Topic number: 6

Gas temperature determination of non-thermal plasma jets from the collisional broadening of argon atomic emission lines

M. C. García[1, *], A. Rodero[1], A. Gamero[1] and C. Yubero[1]

[1] *Grupo de Física de Plasmas: Diagnosis, Modelos y Aplicaciones (FQM-136)*
Edificio A. Einstein (C-2), Campus de Rabanales. Universidad de Córdoba, 14071 Córdoba, Spain

We propose two new spectroscopic tools allowing gas temperature determination of non-thermal plasma jets, based on the measurement of the collisional broadening of two atomic emission lines, Ar I 750.39 nm and Ar I 842.46 nm, respectively. The gas temperature of a microwave non-thermal plasma jet was determined from them. Results were consistent with each other, and with those obtained from the rotational temperature derived from OH ro-vibrational band.

1. Introduction

In some technological applications, such as those related to plasma surface treatments or plasma treatment of liquids, a reliable determination of the gas temperature (T_g) in the plasma could be crucial. To control this plasma characteristic parameter becomes particularly relevant in biomedical applications. Optical Emission Spectroscopy (OES) techniques based on the analysis of molecular emission spectra are commonly used for T_g determination of plasmas sustained at atmospheric pressure. But, the use of molecular emission spectroscopy is not always easy: overlapping of bands, rotational population distribution of levels having a non-Boltzmann nature, wake emission of rotational bands, among others, can make difficult to obtain reliable values of gas temperature.

In this paper we propose two new spectroscopic tools for determination of gas temperature in non-thermal plasmas, based on the measurement of the collisional broadening of two argon atomic lines: Ar I 750.39 and Ar I 842.46 nm, respectively. The new methods have been used to measure T_g of an argon microwave jet open to the air. Values obtained using them, have been compared to the rotational temperatures derived from the OH ro-vibrational bands for validation.

2. Method

Lines Ar I 750.39 and Ar I 842.46 nm are very intense and can be almost always detected with a reasonably good signal-to-noise ratio, using appropriate detectors. They correspond to resonance transitions into both resonance levels s_2 and s_4 of the $3p^5 4s$ configuration of the Ar I system, and have a very high resonance broadening only dependent on the gas temperature. These lines also have a non negligible van der Waals broadening also depending on T_g.

For plasmas with gas temperatures under 2000 K, and electron densities lower than 10^{15} cm^{-3}, contributions of the Stark and Doppler broadenings to the whole line profile are negligible when compared to resonance and van der Waals ones. Under these experimental conditions, the total collisional broadening for these lines is then given by:

$$W_C(T_g) \approx W_W(T_g) + W_R(T_g) = \frac{C_W}{T_g^{0.7}} + \frac{C_R}{T_g} \qquad (1)$$

where constants C_W and C_R are characteristics for each line. Using expressions given by Yubero et al. in [1], and Ali and Griem in [2-3], respectively, we have calculated these constants for Ar I 750.39 and 842.46 nm.

The experimentally measured profiles of the lines (no self-absorbed), can be fitted to a Voigt shaped profile with a FWHM given by

$$W_V = \frac{W_C}{2} + \sqrt{\left(\frac{W_C}{2}\right)^2 + W_I^2} \qquad (2)$$

being W_I the instrumental broadening.

So, by measuring W_V, and knowing W_I, from eq. (2) W_C can be derived, and T_g determined.

Aknowledgements

The authors are grateful to Física de Plasmas: Diagnosis, Modelos y Aplicaciones (FQM-136) research group from the University of Córdoba and MINECO project MAT2016-79866-R for their technical and financial support.

References

[1] C. Yubero, M.S. Dimitrijevic, M.C. García and M.D. Calzada, Spectrochim. Acta B **62** (2007) 169.

[2] A.W. Ali and H.R. Giem, Phys. Rev. **140** (1965) 1044.

[3] A. W. Ali and H. R. Griem. Phys. Rev. **144** (1966) 366.