PRELIMINARY STUDY OF PLASMA STREAM INTERACTION WITH TUNGSTEN TARGET WITHIN RPI-IBIS FACILITY

E. Skladnik-Sadowska [1], K. Malinowski [1], M.J. Sadowski [1], K. Czaus [1], A. Marchenko, A.V. Tsarenko [2]

[1] The Andrzej Soltan Institute for Nuclear Studies (IPJ), 05-400 Otwock-Swierk, Poland, e-mail: eskladnik@ipj.gov.pl;

[2] Institute of Plasma Physics, NSC KIPT, Kharkov, Ukraine, e-mail: marchenkoak@kipt.kharkov.ua

The paper presents results of experimental research on the interaction of a pulsed plasma-ion stream with a tungsten (W) target. The pulsed hydrogen plasma was produced within the RPI-IBIS (Multi-Rod Plasma Injector) facility at IPJ in Swierk. Measurements were carried out by means of optical spectroscopy and corpuscular diagnostic techniques. For experiments with the W-target the operational conditions (so-called PID mode) were chosen when a clean hydrogen plasma stream was generated. Attention was paid to the identification of WI and WII spectral lines.

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1. INTRODUCTION

The pulsed plasma streams, which are produced by coaxial multi-rod injectors (so-called RPI- or IONOTRON-type facilities), have been studied at IPJ for many years [1-3]. The studies performed during recent two years have shed some new light on the operation of such devices [4-7]. Detailed spectroscopic- and corpuscular-measurements appeared also to be of importance for various applications of such plasma facilities. In general the spectroscopic studies deliver important information about dynamics and parameters of the investigated plasma streams, and they are of primary importance for research on the interaction of plasma streams with different targets. The main aim of this paper was to present results of the recent experimental studies.

2. EXPERIMENTAL SET-UP

The recent studies have been performed mainly within the RPI-IBIS facility [5], which was powered from a current pulse generator charged to U_0 = 30 kV, W_0=33 kJ. The operational mode of the device was varied by changes of a time delay (τ) between the gas puffing and the application of a high-voltage pulse. A scheme of this facility is shown in Fig.1

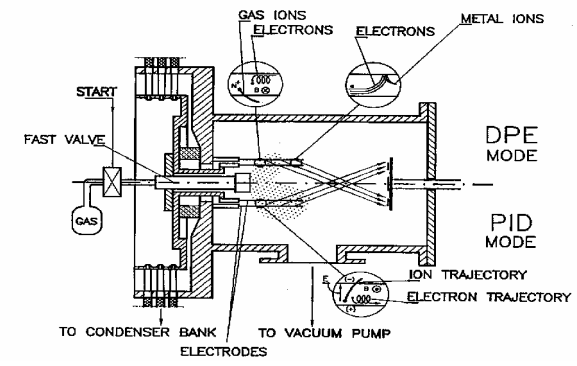

Fig.1. RPI-type facility and its operation modes

The location of the pure tungsten target, which was placed at a distance of about 20 cm from the electrodes outlet, is shown in Fig.2. Spectroscopic measurements of tungsten plasma, which was produced during the interaction of a hydrogen plasma (mostly protons) stream with the tungsten target, were performed by means of the Mechelle®900 optical spectrometer. It was able to record optical spectra in the wavelength range from about 300 nm to 1100 nm, with expositions varied from 100 ns up to 50 ms.

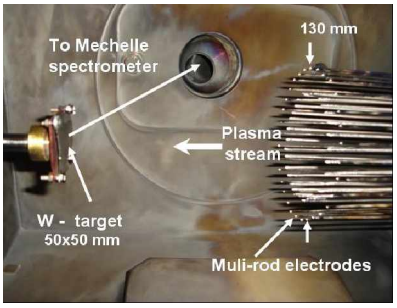

Fig.2. Picture of the ends of multi-rod electrodes and the tungsten target placed inside the RPI-IBIS chamber

In order to determine the spatial structure of the produced proton streams we applied a miniature ion-pinhole camera equipped with exchangeable nuclear track detectors (NTD). An analysis of the mass- and energy-spectrum of the proton streams was performed by means of a Thomson-type spectrometer.

