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LASER ABSORPTION SPECTROSCOPY FOR GAS TEMPERATURE MEASUREMENTS IN A GLOW DISCHARGE

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Abstract. The method of laser absorption spectroscopy is used for the measurements of gas temperature in an argon Grimm-type glow discharge. Measured values compare well with those obtained by means of Fabry-Perot interferometer in an emission experiment.

1. INTRODUCTION

In our first work (Kuraica *et al.*, 1992) we use Fabry-Perot (FP) interferometer for gas temperature measurements in Grimm type glow discharge, and our results agree well with another experiment (Ferreira *et al.*, 1980). However, the design of discharge source used in that work allowed measurements of axial distribution of gas temperatures in several fixed positions from the cathode only. In this paper we present results of absorption line profile measurements and gas temperature determination with better axial spatial resolution. For this experiment we use tunable diode laser.

2. EXPERIMENTAL

The experimental setup is presented schematically in Fig. 1. This discharge source, made in our laboratory, is a flat cathode and hollow cylindrical anode (a modified Grimm type) glow discharge source (GDS). This is well-established source for atomic emission and absorption spectroscopy. It is described in details elsewhere (Kuraica *et al.*, 1992). Here we shall mention only few important details. Hollow cylindrical anode has a longitudinal slot, 15 mm long and 1.5 mm wide for side-on measurements along the discharge axis. The argon pressure was kept constant at 230 Pa throughout the measurements and discharge current was stabilized at value I=10 mA. Water cooled iron cathode is used.

Radiation from tunable diode laser (SDL 5412-H1 with SDL 810 driver) are splitted by pelice beam splitter (Melles Griot) and one beam (1) are directed to the Fabry-Perot interferometer (free spectral range of 0.012 A at 852.1 nm) used to read small wavelength changes when the laser was tuned over transition. For this purpose the transmission peaks of the interferometer were detected with a photodiode PD1 (IHTM) and amplified by lock-in amplifier. Typical interference fringes are given in Fig 2. (b). Second beam (2) is directed towards negative glow parallel to the cathode of the discharge through the longitudinal slot. Several neutral density filters (NDF) were used to attenuate laser beam, wich was detected by the second photodiode PD2. Only a small part of laser power, 10 000 times attenuated by NDF), was coupled into the plasma to avoid saturation of the transition. After absorption in the discharge the intensity distribution of the outcoming laser beam (absorption line profile) is determined with lock-in technique, also. Typical absorption profile is presented in Fig. 2 (a). For both intensity measurements the lock-in amplifiers (SR 510, Stanford Research) are used in conjunction with a radiation chopper (SR 540, Stanford Research) operating at 374 Hz (see Fig. 1).

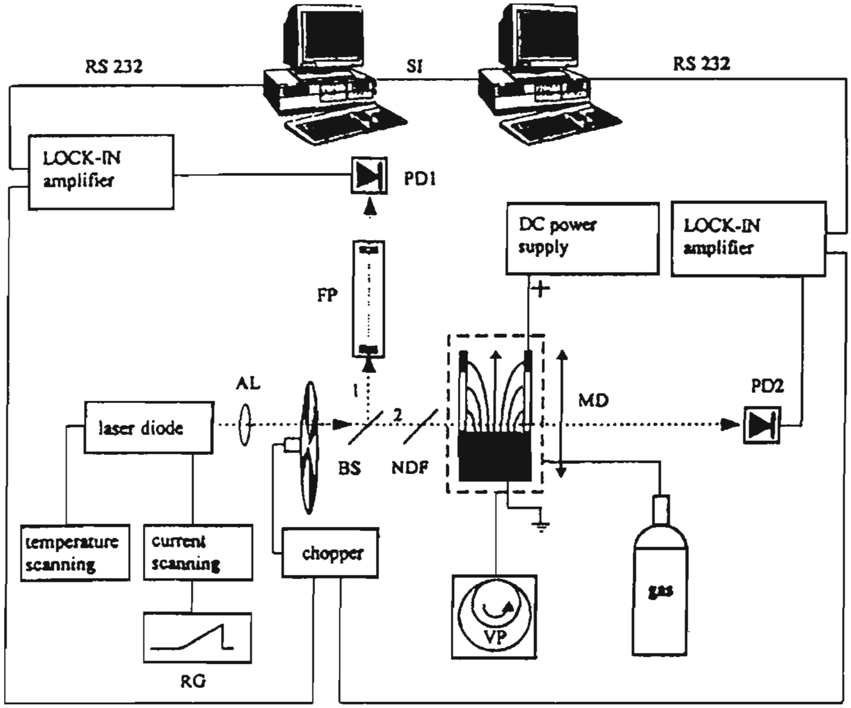

Fig 1. Schematic diagram of experimental setup.
Symbols: RG - ramp generator, VP - vacuum pump, FP - etalon Fabry-Perot, PD1,PD2 - photodiodes, BS - pelice beam splitter, NDF - neutral density filters.

A 100 mW laser diode (SDL 5412-H1) operates in the wavelength region (852 ± 7) nm in the single mode. In this region argon has one strong line originated from the transition $(4s'\,[^1/_2]^0 - 4p'\,[1^1/_2])$ λ=852.1443 nm, and this line is used for gas temperature measurements. According to the manufacturer the spectral linewidth of the laser radiation was $2\cdot10^{-5}$ nm. During the scan over the transition, the preselected laser diode temperature is kept constant. A ramp generator RG (Kronhite) is applied to the diode power supply to vary the laser diode current for fine tuning of the laser wavelength over the absorption line. By changing amplitude and offset of the RG it was possible to adjust the spectral range. This range was about 0.03 nm, which corresponds to five-six half-widths left and right from line center (see Fig.2). A scanning frequency of the ramp generator (f = 0.002 Hz) is used throughout the measurements. Good spatial resolution is achieved by focusing laser beam with an aspherical lens with focal length 4.50 mm (spot less then 0.1 mm in diameter). The whole experiment is controlled by two PC's and one of them is used for data analyses. For gas temperature axial distribution measurements, the discharge tube can be translated in 0.10 mm steps controlled with an analog comparator. In this work we presents only results at distance of 2 mm from cathode. At this distance from the cathode the gas temperatures measured by sputtered material and matrix gas lines are found the same (Ferreira *et al*, 1980).

