DOE/ER--21014-1

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ELECTRIC FIELD MEASUREMENTS FROM SATELLITES-TO- FORBIDDEN LINE RATIOS IN AN OMEGA-UPGRADE LASER-PRODUCED PLASMA

Semi-Annual Report
February 1, 1996 - May 31, 1996

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June 15, 1996

Prepared for the U.S. Department of Energy
Under Grant Number DE-PS03-96SF21014

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ELECTRIC FIELD MEASUREMENTS FROM SATELLITES-TO- FORBIDDEN LINE RATIOS IN AN OMEGA-UPGRADE LASER-PRODUCED PLASMA

Under this FY-96 NLUF program, we began our search for satellite lines to forbidden transitions for localized laser-induced electric field measurements by preparing in our laboratory a flat-field grazing incidence spectrograph for use on the OMEGA-Upgrade facility. This involved wavelength calibration using a (small) laser-produced plasma, as well as designing and constructing a mounting table compatible with the large 60-beam target chamber at LLE. This table was designed for accurate alignment to the target. The spectrograph components and the mounting table are shown and labeled in Fig. 1, prior to installation on the OMEGA-Upgrade vacuum chamber. Both the photographic detection and streak camera are shown here. Shown in the Fig. 2 is the assembly installed on the chamber at LLE, equipped with photographic recording.

Beginning in April 1996 (upon arrival of the FY-96 funding) we installed and aligned the spectrograph at LLE (see Fig. 2). Following installation and prealignment on Monday, April 22, 1996 and final alignment on Monday, April 29, we obtained the following day our first time-integrated spectral data in the 30-250 Å range. Over the next four days a total of 28 successful shots were obtained. For most shots, two beams of the OMEGA-Upgrade laser were used at nominal uv-pulse widths of 1.1 ns and energies ranging from 76-470 J/beam, with focal spots of 80-450 μm and irradiances covering approximately 10^{14}-10^{16} Watt/cm^2. Planar targets used consisted of Mg and NaF (both 5-μm thick), as well as B (boron) mounted on a plastic film, with some of the former two overcoated with 5 μm of CH on each side for containing the plasma, at least during the early portion of the pulse.

Preliminary analyses indicate that we do indeed observe the desired Li-like L-shell spectra for oxygen, fluorine, sodium and magnesium, as well as L-shell lines in the corresponding H- (Balmer) and He-like species. Similarly, we recorded K-shell lines from boron and carbon. Sample traces for magnesium and sodium fluoride (both coated with CH) from our soft x-ray spectrograph are shown in Figs. 3 and 4, with intense lines labeled. Both of these shots were obtained at a rather low applied irradiance of 2×10^{14} W/cm^2, and were chosen mainly for line identification. The parent Li-like 2s-3p allowed lines corresponding to the forbidden-line satellites sought for E-field determinations are clearly present in this figure (highlighted as Mg X, 2s-3p and Na IX, 2s-3p). However, at this low an irradiance, the calculated satellite line intensity relative to the intensity from this 2s-3p transition is ~3%, i.e., hardly measureable.

Higher irradiance shots are currently under analysis. For spectra obtained with the Mg and NaF targets, H- and He-like L-shell lines (n=3 to n=2 transitions) appear to be quite weak in intensity compared to Li-like lines from similar transitions. A rough estimate of the ratio between such species indicates that the electron temperature may be ~600 eV on a time-integrated basis. The most intense line in each spectrum is the $2p^2P$-$3d^2D$ line of the Li-like species, which is opacity broadened and may yield radiative transport information. Magnesium K-shell lines from H- and He-like ions were also measured in the 1.4-2 keV spectral range with a crystal spectrograph and streak camera provided by LLE, and showed that line emission from the former exceeds the latter, again indicating a temperature of ~600 eV. Furthermore, the continuum step (Inglis-Teller limit) indicates an electron density in the range of $N_e \sim 10^{22}$ cm^{-3}. We also obtained with this crystal instrument spectra of zinc at high irradiance using four beams and are still analyzing it.

