Spectroscopic studies on high-pressure Hg-Xe discharges

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The total intensity of self-reversed spectral lines in Hg-Xe high-pressure discharges is measured by means of absolutely calibrated spectroscopic techniques. Observable parameters of the Hg lines at 546.1, 435.8 and 404.7nm are used to characterize the plasma structure on the basis of a simplified model for the light source. The temperature profiles obtained are further used to simulate the spectral emission by solving the equation of radiative transfer.

1. Introduction

The temperature determination is an important step in studying the features of electric discharges. The entire temperature profile is needed for calculation of the species densities in the plasma which in turn affect the emitted radiation. The problem becomes rather complicated in real light sources with complex geometries, filling compositions, and with optically thick plasmas. The investigations presented here concern side-on measurements of spectral lines and a solution of the equation of radiative transfer in the case of cylindrical symmetry.

2. Spectroscopic measurements

Profiles of the 546.1, 435.8, and 404.7 nm mercury lines are obtained from four discharges (differing in Xe-pressure) operated horizontally (Fig. 1). Table 1 presents the characteristics of the discharges under consideration. The measurement of the radiation is made midway between the electrodes where the plasma column could be treated like a cylinder. The optical system is calibrated with a tungsten-strip lamp.

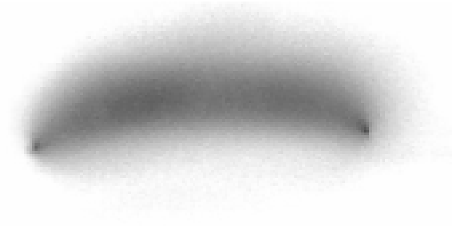

Fig. 1 Picture of the arc

Discharges	P1	P2	P3	P4
Discharge diameter (mm)	2.7	2.7	2.7	2.7
Inter-electrode distance (mm)	4.4	4.4	4.4	4.4
Mass of Hg (μg)	554	554	554	554
Xe-pressure (bar)	0.51	1.28	2.54	5.1
Arc votage (V)	68.8	66.79	73.66	72.8
Arc current (A)	0.564	0.589	0.538	0.544

Table 1. Characteristics of the discharges studied.

Fig. 2 gives an example of experimentally observed line profiles of the Hg 546.1 nm line. These line profiles show self-reversal and well pronounced asymmetry between the blue and red wings.

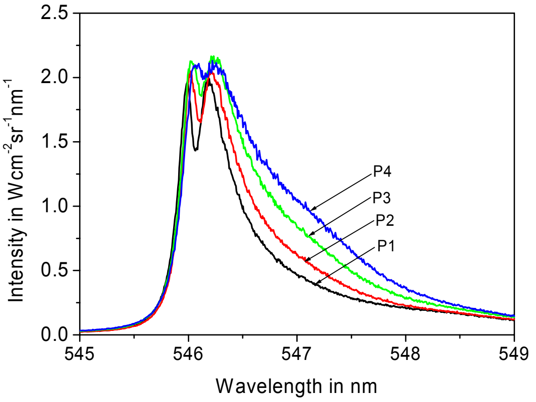

Fig. 2 Experimental profiles of the Hg 546.1 nm line.

3. Temperature determination

In the present work we apply a procedure for determining the temperature in optically thick discharges from experimentally obtained parameters of the shape of self-reversed lines emitted along a line of sight for different distances from the arc axis [1]. These line parameters are the wavelength separation 2s corresponding to the two side maxima and the ratio

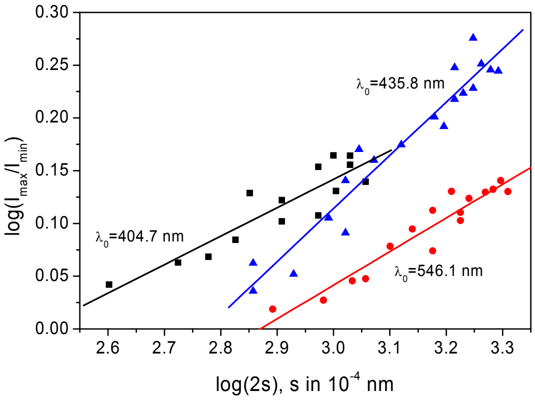

Fig. 3 Experimental dependencies of log (I_{max}/I_{min}) upon log(2s) for discharge P1.

I_{max}/I_{min}, where I_{max} is the higher of the two maxima and I_{min} is the intensity of the minimum. The results obtained for the spectral lines of mercury at 546.1, 435.8, and 404.7 nm in discharge P1 are presented in Fig. 3. Performing a linear regression the slopes of the straight lines are determined. Then the plasma inhomogeneity parameter n [1,2] and the parameter K_0 are determined. These values as well as the parameter D [1] for discharge P1 are listed in Table 2.

