ABSORPTION SPECTRA OF LIGHT IONS IN THE EXTREME ULTRAVIOLET

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We have used the method of two laser produced plasmas (Jannitti et al. 1984a) to measure the absorption spectra of the ions Be^{++} (Jannitti et al. 1984b), Be^{+} (Jannitti et al. 1984c) and B^{+} in the grazing incidence and normal incidence region. Both discrete and continua transitions have been measured and values of the photoionization cross sections are derived.

The experimental set up referring to the normal incidence investigation is shown in Fig. 1. A laser beam of 10 J of energy and 15 ns (FWHM) duration is split in two parts and generates two plasmas: one on target T of high atomic number (Cu) used as a background continuum emitting source and a second on target A for producing the absorbing species to be studied. For the latter a sphero-cylindrical lens is used producing a focal spot 100 μm wide and up to 10 mm long. The continuum radiation produced on a target tilted 45° both with respect to the laser beam and to the axis of observation was collected by a toroidal mirror whose radii of curvature, R = 640 mm in the plane of incidence and ρ = 530 mm in the plane perpendicular to the former are such to compensate the astigmatism of the 2 m radius grating.

On the focal surface of the spectrograph a movable trolley carries a plate, coated with $\approx$ 1 mg/cm^2 of scintillator (TPB). The latter is imaged outside the vacuum with two high speed objectives (N.A. = 0.75) on an intensified photodiode array (512 elements) connected to an optical multichannel analyzer (OMA). In between the objectives a filter selects only the radiation emitted by the scintillator. The output of the OMA is sent to a PDP 11 computer for further data processing. A sequence for acquiring the absorption coefficient $k(\lambda)$ is:

1) acquisition of $I_o(\lambda)$, the spectrum of the background source;
2) acquisition in the same condition of the stray light $I_s(\lambda)$ by moving the stigmatic spectrum out of position;
3) acquisition of $I(\lambda)$, the absorption spectrum with both plasmas;
4) acquisition of the emission spectrum $I_e(\lambda)$ by producing the absorbing plasma alone. Then $k(\lambda)=\ln \left\{ I_o(\lambda)-I_s(\lambda) \right\} / \left\{ I(\lambda)-I_s(\lambda)-I_e(\lambda) \right\}$; from 10 to 30 complete sequences were acquired for any spectral position ≅100 Å wide.

Several of such portions were later cumulated together and joined.

Fig. 2 shows the absorption spectrum of B^{+} in the region 450-1380 Å, recorded at 1.5 mm distance from the target. All of the main transitions in the normal spectrum and several of the displaced one are present with several newly observed lines (Ölme, 1970). Clearly visible are the jumps

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corresponding to the photoionization of a $p(2p \rightarrow \varepsilon d)$ and $s(2s \rightarrow \varepsilon p)$ electron. The region below 450 Å has not been measured because of the lack of reflectivity of the present system (toroidal mirror and grating). Only a minor contribution is present in the spectrum of Fig. 2 from the ion B^{++} and none from neutral boron indicating the selectivity of the present technique.

The region around the $2p \rightarrow \varepsilon d$ limit is shown enlarged in Fig. 3. Here the experimental data are indicated with dashes and refer to a distance from the target of 1 mm. It comprises also few 2p-ns lines. The true absorption coefficient of the series 2p-nd has been derived with the method explained by Jannitti et al. (1984b,c). Briefly a syntetic spectrum, consisting of a series of Voigt profiles simulating the true absorption spectrum, shown with dotted lines in Fig. 3, is convoluted with the instrumental function yielding a model absorption spectrum (solid line in Fig. 3) that is compared with the experimental one. The instrumental function has been carefully determined recording the absorption from a narrow line. A best-fit process is carried on with free parameters the normalized Voigt profiles $\phi_i(\lambda)$ that mainly affect the width of the lines and the line density: $\int n(^3P)d\ell$ where $n(^3P)$ is the density in the $2s2p\ ^3P^\circ$ state and the integral is taken along the plasma length ℓ, that determines the peak value of the absorption coefficient $k(\lambda_o)$ at the centre of the line profile λ_o. The fit obtained is quite good despite the fact that there is nearly a factor of two distortion in the measured absorption coefficient on the 2p-5d and 2p-6d lines due to the instrumental function. The relative values of the oscillator strengths both for discrete and continuous transition can now be determined. Unfortunately no measurements of absolute f values exist for high n numbers 2p-nd lines. We have used the calculations by Markiewicz et al. (1981). The 2p-5d line is not well suited because of a merging with a strong B^{++} line, similarly the 2p-6d line is merged and perturbed by the $2s2p\ ^3P^\circ$-$2p3p\ ^3D$ line. Using the 7d and 8d lines we get: $\int n(^3P)d\ell = (8.2 \pm 0.5) \times 10^{16}\ cm^{-2}$ and $\sigma(2p \rightarrow \varepsilon d) = (4.2 \pm 0.4) \times 10^{-18}\ cm^2$.

