ULTRAVIOLET ABSORPTION OF REFRACTORY ELEMENTS BY A DUAL LASER PLASMA METHOD

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ULTRAVIOLET ABSORPTION OF REFRACTORY ELEMENTS BY A DUAL LASER PLASMA METHOD

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Abstract - The dual laser-produced plasma technique for the study of ionic absorption spectra has been developed by the use of two Q-switched ruby lasers to enable independent generation of the absorbing and back-lighting plasmas. Optical pulse handling is used in the coupling cicuits to enable reproducible pulse delays from 250 nsec. to 10 msec. to be achieved. At delay times > 700 nsec. spectra of essentially pure neutral species are observed. The technique is valuable, not only for obtaining the neutral spectra of highly refractory and/or corrosive materials but also for studying behaviour of ionic species as a function of time. Typical spectra are shown in Fig. 1.

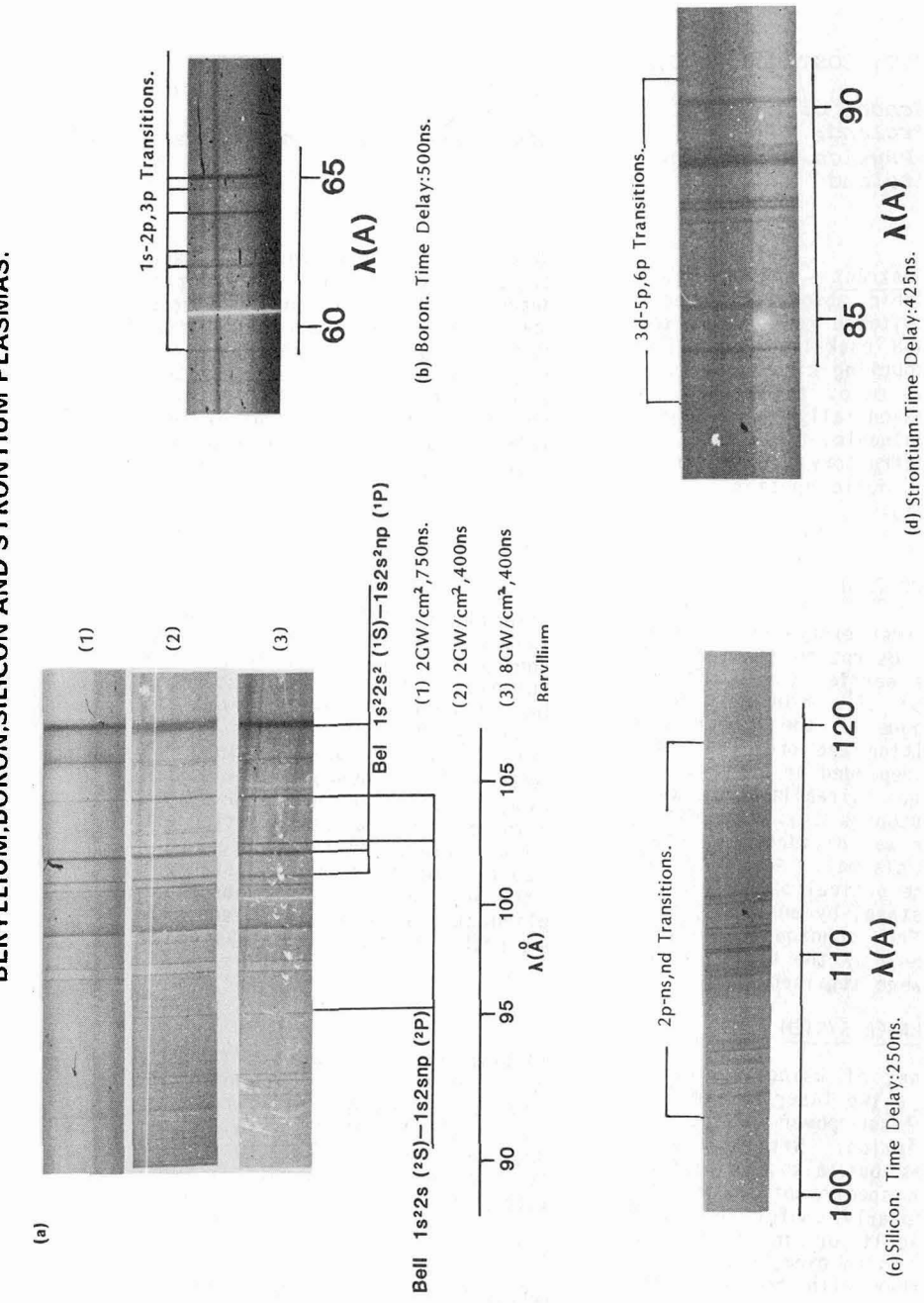
I - INTRODUCTION

The first experiment in which a laser-produced continuum was used to study the absorption spectra of ions generated in a second laser-produced plasma was carried out by Carroll and Kennedy (1) in 1977 to record the spectrum of Li^+. In this work the autoionizing $1s^2$ - 2snp resonances (the analogue of the Madden-Codling series of helium) were observed and their position and profiles compared with theory (2). The success of the technique depended on the availability of clean laser-produced continua (3) and on the suitability of the pulsed source for synchronized or time resolved studies (4). In the original experiment the output of a single ruby laser was divided by a beam splitter to produce both backlighting and absorbing plasma. A limited degree of time resolution was achieved by varying the optical path lengths and some control of the absorbing species, i.e. ion stage, by adjusting the focus of the beam generating the absorbing plasma. The technique has since been applied successfully to the spectrum of Be^+ where by the use of relatively long path lengths time delays up to 70 nsec. were attained (5).