3. SPECTROSCOPY OF PLASMA-ION STREAMS

During the spectroscopic studies particular attention was paid to observations of the Balmer spectral lines of the working gas, i.e. D_α – 656.10 nm, D_β – 486.029 nm and D_γ – 433.298 nm. Before the insertion of the tungsten target into the RPI-IBIS vacuum chamber, we determined the operational gas conditions (PID mode), when a clean hydrogen plasma stream was generated. To study influence of the initial gas conditions, the detailed spectroscopic measurements were performed at different time delays (τ) between the gas puffing and the application of the voltage (current) pulse. A dependence of intensities of the observed spectral line on the time delay values is presented in Fig. 3.

The described measurements confirmed a strong dependence of the basic plasma parameters on the initial

gas conditions, which were varied by changes of the delay time (τ). The selection of the optimal operational conditions could be performed on the basis of the observation of the selected spectral lines.

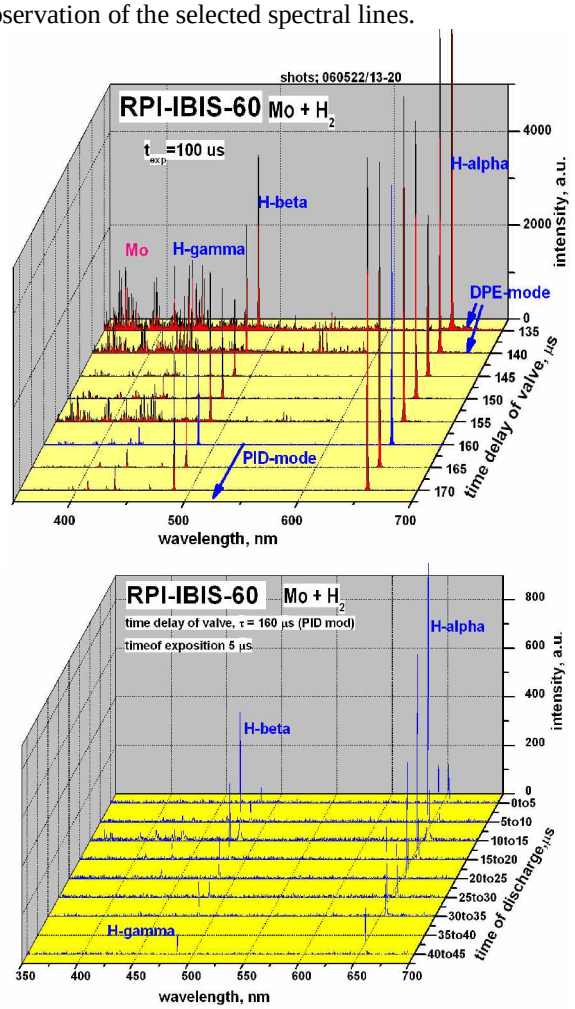

Fig.3. Optical spectra of the pulsed plasma streams emitted from the IBIS-RPI facility, which were recorded at z = 20 cm and exposition of 100 μs (vs time delay) and 5 μs (vs time of discharge) for shots performed at U_0 = 29 kV, W_0 = 33 kJ, and H_2–puffing

On the basis of the obtained spectra it was possible to estimate values of the electron density and temperature of the hydrogen plasma streams, as shown in Fig.4.

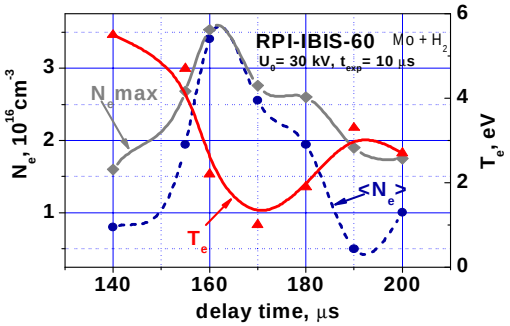

Fig.4. Average values of the electron density and temperature, as estimated from optical measurements performed at z=10 cm and different operational modes

It was observed that for time delays longer than 160 μs the RPI-IBIS facility generated the clean hydrogen (proton) plasma streams, and such conditions were chosen for experiments with the tungsten target. The pure tungsten target of dimensions 50 x 50 mm was usually placed at a distance of z = 20 cm from the electrode outlet (as described above). Using the Mechelle®900 spectrometer we recorded and identified the tungsten spectral lines, as shown in Figs. 5 and 6.

