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Distributions of plasma parameters in the gap between two subsequent stabilizing plates in a cascade arc

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Abstract. Wall-stabilized arcs are commonly used as excitation sources of atoms and low charged ions. Distributions of plasma parameters in the gap between two subsequent stabilizing plates were studied in argon and helium which are commonly used as 'working gas' in experiments aimed at determination of atomic constants. The results were obtained solving set of equations describing plasma in local thermal equilibrium (LTE). As conditions of LTE may be not completely fulfilled obtained absolute values obtained by this method could be deviated from the real one. Nevertheless, the shape of spatial plasma parameters distributions ought to properly represent shape of the plasma. Obtained results reveal very small gradients of plasma parameters in the central part of this gap. This result can be important in future planning of experiments with side-on plasma observation.

Key words: arc discharge • wall-stabilized arc

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Introduction

Wall-stabilized arcs are commonly used as excitation sources of atoms and low charged ions. Because of their high stability, well defined geometry and equilibrium state (at least close to LTE i.e. local thermal equilibrium conditions) the arcs are commonly used in researches aiming at determination of atomic constants as transition probabilities [3] or Stark broadening parameters [1]. In such experiments the plasma is usually produced in inert gas atmospheres (argon or helium) with only small admixtures of the element under study.

The plasma radiation is registered either end-on (i.e. along the plasma column) or side-on (i.e. perpendicular to the plasma column). In the first case the interpretation of registered spectra is usually performed assuming uniformity of the plasma along the arc length. In the case of side-on observation, it is possible to determine radial distributions of plasma emissivity, assuming cylindrical shape of the plasma column and applying the Abel inversion method [2]. In both cases the registered radiation is integrated along the line of sight and originates from well defined plasma volumes.

Wall-stabilized arcs as a simple, stable devices with well defined geometry can be also applied for studies and modeling the properties of arc discharges. The purpose of this work is to study the distributions of plasma parameters in the gap between two subsequent stabilizing plates of the wall-stabilized arc. The results can be important for planning experiments devoted to determination of atomic constants based on spectra registered in side-on direction. By studying plasma parameters gradients between stabilizing plates, one

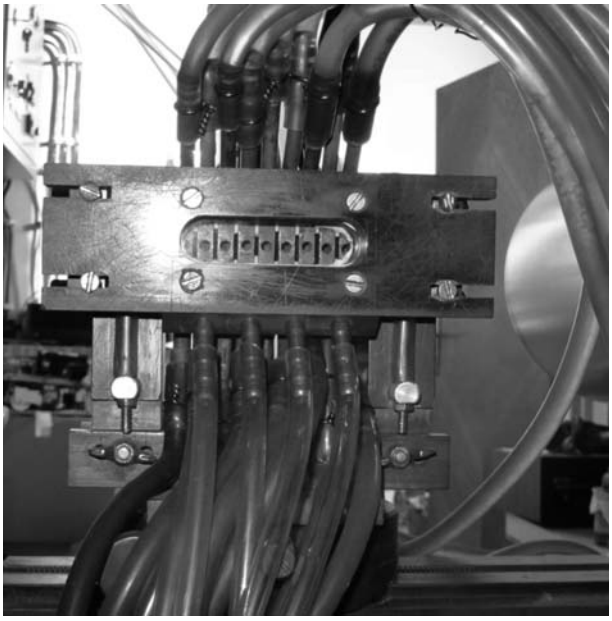

Fig. 1. The device (wall-stabilized arc) used in this work.

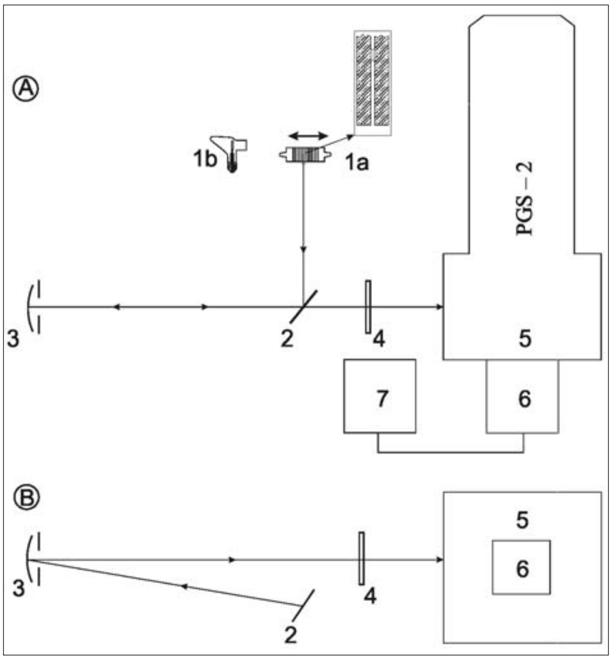

Fig. 2. The scheme of optical set-up: A – top view; B – side view; 1a – wall-stabilized arc; 1b – tungsten strip lamp; 2 – plane mirror; 3 – concave mirror; 4 – filter; 5 – spectrometer; 6 – CCD detector; 7 – computer.

can define requirements and criteria for plasma device positioning and application of solid angles of the optical system, for reliable registration of plasma radiation. The results can also be compared with those obtained from different plasma modeling techniques [4].

