SPATIAL DISTRIBUTION OF ROTATIONAL TEMPERATURE

IN THE GRIMM-TYPE GLOW DISCHARGE

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1. INTRODUCTION

Optical emission spectroscopy (OES) was used for determination of the rotational temperature from the spectra of nitrogen molecule. Relative rotational emission intensities are used to determine rotational temperatures under the assumption that the populations of molecular ions at the different energy levels follow a Boltzmann distribution. Here are followed classical papers (Boumans P.W.J.M,1966, Herzberg G., 1950) for the temperature determination.

We measured relative line intensities within R branch of even rotational quantum numbers of the First Negative System for (0-0) band in the Grimm type glow discharge. The spatial distribution of total intensity of whole band and rotational temperature of N_2^+ were determined. The results are presented at different pressures and currents.

2. EXPERIMENT

The experimental setup is presented schematically in Fig. 1. Our discharge source, a modified Grimm GD is laboratory made and described in detail elsewhere (M. Kuraica et al, 1992). Here, for completeness, minimum details will be given.
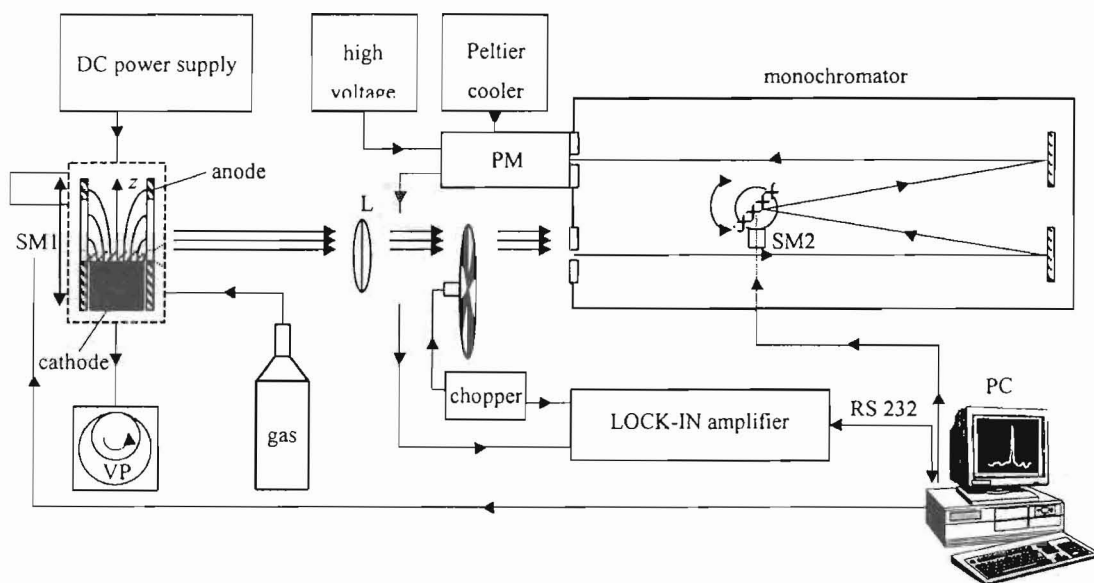
Fig. 1. Schematic diagram of the central part of Grimm GDS and experimental setup for side-on observations. Symbols: VP - vacuum pump, SM 1 and SM 2 - stepping motors L – lens, PM - photomultiplier.

The hollow anode 30 mm long with inner and outer diameters 8.00 mm and 13 mm, has a longitudinal slot (15 mm long and 1 mm wide) for side-on observations along the discharge axis. The water-cooled cathode holder has an exchangeable iron electrode, 18 mm long and 7.60 mm in diameter, which screws tightly into its holder to ensure good cooling. A gas flow of about 300 cm^3/min of nitrogen (99.995%) is sustained at variable pressure means of needle valve and a two-stage mechanical vacuum pump. To run the discharge a 0-2 kV, 0-100 mA current stabilized power supply is used. A ballast resistor of 10 kΩ is placed in series with the discharge and the power supply.

