



DENSITY AND TEMPERATURE DIAGNOSTICS OF A Ne-LIKE GERMANIUM PLASMA CREATED BY LASER

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**DENSITY AND TEMPERATURE DIAGNOSTICS OF A Ne-LIKE GERMANIUM PLASMA
CREATED BY LASER**

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Résumé - Dans le cadre des études sur le laser X, nous avons réalisé des expériences sur un plasma d'ions Germanium néonoides par irradiation laser à $\lambda = 1,053 \mu\text{m}$. Nous avons observé une amplification dans les transitions lasantes en faisant varier la longueur du plasma. Des calculs théoriques de population des niveaux excités nous ont permis de déterminer la densité et la température à partir de rapports d'intensité de raies.

Abstract - In the frame-work of X-ray laser studies, experiments on Ne-like Ge plasma have been performed by laser irradiation at $\lambda = 1.053 \mu\text{m}$. Amplification in lasing transitions has been observed by varying the plasma length. Theoretical calculations of excited level population allow us to determine density and temperature from line intensity ratios.

INTRODUCTION

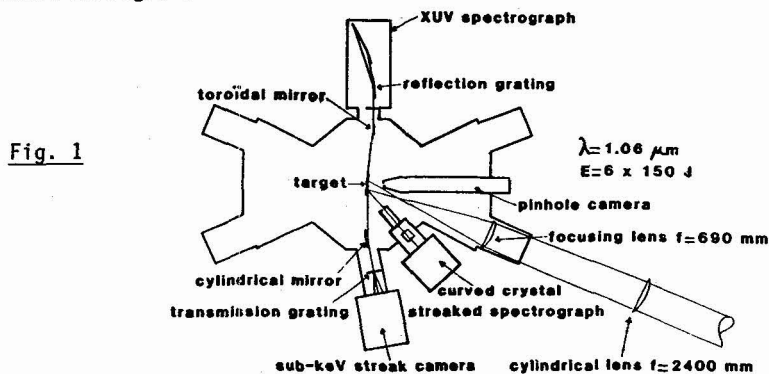
Complete understanding of X-ray laser experiments requires not only amplification studies of the lasing lines, but also suitable diagnostics to determine fundamental plasma parameters : temperature, density, ionization balance. With these two preoccupations in mind, we are now performing experiments on Germanium exploding foils. In this paper, we present some preliminary results which have been obtained recently.

Amplification of X-rays by Ne-like Selenium ions has been demonstrated first at the LLNL [1,2] and can be explained in the so-called collisional excitation scheme. Our experiments have been performed on Germanium targets irradiated by laser beams at $\lambda = 1,053 \mu\text{m}$ and their results seem to be consistent with those of recent experiments at NRL [3].

EXPERIMENTAL FACILITIES

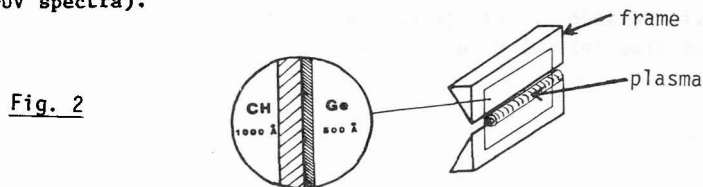
For our X-ray laser studies we used the laser Octal at its fundamental wavelength ($1.053 \mu\text{m}$). This is an eight beam laser delivering up to 150 J/beam within 1 ns. Because of particular distribution of the beam axes, only three of each set of four beams were focused onto targets by both cylindrical and spherical lenses over a line focus of dimension 30 mm x 200 μm .

A simplified schematic representation of the experimental arrangement is shown in Fig.1 :



The two main diagnostic devices viewing in the direction where X-ray amplification occurs were a grazing incidence spectrograph with a toroidal collection mirror and a reflection grating spectrograph associated with a streak camera providing a temporal information of X-UV spectra in the wavelength range 20-300 Å. Perpendicular to the plasma expansion was installed a X crystal spectrograph providing a temporal resolution of the spectrum emitted in the range 7-11 Å, useful for plasma characterisation.

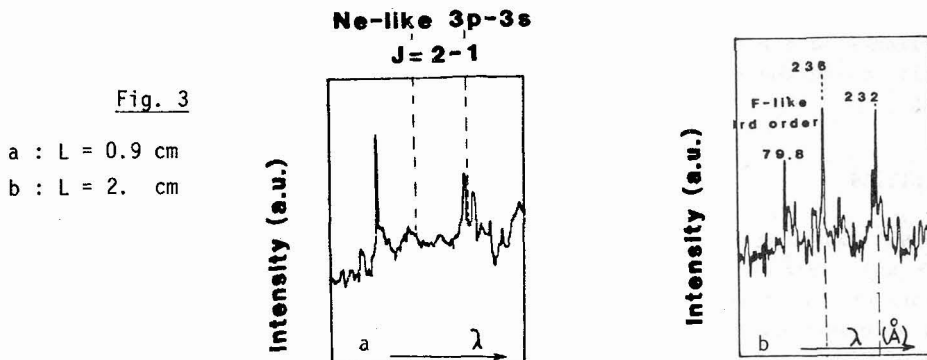
Typical targets were composed (Fig. 2) of a polystyrene substrate (1000 Å) coated with Ge (500 Å) deposited on a frame. This frame was inserted in a special holder allowing us specific measurements (amplification, plasma characterisation from X and X-UV spectra).