3. RESULTS AND DISCUSSION

Typical absorption profile at the 2 mm from the cathode is given in Fig.2(a).

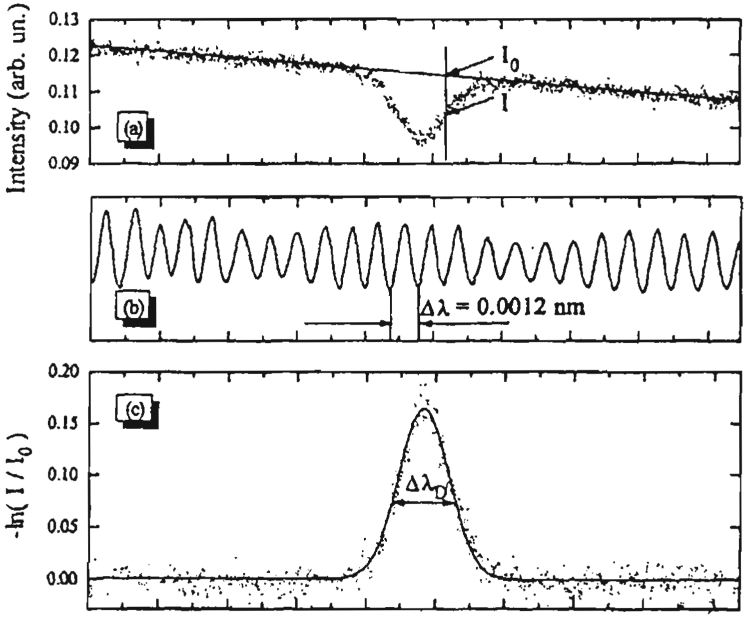

Fig. 2. (a)Typical experimental absorption profile. Discharge condition: I = 10 mA, P = 240 Pa, Fe cathode. (b) Simultaneously registrated interference fringes. (c) Absorption profile with Gaussian best fit.

In all these experiments intensity of the laser beam is attenuated in order to prevent saturation effects. These was checked by repeatedly recording of absorption line profile whose shape should not depend upon the laser beam intensity.

Since the electron density in our GDS is low (n_e=10^{14} cm^{-3}) (Kuraica *et al.*, 1992), Stark broadening of the line can be neglected (Griem, 1974). Pressure broadening at 240 Pa can be neglected also, so the major line broadening mechanism is Doppler broadening. Therefore the half width $\Delta\lambda_D$ of the spectral line (full-width at half maximum) depends only on the absolute temperature T and the atomic weight M of the argon. The temperature can be obtained from the following relationship:

$$T = 1.95 \cdot 10^{12} M \left(\frac{\Delta\lambda_D}{\lambda} \right)^2 \qquad (*)$$

where T is in K, M is in g.

From experimental profiles (see Fig. 2 (a)) are calculated absorption profiles (see Fig. 2 (c)) and fitted to Gaussian. In such way, the mean value $\Delta\lambda_D$ = 0.0028 nm is obtained. The gas temperature T = (820 ± 60) K is calculated from equation (#). This temperature are in good agreement with two emission experiments (Kuraica *et al.*, 1992; Ferreira *et al.*, 1980) (See Fig.3).

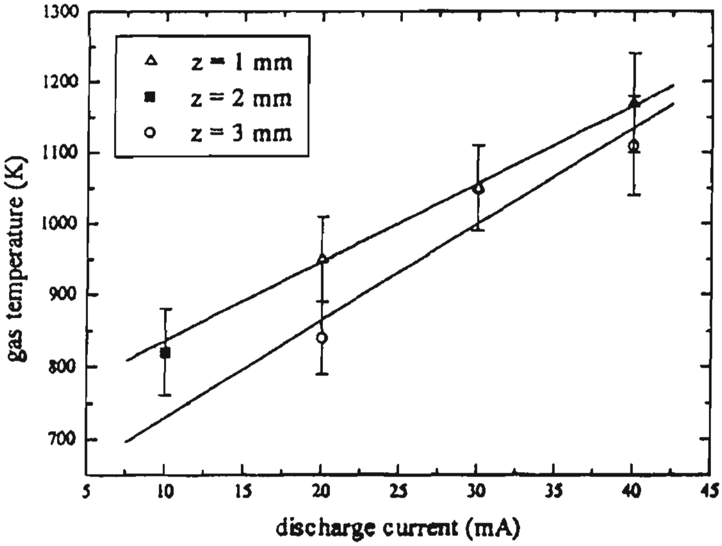

Fig 3. Gas temperature vs. discharge current dependence measured with Fabry-Perot interferometer at various distances (O - z = 3 mm, Δ - z = 1 mm) from the cathode and measured by laser absorption at z = 2 mm (■).

The laser absorption method presented here offers better spatial resolution then emission experiment combined by Fabry-Perot interferometer (Kuraica *et al.*, 1992). This absorption method is particular useful for the cathode fall region study, where line intensities are usually low. Further, experimental studies are directed towards detailed spatial gas temperature distribution measurements in our discharge.

References

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