We have especially studied the spectrum obtained using a plastic target with an overlay of boron. It turns out that the dominant spectral lines are from OVI-OVIII, presumably from the plastic and "glue" used. Interestingly enough, we observe two spectral lines to the long wavelength side of the helium-like OVII $2p^3P$-$3d^3D$ line at 52.0 Å, with the correct positions and relative intensities to be satellites to the $2p^3P$-$3p^3P$ forbidden line at 53.1 Å. If these identifications are correct, they correspond to an electric field of 5.5×10^8 V/cm in the plasma and an equivalent irradiance of $\sim 4 \times 10^{14}$ W/cm^2, which compares extremely well to an incident laser irradiance onto the target of 4.8×10^{14} W/cm^2. We also note strong 2p-nd lines for n=2 of OVII (He-like) and OVIII (H-like) compared to higher-n lines; this does not occur for OVI (Li-like).

The analysis of the data is continuing. We anticipate presenting the results at the APS Division of Plasma Physics Conference to be held in Denver, CO in November 1996. In the meantime and in parallel, we are preparing time resolution for use in a followup series of experiments during the second half of this program period, using either a gated microchannel plate or a streak camera (currently on loan from LLE) and CCD detector. Hopefully these future shots will allow us to extend our measurements to spherical targets. We also anticipate performing experiments during this period at both LANL on the TRIDENT facility (now scheduled for the week beginning July 8, 1996) and at LLNL on the NOVA Two-Beam facility.

