

H_{α} line Doppler broadening in a glow discharge cathode region in the argon–hydrogen mixture

A V Zobnin and A D Usachev

Joint Institute for High Temperatures of the Russian Academy of Sciences, Izhorskaya 13 Bldg 2, Moscow 125412, Russia

E-mail: zobnin@ihed.ras.ru

Abstract. Spectral measurements of Doppler profiles of the hydrogen H_{α} spectral line in a glow direct current discharge in a mixture of 1% hydrogen in argon at pressures of 60, 120 and 180 Pa were performed. Solid and mesh cathodes were used. It is brought out that the line shapes are Gaussian with the width corresponding to the effective temperature of the excited atoms of 35–60 eV for emission from the cathode region. The line width does not change with the pressure and the distance from cathode in the region of negative glowing and increases slightly with the distance from the mesh cathode outside of the discharge gap.

1. Introduction

Fast hydrogen atoms appear in a glow discharge cathode region because of acceleration of atomic and molecular ions and charge-exchange collisions or recombination on a cathode surface [1]. The fast electronically excited hydrogen atoms manifest themselves in broadened wings of the spectral lines in a plasma emission. In the case of discharge in the pure hydrogen the broadened components of the hydrogen lines essentially change with pressure and distance from cathode [2]. However, observations of the H_{α} line broadening in the argon–hydrogen mixtures demonstrate unusual and unexpected features. The broadened component in the spectral line is much intense in the argon–hydrogen mixtures than in the pure hydrogen [3, 4]. The excessively broadened component with a width about 0.25 nm was observed in bulk plasma of the radio frequency (RF) discharge [5, 6] far enough from powered electrode, and the width did not essentially change with the distance from the electrode [5]. In the paper of Akhar *et al* [4], the shape of the H_{α} spectral line was investigated in RF and direct current discharges in a wide pressure range. Independence of the line shape on the gas pressure and direction of view in the case of the argon–hydrogen mixture was reported. These results are difficult for explanation in the frame of field acceleration model and are causes for alternative hypotheses of the fast hydrogen atoms generation [4, 7].

The aim of this investigation is verification of the results reported in [4] and checking the role of the ion and electron acceleration in a cathode sheath of direct current discharge for the fast excited hydrogen atoms generation.

2. Experimental setup

We investigated the H_{α} spectral line shapes in a near-cathode region of the direct current glow discharge in the mixture of argon with 1% of hydrogen. In the first series of measurements, we used a flat solid nickel cathode, which was placed across a glass discharge tube (3 cm in inner



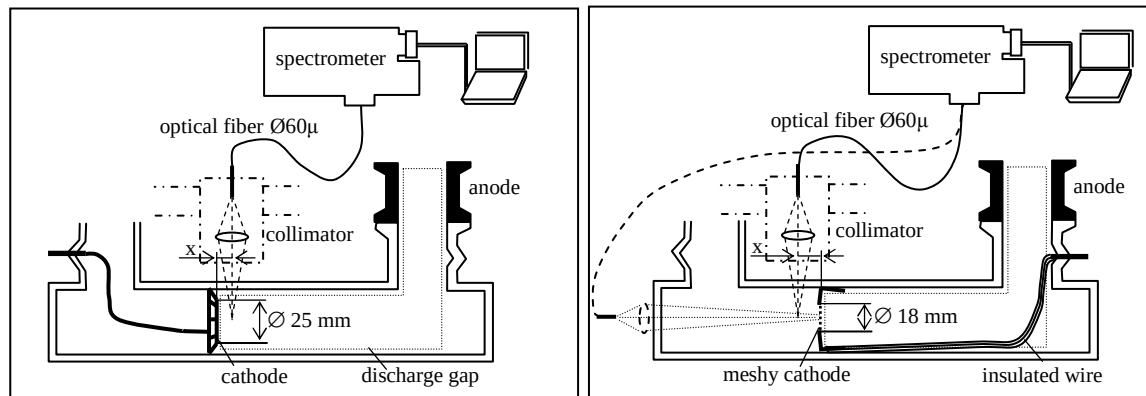


Figure 1. Experimental setup; two configurations.

diameter). The light emission was collected by a lens and optical fiber in the direction of view parallel to cathode surface at different distances from cathode, as shown in figure 1. In the second series, we used a mesh cathode with the mesh of 0.5 mm and 50% transparency. The cathode completely overlapped the discharge tube. The emission was collected in the direction parallel to the mesh at the side out of the discharge gap, as well as along the tube axis (from side of cathode). Spectra were recorded by a spectrometer assembled of the monochromator MDR-23 and CCD array system “MORS”. The spectral resolution was 0.07 nm. A pressure in the discharge chamber was varied from 60 to 180 Pa, a discharge current was 4 mA. A voltage on the discharge gap was in the range of 480–590 V.

3. Experimental results

The H_{α} spectral line shapes recorded in the first series at the pressure of 180 Pa and the current of 4 mA for distances 1.5 mm, 4.5 mm and 42 mm from cathode are presented in figure 2. The last distance corresponds to a stratum of positive column. The shape of line at 42 mm from cathode is similar to the instrumental profile. The line shapes are Gaussian without observable narrow component in the whole region of cathode dark space and negative glowing. Dependencies of H_{α} line integral intensities and widths in half-peak, as well as corresponding kinetic temperatures on distance from cathode are presented in table 1. The distance from cathode is denoted as x . The values of the line width in the table are corrected for the instrumental profile. While the line intensities decrease with x , the widths of line remain almost a constant. Decreasing of the line widths with the gas pressure is only 10% between 60 and 180 Pa.