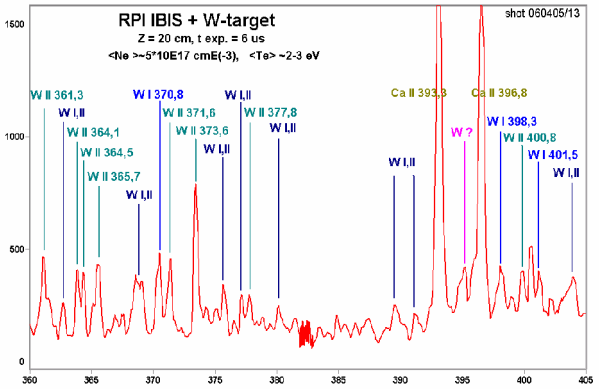

Fig.5 Portion of the spectrum (360…405 nm) recorded at the exposition time equal to equal to 6 μs, which shows distinct tungsten (WI and WII) spectral lines

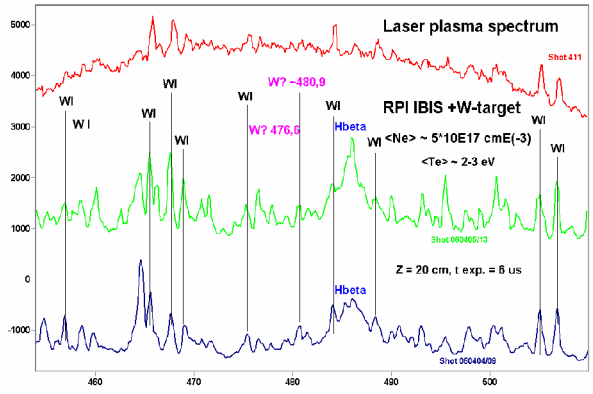

Fig.6 Intensities of the spectral lines measured within the RPI-IBIS experiment for a chosen spectrum portion (near the D_β line) at the exposition time equal to 6 μs. For a comparison the spectrum of a laser-produced tungsten plasma plum [8] is shown on the top

To prove that the recorded spectral lines were emitted from tungsten plasma, we performed spectroscopic measurements also for shots without any target. Some examples of the recorded spectra are shown in Fig.7.

4. MASS- AND ENERGY-ANALYSIS OF IONS

In order to get information about mass- and energy-spectrum of ions, time-integrated measurements of the investigated plasma-ion streams were performed with a Thomson-type spectrometer adjusted along the z-axis. It was equipped with the input ion-acceleration system and exchangeable PM-355 nuclear-track detectors. The Thomson parabolas, which were obtained on the track detectors after their appropriate etching, have been analyzed with an optical microscope. To perform an accurate analysis of the ion tracks, the use was made of an automatic system consisted of a CCD camera coupled with a fast PC (Pentium II) equipped with the Image-Pro-Plus software. The energy distributions of ions, i.e. deuterons obtained from shots performed with the deuterium puffing at different operational modes (defined by various time delays), are shown in Fig. 8.

