraviolet region of the spectrum (40 - 2000 Å) was registered with a DFS-6 spectrograph in a direction perpendicular to the laser beam. When an aluminum target was used, the resultant spectrum contained the lines Al VI - Al XI. The resonance lines Al XII lie below 10 Å and could not be registered by our instrument. To study the localization of the plasma radiation, the spectrograph slit was limited in height to 0.5 mm. It was established from the distribution of the photographic density along the lines on the spectrogram that the ions with the highest multiplicities emit from a region measuring 1 - 2 mm, whereas the region of the glow of the lines Al VIII - Al VI is somewhat larger.

To investigate the possibilities of a spectral source of this type, we chose metallic calcium as the second target. The spectrum of multiply ionized calcium atoms is of great interest in astrophysics, especially for the interpretation of solar-radiation spectrograms obtained in the ultraviolet region with satellites and rockets [4-6]. So far, only two Ca XII lines and two weak Ca XIII lines were registered under laboratory conditions, when a vacuum spark was used as the spectral source [4,7].

Ion	λ, Å	Intensity	Transition
Ca XII	141.036*	10	$2s^2 2p^5\ {}^2P^0_{3/2} - 2s\,2p^6\ {}^2S_{1/2}$
	147.273*	9	${}^2P^0_{1/2} - {}^2S_{1/2}$
Ca XIII	131.23	9	$2s^2 2p^4\ {}^1D_2 - 2s\,2p^5\ {}^1P^0_1$
	148.84	1	${}^1S_0 - {}^1P^0_1$
	156.70	5	${}^3P_2 - {}^3P^0_1$
	159.87	3	${}^3P_1 - {}^3P^0_0$
	161.748*	8	${}^3P_2 - {}^3P^0_2$
	162.98	1	${}^3P_1 - {}^3P^0_1$
	164.15	2	${}^3P_0 - {}^3P^0_1$
	168.412*	5	${}^3P_1 - {}^3P^0_2$
Ca XIV	128.25	0	$2s^2 2p^3\ {}^2D^0_{3/2} - 2s\,2p^4\ {}^2P_{1/2}$
	132.95	00	${}^2D^0_{3/2} - {}^2P_{3/2}$
	134.31	3	${}^2D^0_{5/2} - {}^2P_{3/2}$
	148.11	0	${}^2P^0_{3/2} - {}^2P_{3/2}$

* Identified by Edlen [4].

In our experiment we obtained a spectrogram containing Ca X lines, the already mentioned Ca XII and Ca XIII lines, and a number of new Ca XIII and Ca XIV. The Ca XI lines lie outside the observation region. The measured wavelengths and the identifications are listed in the table. The wavelength standards were the Ca X lines measured by Edlen [8]. The identification of the previously unknown Ca XIII and Ca XIV lines was by extrapolating along the isoelectronic series OI and NI. The two lines $\lambda = 148.84$ Å and $\lambda = 148.11$ Å were identified with a certain indeterminacy, since their extrapolated values are close to each other and lie within the limits of the error arising in the extrapolation process. The wavelength measurement accuracy is ±0.05 Å.

A very rough estimate of the plasma electron temperature can be obtained by using the values of the ionization potentials of the observed ions. Taking into account the foregoing measured values of Ne, we can show that the so-called coronal approximation [9] is applicable in the distribution of the atoms over the degrees of ionization, if it is assumed that the electrons have a Maxwellian energy distribution:

$$\frac{n_{i+1}}{n_i} \approx \frac{7{,}4\cdot 10^8 \exp E\left(\frac{\chi_i}{T_e}\right)}{T_e^2 \left(\frac{\chi_i}{T_e}\right)^3},$$

where T_e and χ_i are in eV.

Assuming $\chi_i = 728.8$ eV for Ca XIII, we obtain $T_e \sim 130$ eV for $n_{\text{Ca XIV}}/n_{\text{Ca XIII}} \approx 1$.

In conclusion, the authors are deeply grateful to O. N. Krokhin and I. L. Beigman for a discussion of the results.

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GENERATION OF ULTRASHORT LIGHT PULSES WITH A GaAs SEMICONDUCTOR LASER

Yu. A. Drozhbin, Yu. P. Zakharov, V. V. Nikitin, A. S. Semenov, and V. A. Yakovlev
P. N. Lebedev Physics Institute, USSR Academy of Sciences
Submitted 25 December 1966
ZhETF Pis'ma 5, No. 6, 180-183, 15 March 1967

In the course of an investigation of the dependence of the time characteristics of a GaAs semiconductor laser on the injection current through the p-n junction, it was established