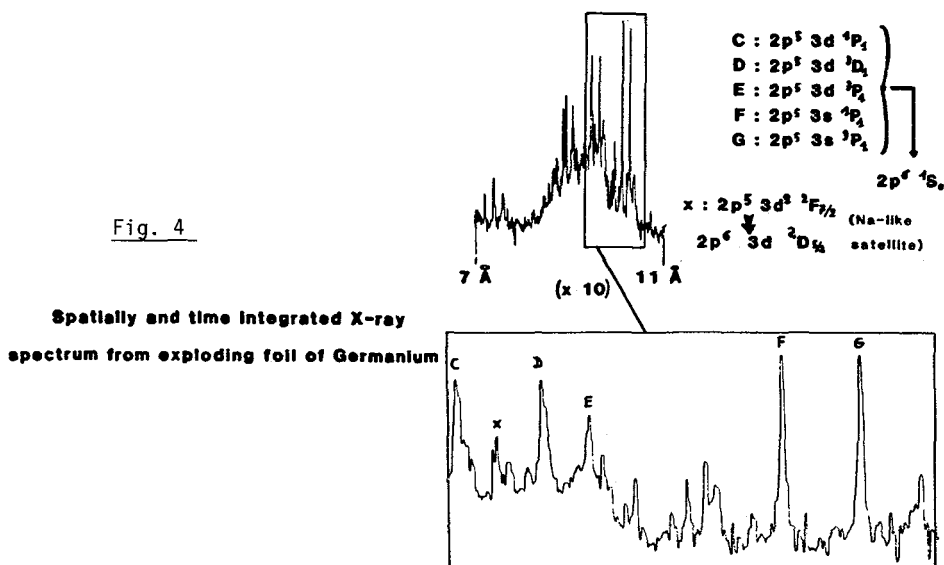
Targets of different lengths (1 cm and 2 cm) were irradiated on both sides with a mean irradiance of $2 \times 10^{12} \text{ W/cm}^2$.

EXPERIMENTAL RESULTS AND INTERPRETATION

Amplification of the 3p-3s ($J = 2 - 1$) transitions of Ne-like Germanium ions has been observed in the intensities of corresponding lines when varying the target lengths (Fig. 3)



In order to determine plasma temperature and density, we have studied X-ray spectra in the spectral range of Ne-like resonance lines. A typical experimental result is given in Fig. 4.



To analyse these results a numerical model, has been built. This model includes all the 75 lowest-lying neon-like states ($1s^2 2s^2 2p^5 3l$, $1s^2 2s 2p^5 3l, 1s^2 2s^2 2p^5 4l$), the fundamental F-like state, and the five $2p^6 3l$ simply excited as well as the $2p^5 3l 3l'$ doubly excited sodium-like levels. For a first approach, the doubly excited levels are grouped together in configurations which are populated by dielectronic capture from the fundamental neon-like level and depopulated by auto-ionization and radiative de-excitation. The detailed levels are distributed according to BOLTZMANN equilibrium, for each configuration, in order to take into account their collisional mixing.

Radiative transfer is treated by means of an escape factor in which the plasma length is taken as the velocity gradient length for which the bulk doppler shift is equal to the thermal doppler half-width.

After the determination of the populations, reabsorption effect is taken into account by using a reabsorption factor :

$$\frac{\phi(v_0)}{k_0 L} \int_0^{+\infty} [1 - \exp(-k_0 L \phi(v)/\phi(v_0))] dv$$

on each line (here, L is the plasma depth along the line of sight of the spectrograph and k_0 is the absorption coefficient at the line center ; for $\phi(v)$ we chose a Doppler profile).

As the satellite lines are very numerous, and because the instrumental broadening is rather large, the diagnostic is realized as follows :

For any unsufficiently resolved group of spectral lines defined by its wavelength and experimental FWHM, and for given N_e and T_e , the model allows us to calculate the contribution of all the lines lying in this FWHM in order to obtain the whole emitted energy of this group.

The density-temperature dependence of I_C/I_F and I_C/I_X ratios has been obtained by this procedure : the I_C/I_X line ratio exhibits a strong dependence on T_e and N_e as the I_C/I_F is only density dependent. Comparison with experimental values gives us an electronic temperature of 700 eV and an electronic density of about $2 \cdot 10^{20} \text{ cm}^{-3}$.

CONCLUSION

Amplification in lasing transitions of Neon-like Germanium ions has been obtained. A first spectroscopic determination of plasma parameters has been performed. We are now working to obtain new experimental results with temporal or/and spatial resolution. Theoretical models used for interpretation are also being improved.

REFERENCES

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