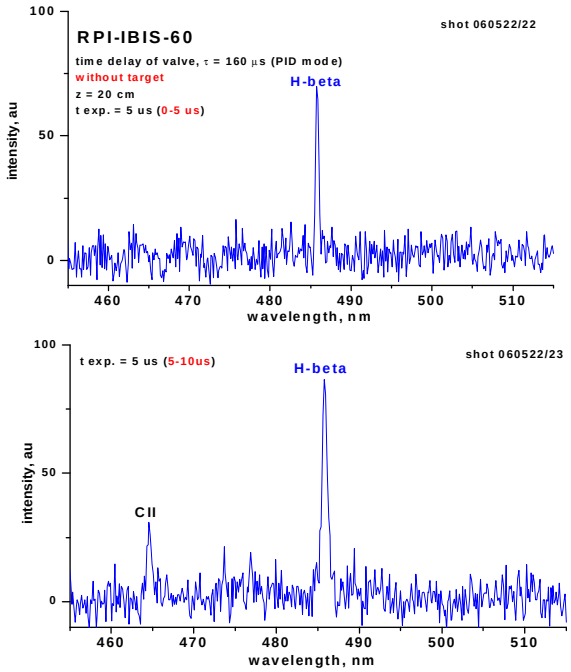

Fig.7. Spectral lines observed for hydrogen shots within the RPI-IBIS facility without any target, at the same observation plane (z = 20 cm) and different phases of the discharge (0..5 μs and 5..10 μs)

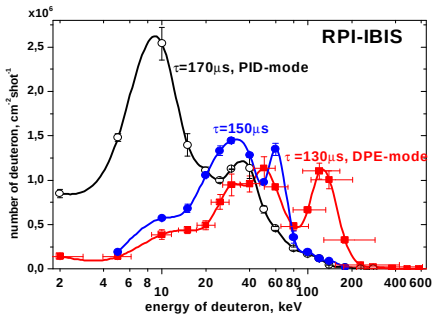

Fig.8. Energy spectra of deuterons obtained at different gas condition. The bars show experimental errors

On the basis of the ion energy spectra, obtained from various shots performed with the pure deuterium puffing and different time delays (τ), it was possible to determine the average energy values and total numbers of the emitted deuterons.

5. SUMMARY AND CONCLUSIONS

The results of this work can be summarized as follows:

- The described experiments, which were performed within the RPI-IBIS facility equipped with the multi-rod plasma injector, concerned the interaction of pulsed plasma streams with tungsten targets.
- The chosen operation regime of the injector (PID mode) ensured the generation of a clean hydrogen-plasma stream. Average energy of protons decreased from about 70 keV to a few keV with an increase in the gas-puffing delay (τ). The total number of protons was the highest at time delays τ = 160…190 μs.
- For the first time, using a Mechelle-900 optical spectrometer, we recorded distinct spectral lines (WI and WII) emitted from tungsten plasma produced during the interaction of the hydrogen plasma stream with the tungsten target.

The obtained results, i.e. the optical spectra and other characteristics, have demonstrated applicability of the RPI-IBIS facility for further research on the interaction of plasma streams with tungsten targets, e.g. those of particular interest for a future fusion reactor.

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ИЗУЧЕНИЕ ВЗАИМОДЕЙСТВИЯ ПЛАЗМЕННОГО ПОТОКА С ВОЛЬФРАМОВОЙ МИШЕНЬЮ НА УСТАНОВКЕ СПИ-ИБИС

Э. Складник-Садовска, К. Малиновский, М. Садовский, К. Чаус, А. Марченко, А. Царенко

Представлены результаты экспериментального исследования по взаимодействию импульсного плазменного потока с вольфрамовой мишенью. Установка СПИ-ИБИС (стержневой плазменный инжектор) генерирует импульсные водородные плазменные потоки. Измерения проводились с помощью оптической спектроскопии и корпускулярной диагностики. Для экспериментов с вольфрамовой мишенью был выбран рабочий режим, когда генерируется чистый водородный плазменный поток. Большое внимание уделялось идентификации спектральных линий WI и WII.

ВИВЧЕННЯ ВЗАЄМОДІЇ ПЛАЗМОВОГО ПОТОКУ З ВОЛЬФРАМОВОЮ ПЕРЕШКОДОЮ НА ПРИСТРОЇ СПІ-ІБІС

Е. Складнік-Садовська, К. Маліновський, М. Садовський, К. Чаус, А. Марченко, О. Царенко

Представлено результати експериментального дослідження по взаємодії імпульсного плазмового потоку з вольфрамовою перешкодою. Пристрій СПІ-ІБІС (стержневий плазмовий інжектор) генерує імпульсні водневі плазмові потоки. Виміри проводились за допомогою оптичної спектроскопії та корпускулярної діагностики. Для експериментів з вольфрамовою перешкодою було обрано робочий режим, коли генерується чистий водневий плазмовий потік. Велика увага приділялась ідентифікації спектральних ліній WI та WII.