II - TWO LASER SYSTEM

Instead of using a single laser and beam splitter we have recently developed a two laser system (6) which has the advantages of (a) delivering enhanced laser power on each target and (b) providing a greater range in time resolution. With the system it is possible not only to study various ion stages but also, by using suficiently long time delays, to observe absorption spectra of neutral species free from ionic contamination. This is particularly useful in studying refractory or corrosive elements which are difficult or impossible to obtain in vapour by more conventional methods. As an example we show in Fig. 2 the $5d\text{-}5,\varepsilon f$ giant resonance of UI (7) together with the theoretical profile as calculated by Wendin (8). Similar results were obtained for the analogous spectrum of atomic thorium which was observed in absorption for the first time with the new technique (6).

Fig 1. TIME-RESOLVED XUV ABSORPTION SPECTRA OF BERYLLIUM,BORON,SILICON AND STRONTIUM PLASMAS.



The experimental laser system is shown schematically in Fig 3. The two ruby lasers (not identical) are triggered so that the pumping pulses peak simultaneously, (they may be offset if delays > 1000 nsec. are required). Part of the Q-switched output pulse of the laser which generates the absorbing plasma is passed through a variable time delay circuit and used to activate the Pockels cell unit of the second laser. The output from both lasers is ∿1.5J in 25 nsec. and the repetition rate of the system as a whole is limited by the performance of the slower laser (∿ 1 ppm). Inter-plasma delay times, Δt, range from 250 nsec (our present *minimum* delay) to 10 msec. For the larger Δt values (> 1000 nsec.) an appropriate delay is introduced in the pumping pulses to ensure that maximum output is available at time of observation.

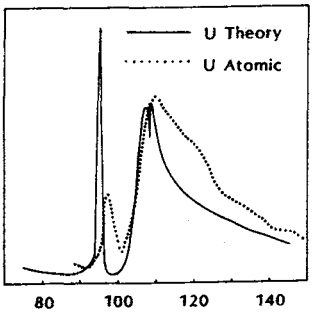


Fig. 2. Absorption of atomic uranium in the vicinity of the 5d threshold.

To improve the reliability of the original two laser system (6) the timing electronics have been redesigned to secure noise immunity. The current system uses a simplified trigger-pulse delay generator, fibre optic coupling for the flash-tube trigger pulses and a high speed optical trigger unit to activate the Pockels cell of the second laser. As a result a 100% reproducibility in shot to shot time delays has been achieved.

In Fig. 1 we show spectra, some new, to illustrate the capability of the system. In the case of beryllium, at a time delay of 400 nsec. absorption of Be^+ appears with our intensity comparable to that of the neutral [Fig. 1a (2,3)] whereas at Δt = 750 nsec. [Fig. 1a (1)] it is absent except for a trace of the 1s-2p transition which completely disappears at still longer delays. In early work (1) when only short time delays were available lower ion stages were favoured by defocusing the beam generating the absorbing plasma but with the new system tight focusing [Fig. 1 (3), Δt = 400 nsec.] may still be used; the crucial factor in reaching lower ion stages is the availability of longer time delays.

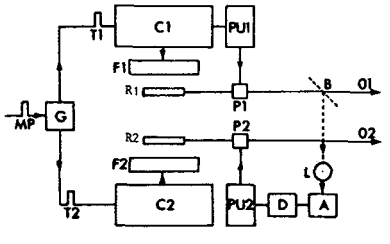


Fig. 3. Schematic diagram of the twin-laser system. MP-master trigger pulse; G-trigger pulse delay generator- T1/T2 flashtube trigger pulses; C1/C2-high voltage charge/Trigger circuits; F1/F2-flashlamps; R1/R2-ruby rods; P1/P2-Pockels cell; PU1/PU2-Pockels cell drive units; B-beam splitter; L/A-fibre-optically coupled trigger unit; D-delay unit- O1/O2-Q-switched laser pulses.

In Fig. 1 (b) we show the 1s-2p,3p absorption of neutral boron, the 2s absorption of which had previously been observed in the normal incidence region (9). Fig 1 (c) shows the 2p-ns,nd transitions of silicon. The spectrum, here recorded for the first time, is of some theoretical interest because of the predictions of Daum and Kelly (10). Although analysis has not yet been carried out the dominant lines are believed to be due to Si I and II. In Fig. 1 (d) we show the spectrum of strontium at a delay of 425 nsec. The longer wavelength group of lines corresponds to the 3d-5p,6p transitions previously observed by Mansfield and Connerade (11) and those at shorter wavelength comprise the 3d transitions of SrII, which are isoelectronic with the known 3d spectrum of RbI (12).

III - CONCLUSION

The two laser technique is not only effective in controlling the ion stages observed in dual plasma absorption but at sufficiently long time delays enables pure neutral absorption to be studied. In particular refractory and corrosive materials, whose atomic spectra have in some cases not yet been observed, are now readily accessible to study. It should also prove useful in the case of other elements such as sulphur or phosphorus whose vapour phase tends to be dominated by molecular species.

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