June 15-18, 2025

High Tatras, Podbanské

PROCEEDINGS OF ADEPT

Advances in Electronic and Photonic Technologies

Editors

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I. Lettrichova

ADEPT Advances in Electronic and Photonic Technologies

2025

PROCEEDINGS OF ADEPT

13th International Conference on **ADVANCES IN ELECTRONIC AND PHOTONIC TECHNOLOGIES**

Advances in Electronic and Photonic Technologies

Podbanské, High Tatras, Slovakia

June 15 - 18, 2025

UNDER THE AUSPICES OF

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University of Žilina,
Žilina, Slovakia

ORGANIZED BY

Institute of Electronics and Photonics,
Faculty of Electrical Engineering and Information Technology,
Slovak University of Technology, Bratislava

Department of Physics,
Faculty of Electrical Engineering and Information Technology,
University of Žilina, Žilina

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Introduction

The international conference on

ADVANCES IN ELECTRONIC AND PHOTONIC TECHNOLOGIES (ADEPT 2025)

is the 13th conference focused on the latest results of research and development in the area of novel materials, structures, devices and systems for micro/nano- electronics, sensors and photonic solutions. Its goal is to bring together leading experts with young generation of researchers from universities, as well as institutes interested in progress of advanced technologies.

The conference attracted young and senior scientists from Slovakia and other countries to submit 69 abstracts. In review process 64 papers have been accepted for publishing in conference proceedings as 63 contributed and 1 invited paper divided in 36 oral and 28 poster presentations. At this point, we would like to thank all reviewers for review activities and valuable comments.

The objective of ADEPT 2025 is to provide a forum for researchers, teachers and engineers involved in general areas of electronics, photonics and material engineering to disseminate their research results, exchange views on future research directions and to create partnership for further fruitful collaboration in specified fields. We believe that ADEPT will create this new space for scientist from field of electronics and photonics.

Editors

DIAGNOSTIC OF TUNGSTEN PS LASER INDUCED PLASMA PRODUCED UNDER AIR AT ATMOSPHERIC PRESSURE

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Abstract *For fusion devices, tungsten (W) and W based alloys are potential material for the first wall (FW) and other plasma facing components (PFC). Laser-induced breakdown spectroscopy (LIBS) is the most promising "online" and "remote" analytical method for the monitoring of the material migration and the D/T fuel retention in the FW. In this work, picosecond (~250 ps) LIBS spectra of pure W were recorded, and the selection of self-absorption and interference free lines were selected for the plasma characterization. The plasma temperature T_e was calculated using the Boltzmann plots (BP) of W I for the characterisation of ps laser excitation capabilities (250 ps, 2 mJ/pulse, fluence of 1.7 J/cm^2). The obtained T_e (0.41-0.44 eV) was compared with LIBS plasma generated by shorter pulse ps laser.*

Keywords Laser induced breakdown spectroscopy (LIBS), ps laser, Tungsten

1. INTRODUCTION

The nuclear fusion reaction usually takes place in the vessel with magnetic confinement to keep the hot plasma away from the FW of the reactor. The FW and PFC are exposed to the heat flow, strong flux of energetic neutral particles, neutrons and plasma radiation. Plasma interactions with FW leads to sputtering of the material from the walls, and consequent migration and re-deposition of sputtered particles on the other places of the vessel. D/T fuel is, to some extent, trapped and retained in the FW, levels of which should not exceed the pre-defined limits and must be monitored [1].

Suitable techniques for elemental composition/fuel retention include secondary-ion mass spectrometry (SIMS), thermal desorption spectroscopy (TDS), nuclear reaction analysis (NRA) and LIBS [2-7]. Whereas SIMS isn't absolute, TDS, SIMS require sample preparation, NRA is not suitable for the scanning and depth profile analysis and only LIBS, can be applied "*in situ*" and "*remotely*" using eventually a robotic arm [8-11].

First wall of high temperature plasma devices dedicated for fusion (operated: e.g. JET, WEST, in construction: ITER) are from tungsten as W has highest melting temperature and good resistance for high heat flow [12]. W and other high Z materials have very high number of spectral lines (several thousand of neutral and singly ionised spectral lines in the range 200-1000 nm according to the spectral lines databases [13-14]).

For accurate determination of T_e, and subsequent CF approach [15], it is necessary to find a suitable subset of sufficiently strong lines that don't suffer from interference or self-absorption. the case of ps laser pulse the intensity of LIBS spectra should be less important than in the case of ns pulse.

The advantage of ps over ns ablation is the lower energy per pulse threshold for plasma generatrion, leading to greater depth resolution due to lower ablation rate. This work builds upon recent works on PFC/fusion related sample analysis done by ps LIBS; i.e. comparison of measured LIBS spectra generated at fundamental Nd:YAG laser wavelength at 1064 nm using 8 ns a 150 ps laser pulse [16], the influence of the laser fluence in vacuum on LIBS spectra using 35 ps laser was tested on a Mo sample [17], depth profile LIBS-analysis of the PFC from Wendelstein 7-X stellarator samples in combination with the laser induced ablation QMS method using 35 ps laser excitation at 355 nm [18], and ablation and plasma generation of W and W-based materials by ps lasers [19-21]. The goal of this work is the selection of W suitable lines for the precise T_e evaluation by the BP for ps LIBS (pulse duration >100 ps).