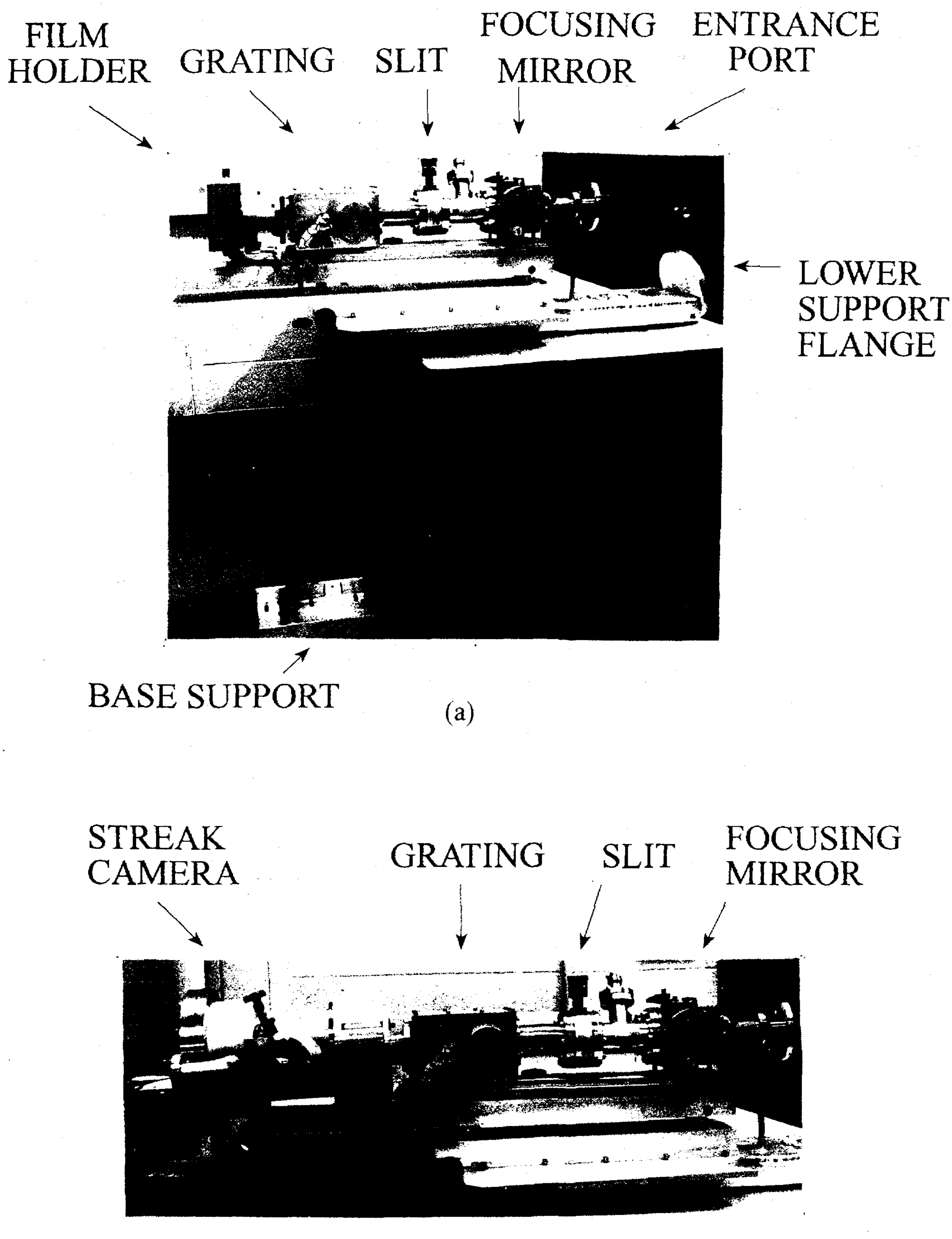

Fig. 1. Spectrograph shown before mounting on Omega Upgrade, with film holder (a) and streak camera (b).

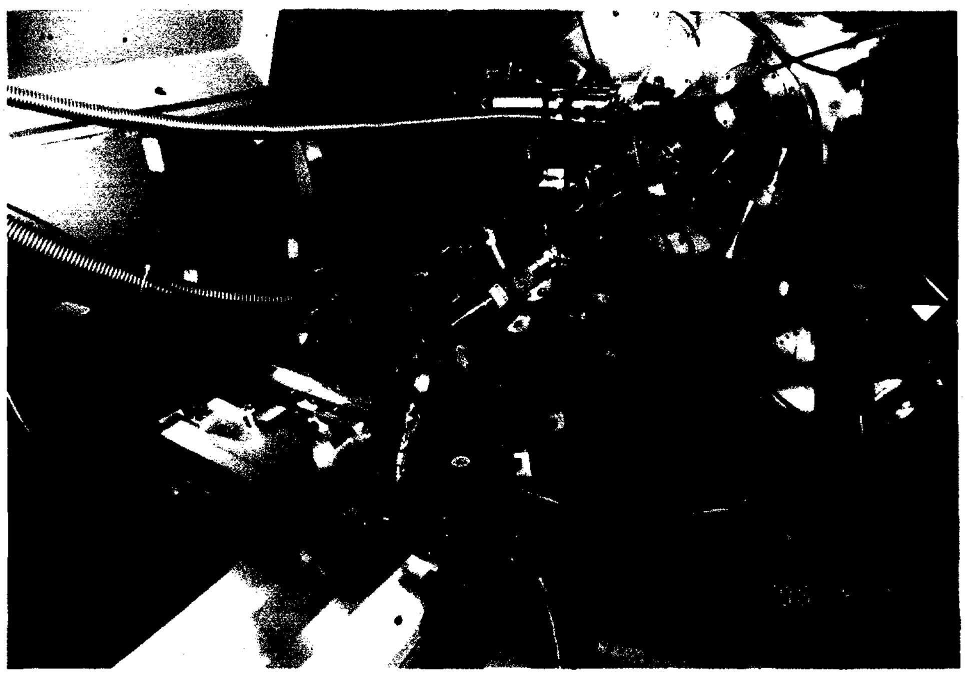

Fig. 2. Flat-field spectrograph shown mounted on chamber.

