

POPULATION OF EXCITED STATES OF Al^{10+} IN A PLASMA
BY A TIME-DEPENDENT MODEL

H. Guennou and A. Sureau
Laboratoire de Spectroscopie Atomique et Ionique
Université Paris-Sud and C.N.R.S.
Orsay, France

The present model is the time-dependent version of a previous model (Sureau et al. 1983) in which the population distribution was assumed in steady state. A finite set of levels is partitioned in four subsets : the Z-ion ground-level and, contingently, the first near-degenerated levels (subset 1) ; all the successive excited Z-ion levels up to $n=5$ (subset 2) ; a finite number of higher Rydberg levels (because of the limitation of the series in the plasmas) which are assumed in LTE with the Z+1-ion ground-level (subset 3, called the thermal band) ; and the Z+1 ion ground-level (subset 4).

The physical processes explicitly considered are the radiative cascades and the transitions between the Z-ion bound levels induced by electron-ion collisions. The radiative-transition probabilities are given by ab-initio calculations using a modified Hartree-Fock method including the spin-orbit interaction (Sureau et al., 1984). The collision rates are derived by the Van Regemorter formula multiplied by an adjustable parameter F_c .

The ionization and recombination balance is implicitly ensured in fixing the populations of the levels of subsets 1 and 3 above with regard to the Z+1-ion ground-level population : LTE for subset 3, LTE multiplied by a parameter δ for subset 1. The situations where subsets 1 and 4 are not in LTE ratio can then be accounted for in taking $\delta \neq 1$.

The specifications of the model are summarized on the next page.

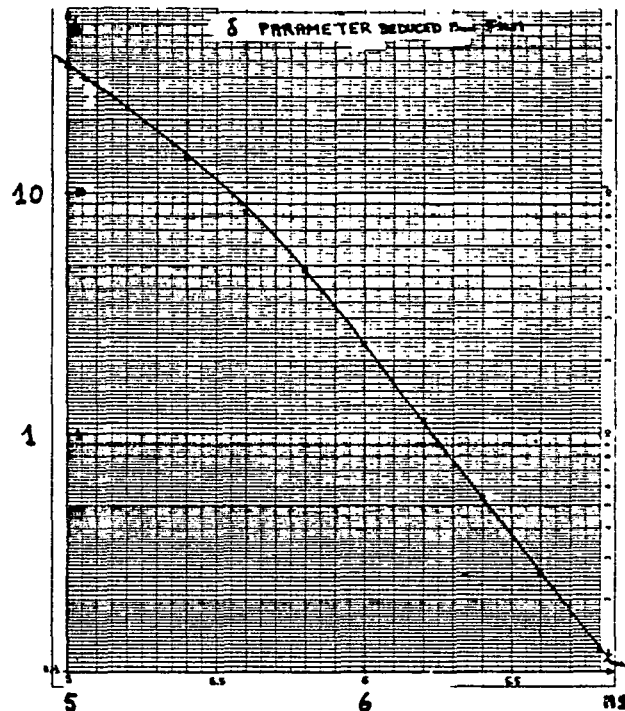
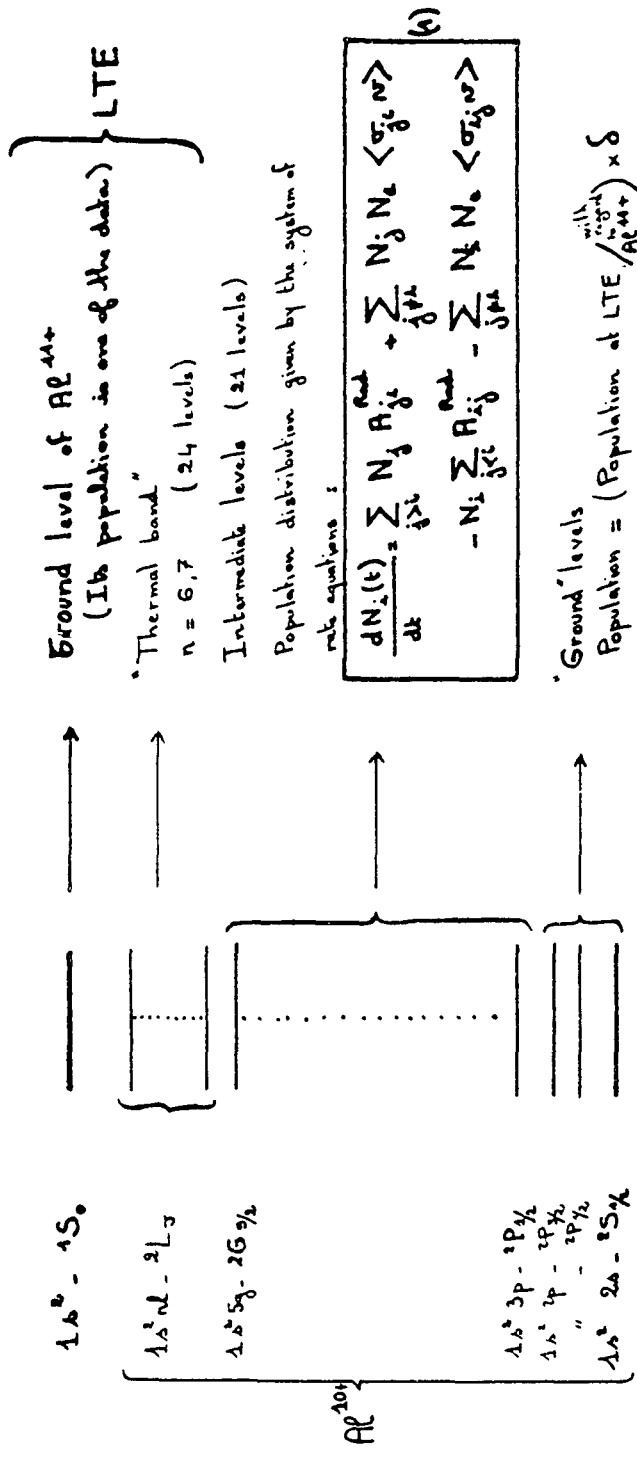