The radiation from the discharge source is focused with unity magnification (8 cm focal length achromat lens) onto the entrance slit of the scanning monochromator-photomultiplier system, see Fig. 1. For spectral line intensity axial distribution measurements, the discharge tube is translated in ≈0.1 mm steps by a stepping motor, so that the discharge image obtained through the observation slot is translated in the plane of the entrance slit (30 µm) of the monochromator. For the spectral recordings, 4 m Hilger and Watts Ebert type spectrometer with inverse dispersion of 0.242 nm/mm is used. All spectra are recorded with 30 µm entrance and exit slits, giving a Gaussian instrumental profile with 0.020 nm half-width. The monochromator is equipped with a stepping motor, which enables minimum wavelength change in steps of 0.0028 nm. For radiation detection, a photomultiplier with Peltier cooling is used. A lock-in signal amplification technique is employed. The entire experiment is controlled by a PC. The same computer is used for data acquisition.

3. RESULTS

In this paper are presented results of spatial distribution of whole line intensity and rotational temperature determination (as example Fig 3.) in the Grimm discharge with an iron cathode. The observation were performed side-on.

The method of determining a "rotational" temperature has been applied for the First Negative System of molecular ions N_2^+ which is $B^2\Sigma_u^+ - X^2\Sigma_g^+$ transition, for 0-0 band degraded to shorter wavelengths (Fig 2.).
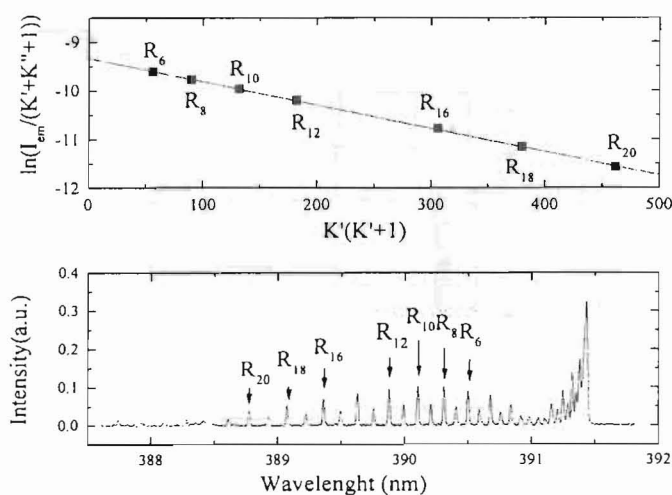