Merging lines can be resolved moving further out from the target. At 1.5 mm the density of the plasma is lower and the lines are resolved. However the broadening of the lines is now comparable with the instrumental one and the convolution process becomes less precise. Fig. 4 shows the true absorption coefficient (solid line) for the same region as in Fig. 3 with the various components present (dotted lines as marked).

We conclude that the present technique is well suited for the measurement of relative f-values both for discrete and continuous transitions in ions.

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REFERENCES

Jannitti, E., Nicolosi, P. and Tondello, G. Physica, 124C, 139, 1984a.

Jannitti, E., Nicolosi, P. and Tondello, G. Opt. Commun., 50, 225, 1984b.

Jannitti, E., Mazzoni, M., Nicolosi, P., Tondello, G. and Yongchang, W., submitted to J.O.S.A. part B, 1984c.

Markiewicz, E., McEachran, R.P. and Cohen, M. Phys. Scripta, 23, 828, 1981.

Ölme, A. Phys. Scripta, 1, 256, 1970.

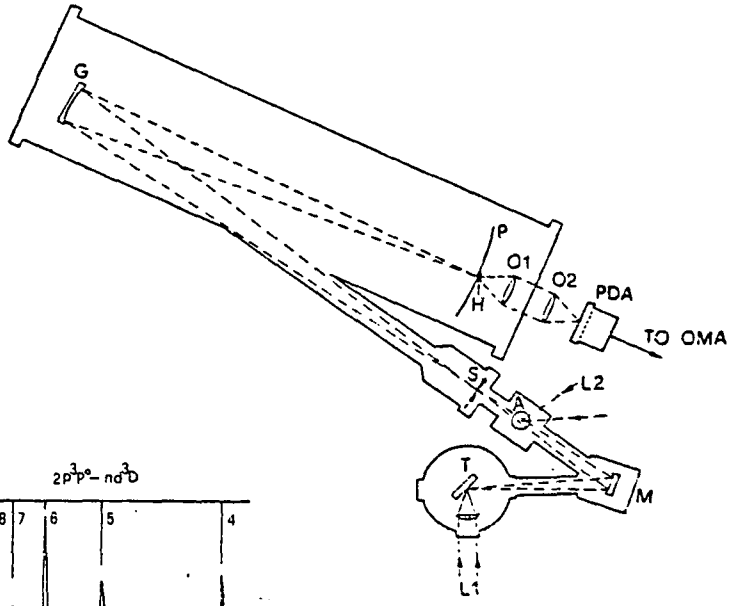

Fig. 1

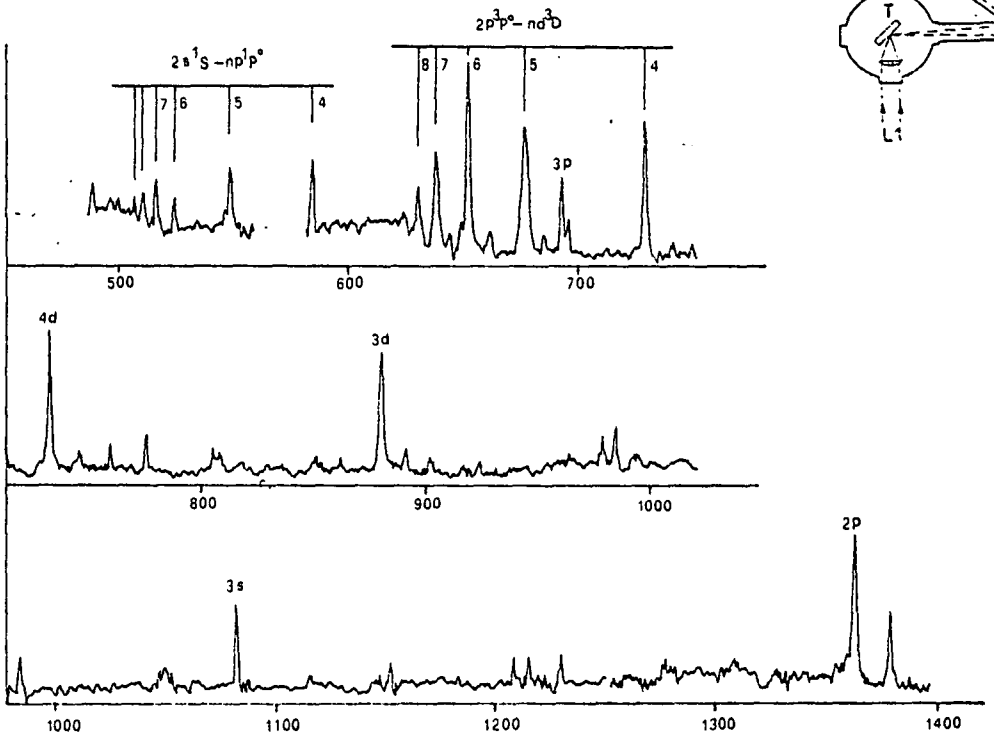

Fig. 2

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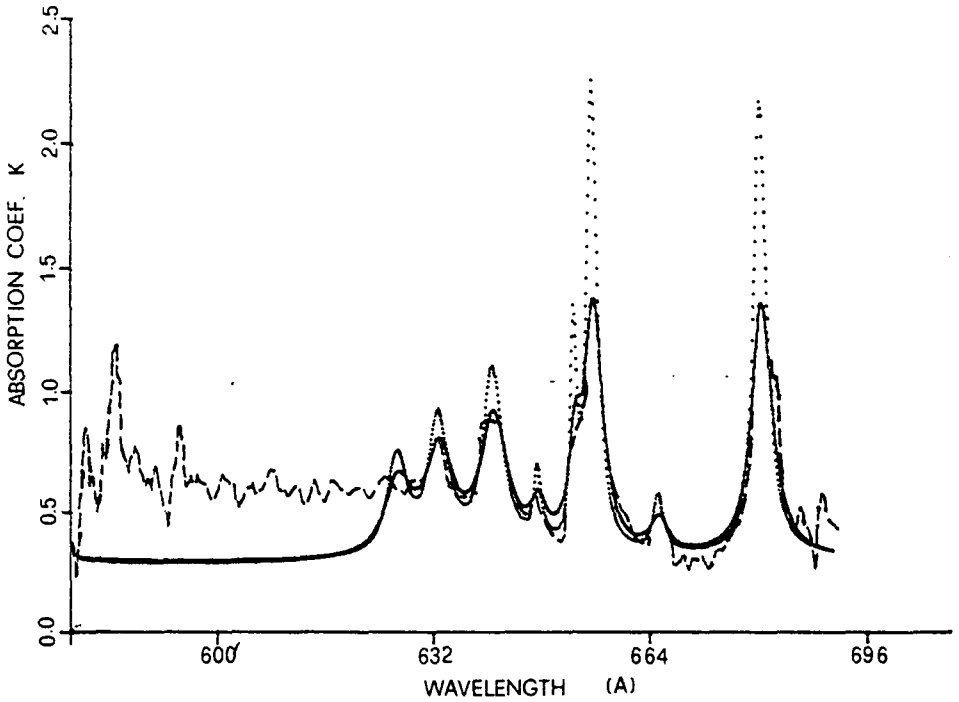

Fig. 3

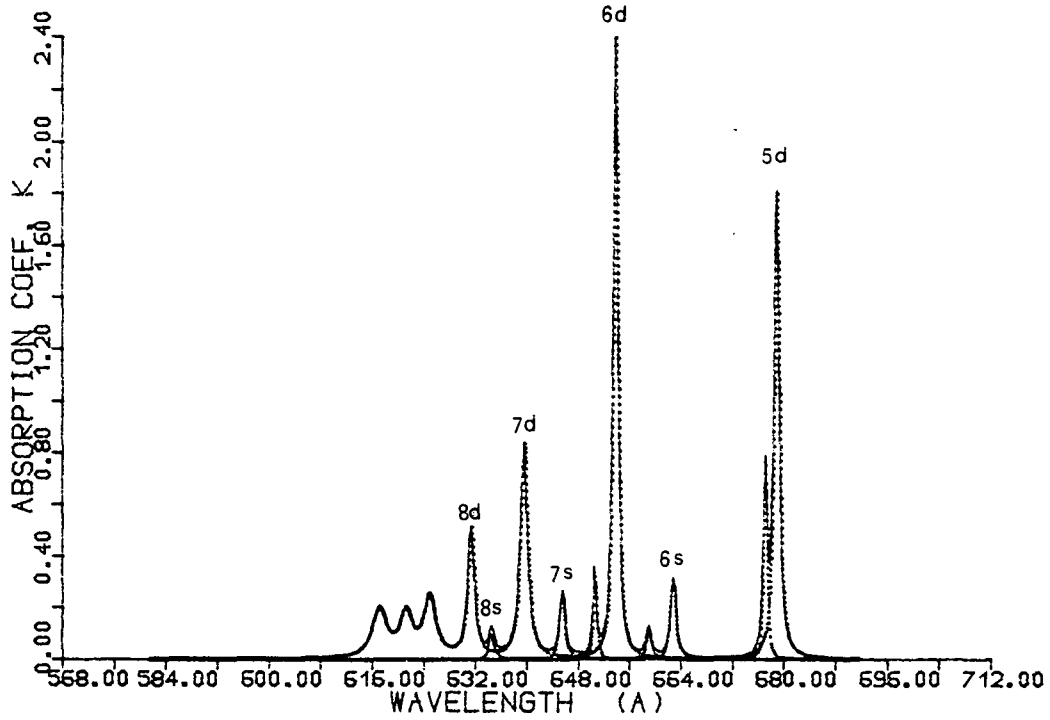

Fig. 4

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