FIG.1 : δ versus time according to simulation 2 (see after)



Solutions of (1) by (*): $y(t+k) = y(t) + \Omega(k) * (\delta y(t) - \mathcal{E})$

Where $\Omega(k)$ is obtained by a recurrence relation:

$$\Omega\left(\frac{k}{2^l}\right) = \Omega\left(\frac{k}{2^{l-k+1}}\right) * \left[2E + \delta \Omega\left(\frac{k}{2^{l-k+1}}\right) \right]$$

From:

$$\Omega\left(\frac{k}{2^l}\right) = \sum_{i=1}^k \frac{1}{2^i} \delta^{i-1} \left(\frac{k}{2^i}\right)^2$$

$k, l =$ parameters chosen in order to obtain a sufficient precision.

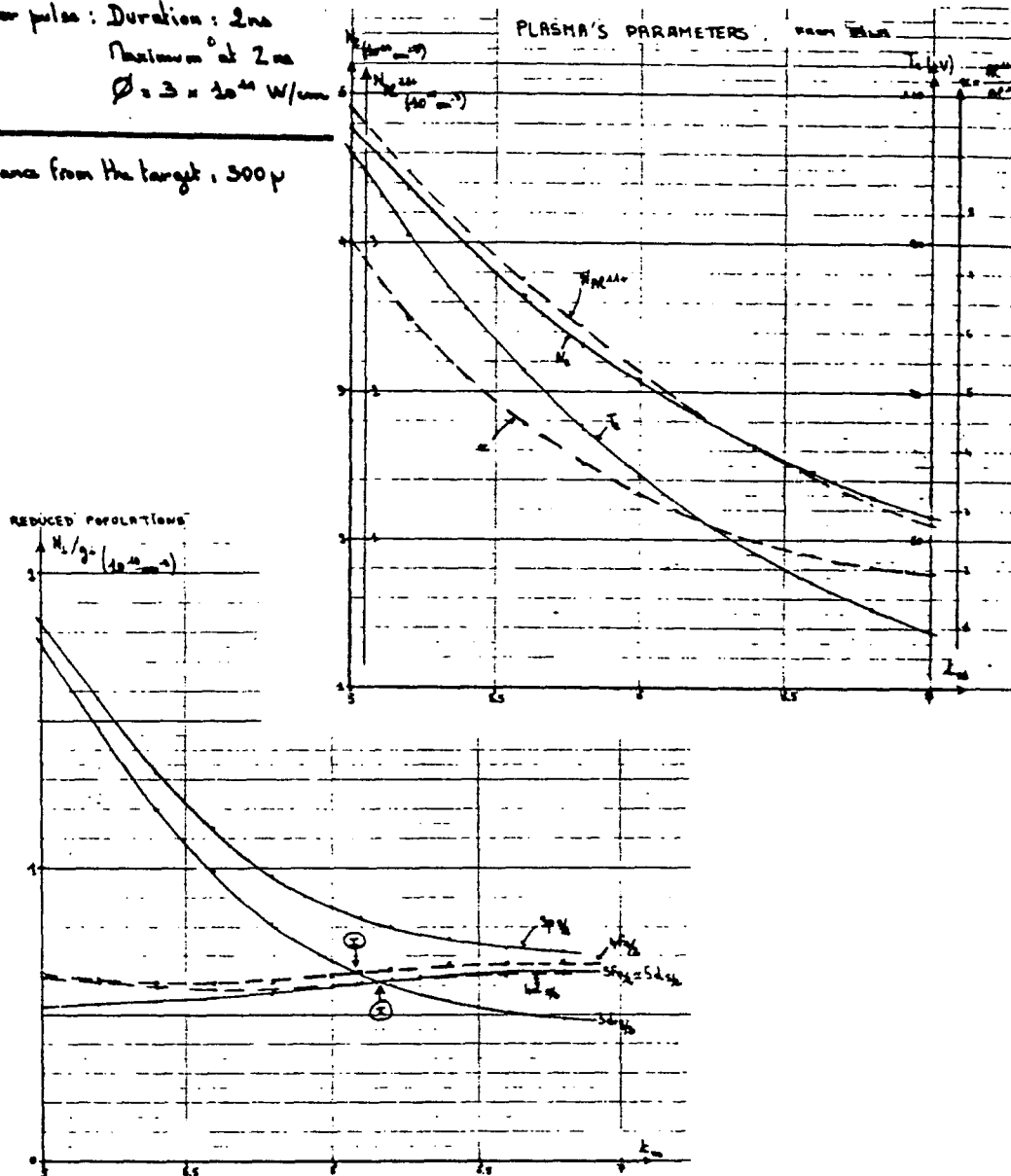
(*) N. BAKHVALOV - Méthodes numériques - Editions Mir

The time evolution of the plasma parameters (electron density N_e and temperature T_e , relative abundances of Al^{III+} and Al^{II+} ions, from which the parameter δ is deduced) being taken from a hydrodynamic simulation code for laser-produced plasmas (code FILM by Gauthier et al. 1983), the time evolution of the population of individual states has been obtained for some realistic cases, showing the occurrence of some population inversions during the recombination of the plasma. One exemple of this is given below :

SIMULATION 3 - Cylindrical geometry

Laser pulse : Duration : 2 ns
 Maximum ϕ at 2 ns
 $\phi = 3 \times 10^{14}$ W/cm²

Distance from the target : 300 μ



The corresponding δ values are given in figure 1.

REFERENCES

- Sureau A., Guennou H., Jaeglé P., 1983 Communication at the 4th
Topical Conference on Atomic Processes in High Temperature
Plasmas,
Princeton (N.J.) April 1983
- Sureau A., Guennou H. and Cornille M., 1984
J. Phys. B : At. Mol. Phys., 17, 541
- Gauthier J.C., Geindre J.P., Grandjouan N., Virmont J., 1983
J. Phys. D, 16, 321