Fig.2. Example for emission spectra of the (0-0) band of the First Negative System of N_2^+ and a Boltzmann plot for lines R(6)-R(20) corresponding to a rotational temperature T_{rot}=620K.
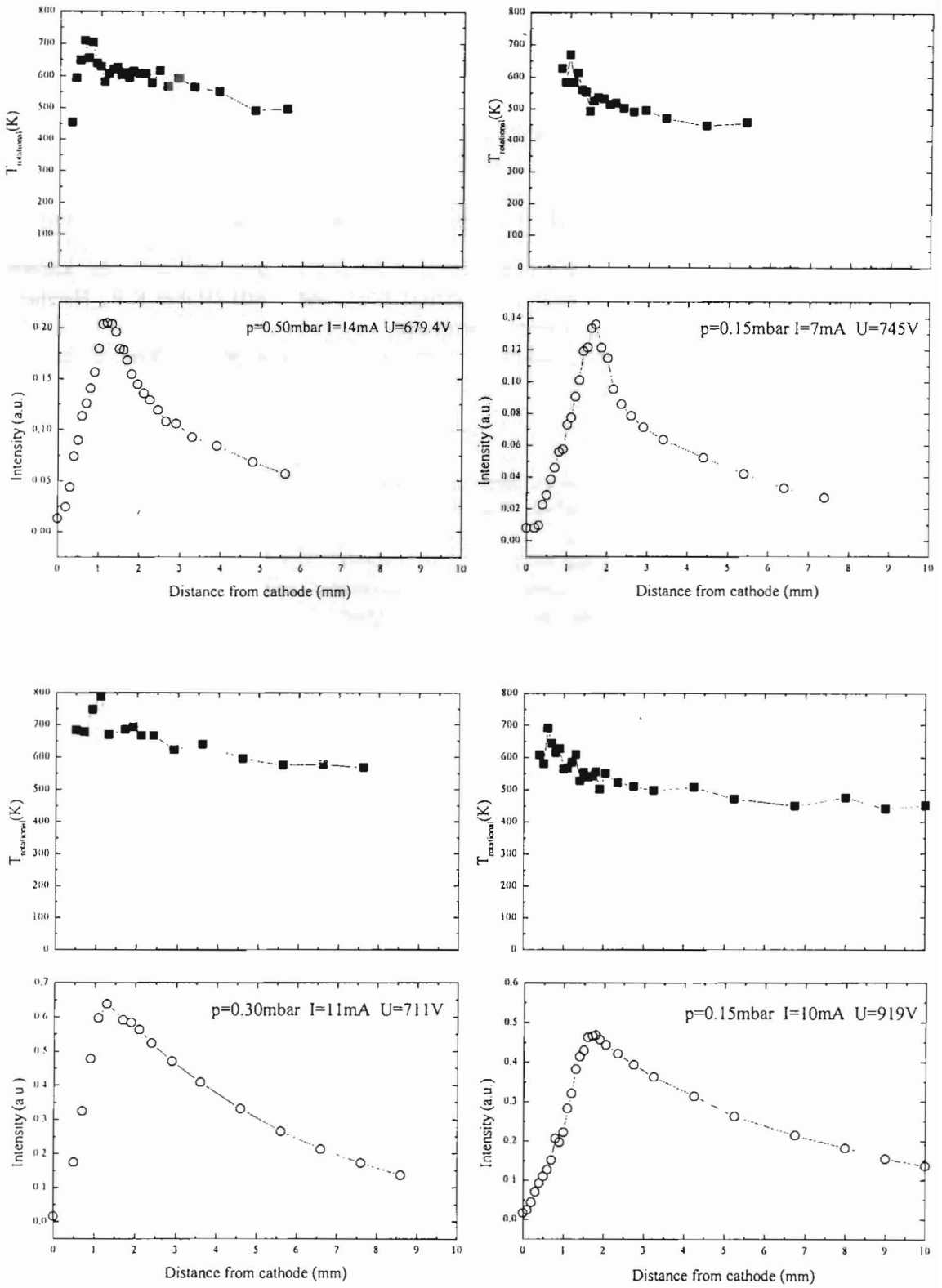
Fig.3. Spatial distributions of T_{rot} and whole band intensity for (0-0) band of the First Negative System of N_2^+ (391.44 nm) at different pressures and currents.

The variation of the intensity of the lines J_{em} in a rotational band as a function of quantum number J is given essentially by the thermal distribution of the rotation levels (Boumans P.W.J.M,1966, Herzberg G., 1950)

$$J_{em} = \frac{C_{em} v^4}{Q_r}(J' + J'' + 1)e^{-B_v J'(J'+1)\frac{hc}{kT}}$$ where $\frac{C_{em} v^4}{Q_r}$ very nearly is constant.

By plotting $\ln \frac{J_{em}}{J' + J'' + 1}$ against J'(J'+1) a straight line with the slope $\frac{B_v hc}{kT}$ is obtained. Relative intensities of R branch lines are measured from the band and with the known rotational constant of upper rotational states (from $B^2\Sigma_u$ and v'=0) (Huber K.P., Herzberg G.,1979) the temperature of the source were determined.

On the Fig.3. are presented results taken on three pressures and one of them is on two currents.

References

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