

Spectrally Resolved Intensities of Ultra-Dense Hot Aluminum Plasmas

Cite as: AIP Conference Proceedings **1058**, 75 (2008); <https://doi.org/10.1063/1.3026501>

Published Online: 27 October 2008

J. M. Gil, R. Rodríguez, R. Florido, J. G. Rubiano, P. Martel, E. Mínguez, P. Sauvan, P. Angelo, R. Schott, E. Dalimier, and R. Mancini



[View Online](#)



[Export Citation](#)

AIP | Conference Proceedings

Get **30% off** all
print proceedings!

Enter Promotion Code **PDF30** at checkout



Spectrally Resolved Intensities of Ultra-Dense Hot Aluminum Plasmas

J. M. Gil^{*,†}, R. Rodríguez^{*,†}, R. Florido^{*,†}, J. G. Rubiano^{*,†}, P. Martel^{*,†},
E. Mínguez[†], P. Sauvan^{**,†}, P. Angelo[‡], R. Schott[§], E. Dalimier[‡] and
R. Mancini[§]

**Departamento de Física, Universidad de Las Palmas de Gran Canaria, 35017 Las Palmas de Gran Canaria, Spain*

†Instituto de Fusión Nuclear, Universidad Politécnica de Madrid, 28006 Madrid, Spain

***Departamento de Ingeniería Energética, UNED, Madrid, Spain*

‡Physique Atomique dans les Plasmas Denses, LULI, CNRS-CEA-École Polytechnique-Université Paris VI, 75252 Paris cédex 05, France

§Department of Physics, University of Nevada, Reno, NV 89557, USA

Abstract. We present a first study of spectroscopic determination of electron temperature and density spatial profiles of aluminum K-shell line emission spectra from laser-shocked aluminum experiments performed at LULI. The radiation emitted by the aluminum plasma was dispersed with an ultra-high resolution spectrograph ($\lambda/\Delta\lambda \approx 6000$). From the recorded films one can extract a set of time-integrated emission lineouts associated with the corresponding spatial region of the plasma. The observed spectra include the Ly α , He β , He γ , Ly β and Ly γ line emissions and their associated He- and Li-like satellites thus covering a photon energy range from 1700 eV to 2400 eV approximately. The data analysis rely on the ABAKO/RAPCAL computational package, which has been recently developed at the University of Las Palmas de Gran Canaria and takes into account non-equilibrium collisional-radiative atomic kinetics, Stark broadened line shapes and radiation transport calculations.

Keywords: laser-shocked plasmas, X-ray measurements, opacities and emissivities, spectroscopic diagnostics

PACS: 52.25.Os, 52.50.Jm, 52.70.La

INTRODUCTION

An experimental study devoted to measure the opacity and emissivity of bound-bound transitions in laser-shocked dense and hot aluminum plasma was carried out at the LULI laser facility [1]. Theoretical investigations performed in parallel to these experiments permitted to obtain opacity estimations for some He- and H-like Al transitions, such as Ly β , He β and He γ , for particular physical conditions. However, until now there had been no spectroscopic analysis including all the recorded emission features simultaneously, nor systematic study of the spatial dependence of the physical conditions which is observed in the experiments. Thus, in this work we present a first study of spectroscopic determination of electron temperature and density spatial profiles of aluminum K-shell line emission spectra from those mentioned LULI experiments. The next section describes the experimental set up and the details of the data analysis. In the last section the main results are presented.

EXPERIMENTAL SET UP AND DATA ANALYSIS

The experiments were carried out at LULI-École Polytechnique on the nanosecond laser facility. The neodymium laser chain provided a 600 ps Gaussian pulse with a maximum energy of 80 J and a wavelength of $1.053 \mu\text{m}$. A 4ω beam was focused onto a structured target, the $100 \mu\text{m}$ focal spot yielded intensities as high as $2 \times 10^{14} \text{ Wcm}^{-2}$. Then, the 4ω laser beam irradiates the edge of a three layered-foil (CH/Al/CH). The plastic is entirely converted into plasma during the laser shot. This CH plasma ensures the aluminum plasma confinement. The laser-target interaction gives rise to a nick instead of a crater and this was the key to ensure that the ultra-dense plasma was rigorously observed transversely. In addition, this implementation produces automatically a progressive spatial integration along the laser-target axis in the recorded film -see Fig. 1(left)-.

For the data analysis the computational package ABAKO/RAPCAL was used. This package has been recently developed at the University of Las Palmas de Gran Canaria and it is composed by two numerical codes. The first one named ABAKO [2] is a collisional-radiative (CR) model that calculates atomic data and level populations for steady state plasmas. The second code is called RAPCAL [3] and it carries out the computation of radiative properties such as spectrally resolved and mean emissivities and opacities, intensities and radiative power losses. ABAKO/RAPCAL assembles a set of simple analytical models which yield substantial savings of computer resources, but yet still providing good comparisons with more elaborated codes and experimental data.