Experimental results

A wall-stabilized arc consisting of 11 copper plates 5 mm thick, separated by 1.5 mm teflon rings was applied (Fig. 1). The stack of copper discs with central orifices of 4 mm in diameter formed the discharge channel. The stabilizing plates were cooled by flowing tap water. The insulating rings were cut at a length which allow the observation of radiation originating from the plasma volume between stabilizing plates. The wall-stabilized arc was mounted on translational stage driven by a stepping motor. The optical imaging system and grating spectrometer PGS-2, equipped with a two-dimensional (2-D) CCD detector allowed lateral distribution of selected spectral regions to be registered. Eighty spectra at different axial positions (along the arc axis), within one selected gap between stabilizing plates, were registered. The spacing between measurement positions (i.e. cross-sections of plasma column) along the discharge axis was 0.025 mm (Fig. 2).

Applying a grating with 651 grooves/mm and dividing the CCD detector area into 64 tracks one can register simultaneously the lateral distribution of radiation in the wavelength range 654–668 nm. This spectral range can be used for studying argon as well as helium plasmas, because in this interval well separated spectral lines of the main plasma components – Ar I 667.7 nm and He I 667.8 nm appear. Because the applied gases are slightly contaminated with hydrogen, the hydrogen line H I 656.3 nm was simultaneously registered. From measured Stark-broadening parameters (FWHM) of this line the electron densities of the plasma can be determined.

In case of the arc discharge in helium, small amount of argon was introduced into near-electrode regions in order to improve the stability of the arc source. The diffusion of this admixture towards the central part of the arc results in emission of Ar II lines as one can see in Fig. 3.

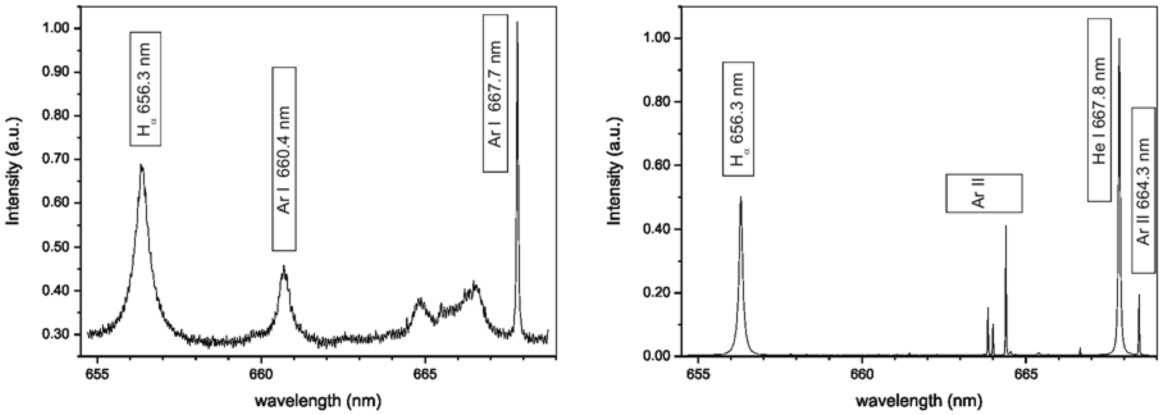

Fig. 3. Spectra in the selected wavelength range in argon and helium plasmas are shown.