2. EXPERIMENTAL SET-UP

LIBS spectra of pure W were measured in ambient air at atmospheric pressure using an passively Q-switched, diode-pumped solid-state picosecond laser (QS Lasers, model MPL2210) with pulse duration 250–270 ps, pulse energy 2 mJ and repetition rate up to 100 Hz. Plasma plume emission was guided to the spectrometer via an optical fibre (Thorlabs, 0.5 NA, 1000 μm core diameter) and analysed using an echelle spectrometer (ME5000, Andor Technology, aperture F/7, resolving power λ/Δλ= 4000) equipped with an iCCD camera (iStar DH734I-18F-03, Andor Technology). Broadband optical emission spectra (200–975 nm) were recorded with different delay and gate time (80 ns / 40 ns, 100 ns / 200 ns, 500 ns / 250 ns). Accumulation of 50 shots per spectrum was done from 2 different spots on the sample surface to improve SNR. Energy for the ps laser was 2 mJ/pulse giving the fluency 1.74 J/cm^2.

3. RESULTS AND DISCUSSION

For precise T_e evaluation using Boltzmann plots and for calibration free LIBS [15], the selection of suitable W lines is necessary. Pure W, WCu alloys or W containing mixed layers were studied by ps and ns LIBS, resp. [19-21], where suitable W lines were identified, selection which depended

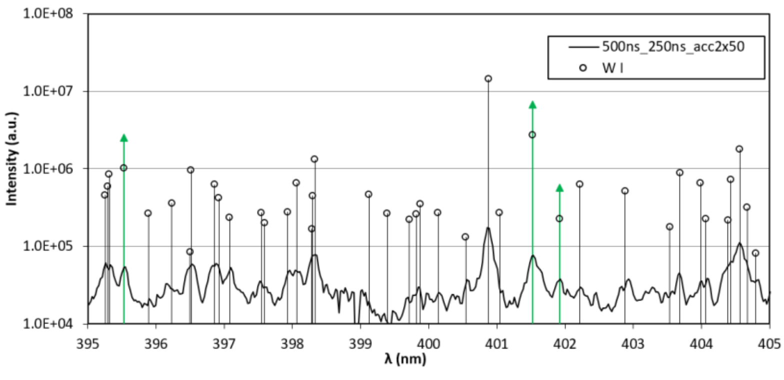

Fig. 1 Example of ps LIBS spectra of pure Wgenerated in air at atmospheric pressure at delay 500 ns and gate times 250 ns (accumulation 100 laser shots, spectrum corrected by the sensitivity).

on LIP parameters such as fluence. Fig. 1 shows spectrum of ps LIBS generated during the ablation of pure W under air (spectral range 395-405 nm). For the BP lines selection, we used only lines not affected by self-absorption and interference (Fig. 1 marked green).

T_e in the ps LIP was evaluated from the slope of BP. The intensity of each line was corrected for the sensitivity after subtraction of the background. The transition probabilities, degeneracy and all other necessary spectral information of W spectral lines were obtained from the spectral lines databases [13-14]. The examples of obtain BP for two different delays is presented in the Fig.2.

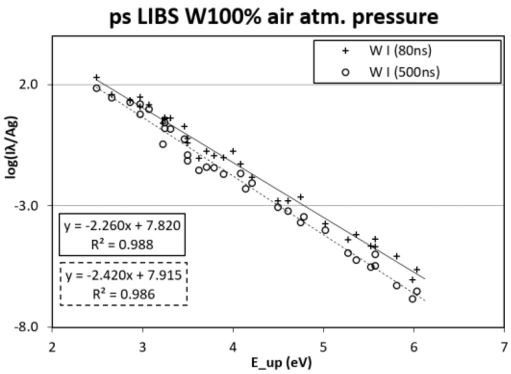

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Fig. 2 Boltzmann plots constructed from W I spectral lines observed in LIBS spectrum at atmospheric pressure under air at following delay and gate times: 80 ns / 40 ns and 500 ns / 250 ns.

The evaluated T_e of ps LIBS plasma generated by W ablation in air at atmospheric pressure were: 0.44 eV (for 80 ns / 40 ns) and 0.41 eV (for 500 ns / 250 ns). The observe T_e is lower in early plasma afterglow comparing to our previous ps LIBS plasma measurements of W and Mo using 30 ps laser (pulse energy 0.3 mJ), where the fluency was similar [20]. But at the later plasma afterglow at delay 400-600 ns the plasma is only slightly lower than the T_e reported in mentioned publication [20]. The comparison of ablation rates of both ps lasers with pulse duration 30 ps and 250 ps will be necessary.

Acknowledgement

Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I01-03-V04-00066.

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Proceedings of the International Conference on **Advances in Electronic and Photonic Technologies**, held in Podbanské, High Tatras, Slovakia, June 15th – 18th, 2025.

Editors: D. Jandura, I. Lettrichová
Published by: University of Zilina in EDIS-Publishing Centre of UZ
Number of pages: 257
Number of copies: 100

ISBN 978-80-554-2208-4