Related data for the second series are presented in table 2. The H_{α} line shapes in side view emission are Gaussian also. A spectrum of H_{α} line in emission along the tube axis for 60 Pa is shown in figure 3 by a thick line. It contains narrow component, which appears from a positive column emission transmitted through the cathode mesh. The broad component is slightly asymmetric with the blue wing excess. A width of the broad component is about 0.40 nm and comparable with width of the line in side view emission at 9 mm from cathode, which is presented in figure 3 by a thin line.

4. Conclusion

Our experiments have demonstrated that in vicinity of cathode the excited hydrogen atom velocity distribution function exhibits the intriguing features. It is almost isotropic and Maxwellian-like with the temperature about 40 eV. This temperature only slightly changes with the gas pressure, does not depend on the distance from the cathode in the negative glowing

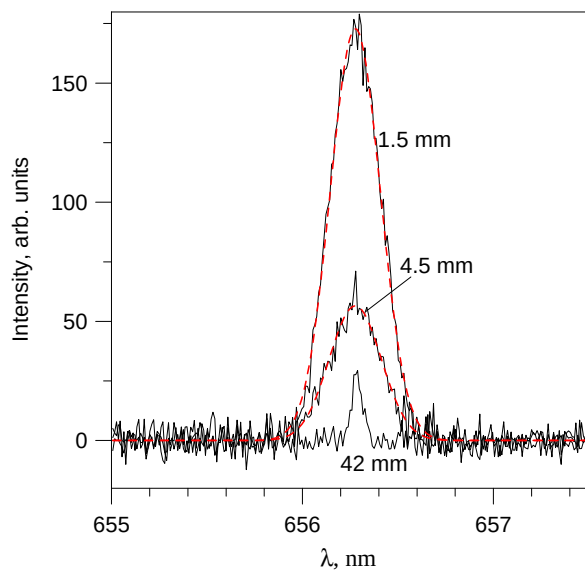


Figure 2. H_{α} line spectra in the negative glowing of discharge (1.5 and 4.5 mm from cathode) and in a stratum (42 mm from cathode) at the pressure of 180 Pa; dashed red lines—Gaussian approximations.

Table 1. Relative intensities and widths of H_{α} line and kinetic temperatures of excited hydrogen atoms at different distances from cathode in the cathode region.

x , mm	Intensity, a.u.	Width, nm	Error, %	Temperature, eV
60 Pa				
1.5	6.9	0.339	2	45
3.0	7.2	0.325	2	41
4.5	5.6	0.309	3	37
7.5	3.1	0.309	4	37
13.5	1.1	0.311	7	38
120 Pa				
1.5	8.5	0.327	2	42
2.25	7.5	0.321	2	40
3	5.7	0.315	3	39
6	2.4	0.303	5	36
9	1.0	0.314	7	38
180 Pa				
1.5	4.8	0.303	3	36
3	3.4	0.307	4	37
4.5	2.0	0.309	5	37
6	1.0	0.295	7	34
9	0.3	0.272	10	29

space of discharge, and even increases up to 60–70 eV away from the mesh cathode outside of the discharge plasma. A presence of the broadened H_{α} emission behind the mesh cathode indicates the dominant role of the ion acceleration in the excited fast atoms formation and contradicts the alternative resonance transfer model [7]. Unexpected behavior of the line width

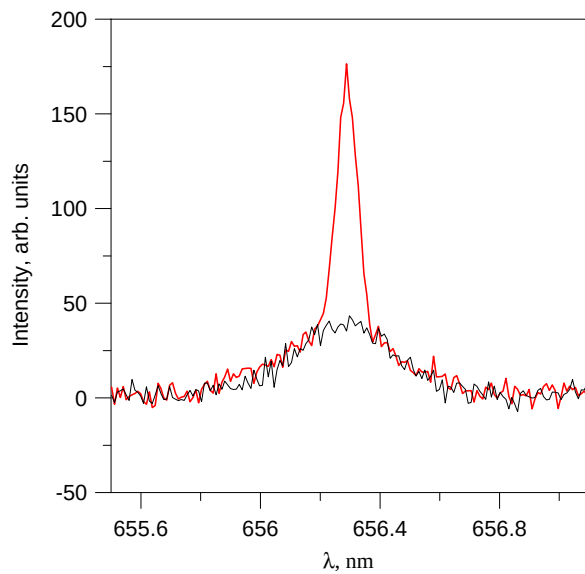


Figure 3. H_{α} line spectra for a view along the tube axis (thick red line) and for the side view at 9 mm behind the mesh cathode (thin black line) at the pressure of 60 Pa.

Table 2. Relative intensities and widths of H_{α} line and kinetic temperatures of excited hydrogen atoms at different distances from the mesh cathode outside of discharge.

x , mm	Intensity, a.u.	Width, nm	Error, %	Temperature, eV
60 Pa				
1.5	2.7	0.327	5	42
3	2.4	0.314	5	39
4.5	2.4	0.335	5	44
6	2.0	0.337	5	44
7.5	1.8	0.384	6	57
9	1.5	0.381	6	57
10.5	1.4	0.387	6	58
120 Pa				
1.5	1.9	0.383	3	57
3	1.6	0.408	3	65
4.5	1.3	0.394	4	61
6	1.0	0.408	4	65
7.5	1.0	0.430	4	72
9	0.8	0.400	5	62

with distance from high field region of discharge can be explained by excitation of long-living high-excited hydrogen levels with large angular momentums in the hydrogen–argon collisions. An assumption that the H_{α} emission arises by cascade from nf levels does not contradict emission cross-section measurements [8].

Acknowledgments

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