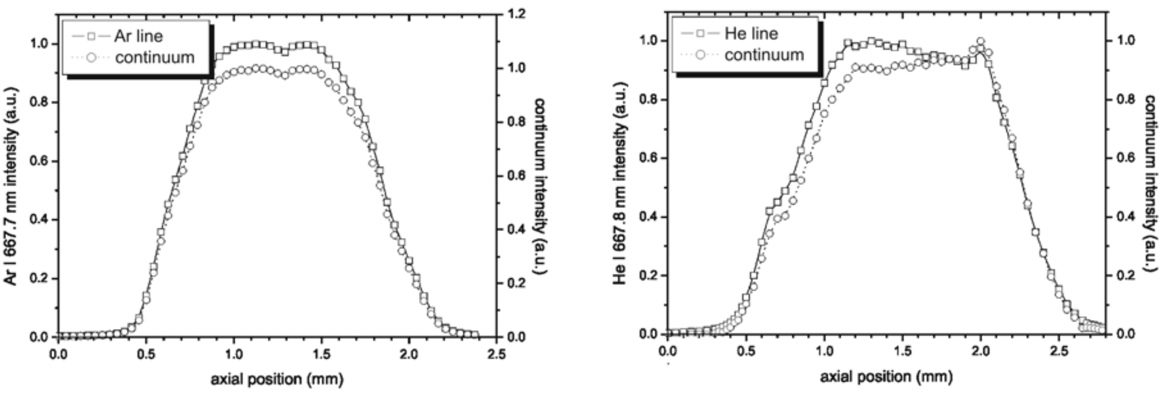

Fig. 4. Axial distributions of intensities integrated along plasma column diameter, registered within the gap between two subsequent stabilizing plates. The circles represent the continuum intensity; rectangles represent the intensity of the selected line of the main plasma component, i.e., argon or helium.

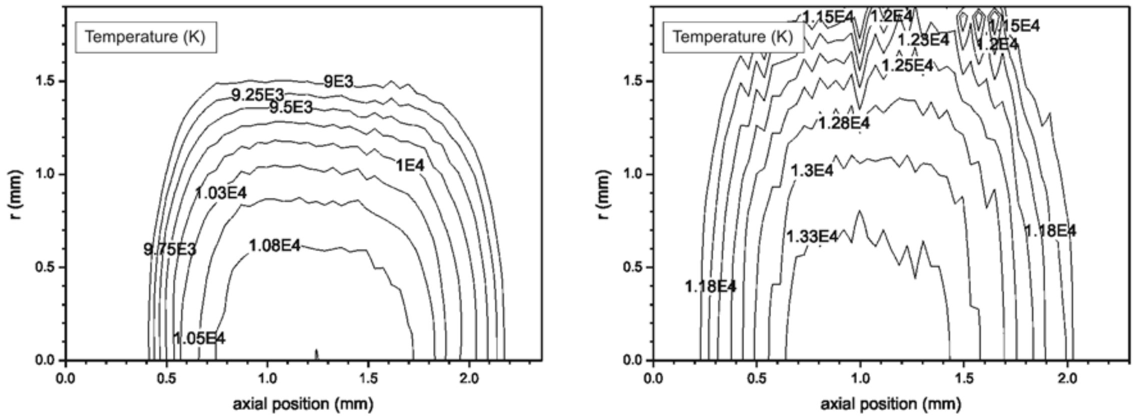

Fig. 5. Radial temperature distributions in a plasma column.

By selecting one track on the CCD detector plate one can determine the radiation integrated along the diameter of the plasma column. By fitting Gaussian profiles to Ar I and He I lines the intensities of these spectral lines were determined. By selecting a well defined range of the spectrum in the far wings of the spectral lines one can estimate the intensities of the continuum. Performing such procedure for eighty cross-sections of the plasma column along the gap between two subsequent stabilizing plates, the axial distribution of the line and continuum intensity can be determined (see Fig. 4).

Based on measurements of the standard source (tungsten strip lamp) the absolute values of spectral intensities were determined. After performing the Abel inversion procedure, the radial distributions of spectral line emissivities were obtained. Then, by solving a set of equations, describing the plasma in local thermal equilibrium conditions, one can determine radial distributions of plasma parameters. The set of equations consists of: Dalton law together with the gas equation (assuming pressure as constant and equal to 101.3 kPa), Saha-Eggert law describing the ionization equilibrium, and Boltzmann law describing the population of excited states for atoms and ions. By solving this set of equations for subsequent cross-sections of the plasma column, the spatial distributions of plasma parameters were obtained. In Fig. 5 the determined temperature distributions are presented.

As the conditions of LTE could not be completely fulfilled, especially in case of the helium plasma, the absolute temperature values can slightly deviate from the real one but the shape of plasma parameters distributions ought to be correct.

Summary and conclusions

This work is our first attempt to determine the plasma parameters within the gap between the stabilizing plates of the arc which is our laboratory plasma source often applied for determination of atomic constants. The obtained results shows that in the central part of the gap, the gradients of plasma parameters are very small, so precise positioning of the wall-stabilizing arc is not a crucial point in experiments based on side-on registration.

The obtained results can be influenced by scattering of the plasma radiation on the arc side-window and somewhat too large solid angle of the optical system. In further experiments one ought to modify the optical system in order to reduce the influence of scattered and reflected radiation and improve the spatial resolution.

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