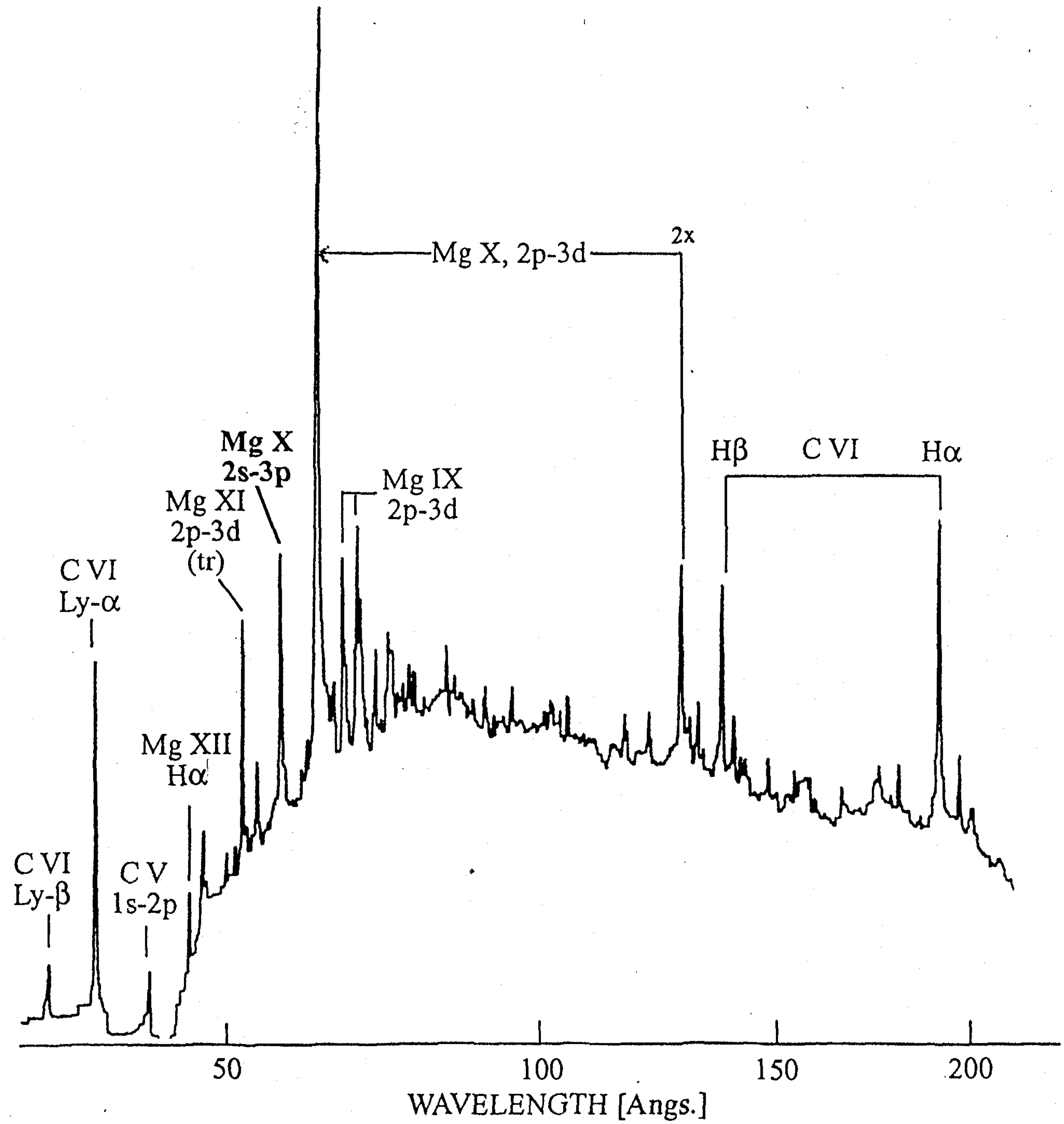

Fig. 3. Densitometer scan showing the H-, He- and Li-like magnesium spectrum, accompanied by carbon lines from a CH overcoating. The short wavelength decline is due to carbon absorption in the film.