For this particular application, we used ABAKO/RAPCAL to compute a database of emergent intensities in the photon energy range from 1700 to 2400 eV over a 20×20 grid of electron temperatures T_e and densities n_e in the domain of interest, i.e. 300-500 eV and 10^{21} - 10^{23} cm^{-3} . For these calculations an optically $80 \mu\text{m}$ -thick aluminum plasma was assumed, which matches with the thickness of the aluminum layer of the target for the case analysed here. To satisfy the required accuracy in the atomic data, we took them from FAC [4], following a relativistic detailed-configuration-accounting approach. We used a semiempirical formula for estimation of Stark widths [5]. Natural, Stark and Doppler broadenings were taken into account in the context of Voigt line profiles. Complete redistribution was assumed and line overlapping considered. Finally, the extraction of T_e and n_e for a given spectral lineout is performed by searching in the database the synthetic spectrum that yields the best fit to the data in the sense of a least-square minimization. An example is given in the Fig. 1 (right). A systematic application of this procedure to each of the lineouts in the recorded film results in a spatial profile of T_e and n_e .

RESULTS

According to the analysis described above, in the Fig. 2 we show the inferred electron temperature and density spatial profiles. As we could expected the density peaks at points near the target. The average temperature is about 430 eV, showing some oscillations in a 50 eV-width interval. This is because we have analysed only the first $65 \mu\text{m}$ of the plasma and we should expect temperature to drop at points far from the target.

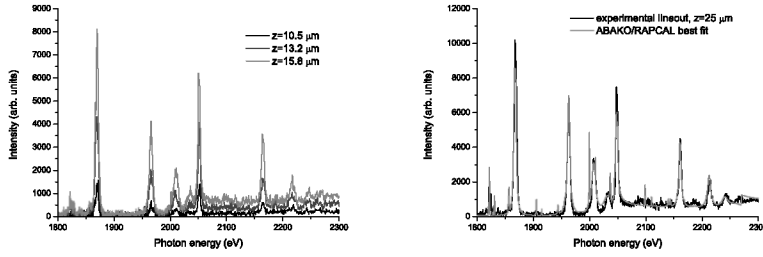


FIGURE 1. On the left several extracted experimental lineouts are represented. The spatial integration along target-laser axis (z -axis) given by the experimental set up can be observed, since each lineout yields below the following one. On the right we show an ABAKO/RAPCAL best fit for an aluminum K-shell emission spectrum. The analysis gives $n_e = 1.198 \times 10^{22} \text{ cm}^{-3}$ and $T_e = 396 \text{ eV}$.

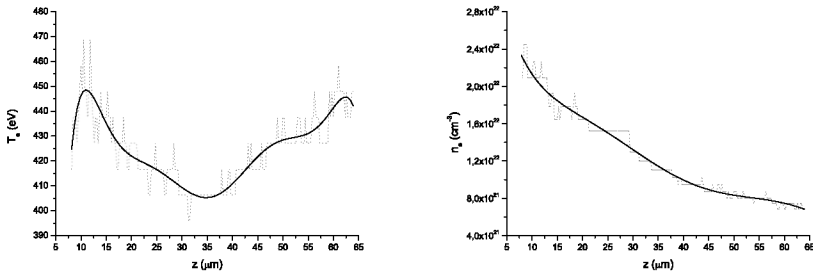


FIGURE 2. Extracted spatial profiles of temperature (left) and density (right). The z -axis represents the target-laser axis and it grows in the same direction. For clarity in the interpretation smoothing polynomials have been added over the point-by-point diagnostic values.

ACKNOWLEDGMENTS

This work has been supported by the Spanish Ministry of Science and Innovation under Research Grant No. ENE2008-06668-C02-02 and also by the *Keep in touch* Program of the European Union under Contract No. FU07-CT-2007-00050.

REFERENCES

1. R. Schott, F. Philippe, P. Angelo, E. Dufour, A. Poquérousse, E. Dalimier, P. Sauvan, E. Mínguez, J. M. Gil, J. G. Rubiano, R. Rodríguez, P. Martel, and R. Mancini, *J. Quant. Spectrosc. Radiat. Transfer* **81**, 441–450 (2003).
2. R. Florido, R. Rodríguez, J. M. Gil, J. G. Rubiano, P. Martel, D. Suárez, M. Mendoza, and E. Mínguez, *J. Phys.: Conf. Ser.* **112**, 042008 (2008), and references therein.
3. R. Rodríguez, R. Florido, J. M. Gil, J. G. Rubiano, P. Martel, and E. Mínguez, *Laser Part. Beams* (2008), doi:10.1017/S026303460800044X, and references therein.
4. M. F. Gu, *Astrophys. J.* **582**, 1241–1250 (2003).
5. M. S. Dimitrijevic, and N. Konjevic, *Astron. & Astrophys.* **172**, 345–349 (1987).