λ_0, nm	D	n	K_0
546.1	0.319	1.324	0.673
435.8	0.504	1.268	0.712
404.7	0.269	1.146	0.809

Table 2. Evaluated values of the parameters needed for temperature determination in P1 discharge.

The maximum temperature T_{max} along the line of sight is given by the relation

$$T_{\max} = \frac{hc/(\lambda_0 k_B)}{\ln(2hc/\lambda_0^3) + \ln K_0 - \ln I_{\max}} . \qquad (1)$$

The radial temperature profile as determined according to Eq.(1) is shown in Fig. 4. Since the emission spectra from the outer region are not self-reversed, the temperature evaluation is possible only in the central part of the discharge. The temperature values for the outer region are determined in such a way that a good agreement between calculated and measured line profiles is achieved.

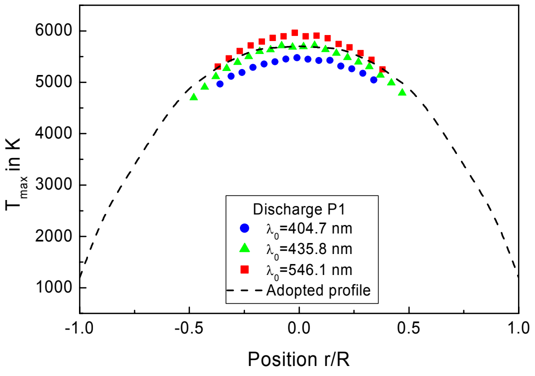

Fig. 4 Maximum temperature obtained for various distances from the arc axis in discharge P1.

4. Lineshape modelling

The observed line profiles can be compared with calculated ones. Assuming LTE conditions and constant pressure in the discharge, the electron and neutral atom densities can be obtained from the equation of state of ideal gases and the Saha equation, these combined with the temperature field evaluated from the experiment.

The line profile shapes are calculated by solving the radiative transfer equation [3]. For this purpose the transition probabilities, the number densities of the emitting and absorbing atoms, and the normalized emission/absorption profiles must be known.

The densities of the emitters and absorbers are calculated from the temperature distribution (Fig. 4) assuming that the Saha-Boltzmann relation is well established in the entire plasma. The LTE expressions for the emission and absorption coefficients (stimulated emission is neglected) are used with a normalized line profile obtained as a convolution of Lorentz and Van der Waals quasi-static profiles [4].

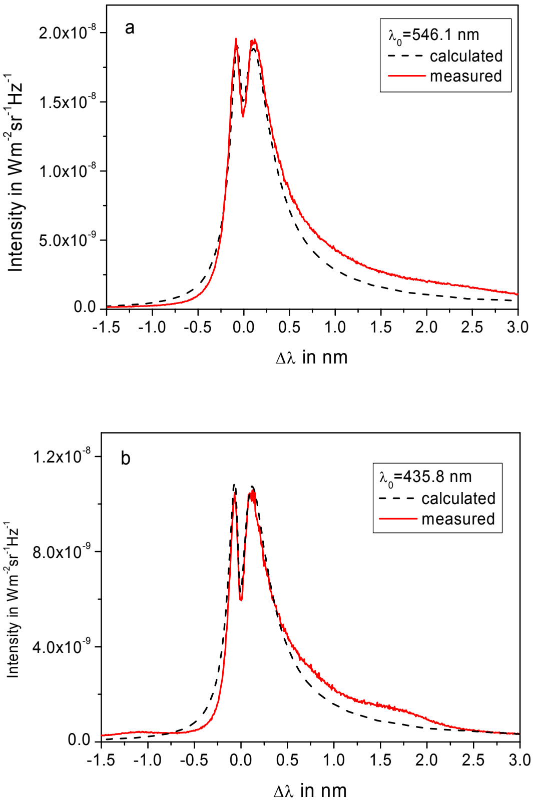

Fig. 5 Line profiles of Hg546.1nm (a) and 435.8nm (b).

The calculated line profiles for a line of sight crossing through the centre of discharge P1 are shown in Fig. 5 in comparison with the measured ones. A good agreement between experimental and calculated profiles is achieved with values of the broadening constants for Hg perturbing atoms C_6=0.25x10^{-42}m^6/s and $C_{6,qs}$=0.5x10^{-42}m^6/s, and C_4=0.45x10^{-22}m^4/s for Stark broadening. These values are relatively low compared to hitherto published data.

5. Acknowledgments

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6. References

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