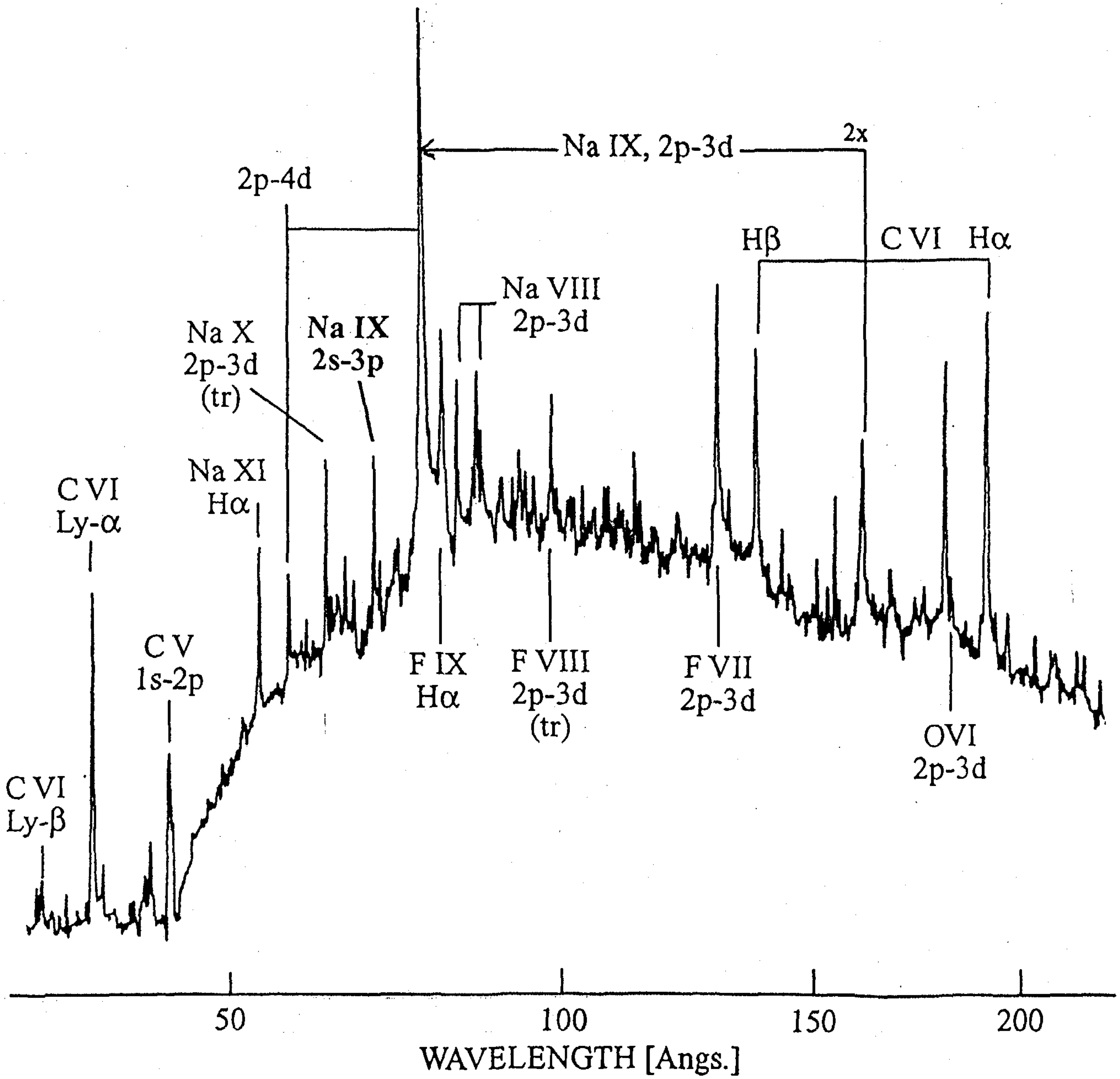

Fig. 4. Densitometer scan showing the H-, He- and Li-like sodium and fluorine spectrum from NaF, accompanied by carbon lines from a CH overcoating and oxygen from oxidation during target manufacture. The short wavelength decline is due to carbon absorption, mostly in the film.