29th Summer School and International Symposium on the Physics of Ionized Gases

Aug. 28 - Sep. 1, 2018, Belgrade, Serbia

CONTRIBUTED PAPERS

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ABSTRACTS OF INVITED LECTURES, TOPICAL INVITED LECTURES, PROGRESS REPORTS AND WORKSHOP LECTURES

Editors:

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PREFACE

This publication contains the contributed papers and abstracts of Invited Lectures, Topical Invited Lectures, Progress Reports and Workshop Lectures that will be presented at the International Symposium on the Physics of Ionized Gases 2018. This is the 29th of a series of events which reflect the progress in this challenging field of science. The event is organized by the Vinča Institute of Nuclear Sciences in Belgrade and Serbian Academy of Sciences and Arts, with the support of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

The aim of this book is to present new results in the fundamental and frontier theories and technology in the area of general plasma physics (including astrophysical and fusion plasmas), atomic collision processes and particle and laser beam interactions with solids. Also, the presented results and lectures of the 3rd Workshop on X-ray and VUV interaction with Biomolecules in Gas Phase - XiBiGP are also included.

Herein, the Editors would like to thank the authors and reviewers for their support of this event and to wish all participants a pleasant and productive stay in Belgrade. We are grateful to the Serbian Academy of Sciences and Arts for their long term commitment to support this event as well as the Serbian Ministry of Education, Science and Technological Development for their continuing help. We also acknowledge the support of the open access journal "Atom"

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SPATIAL MEASUREMENTS OF LASER-INDUCED BREAKDOWN IN AIR

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Abstract. We present time resolved measurements of the plasma expansion produced by laser induced breakdown in atmospheric air. A Q-switched Nd:YAG laser is employed as the excitation source. The detection part of the acquisition system is based on a streak camera equipped with the spectrograph. A simple modification of the spectrograph enables the easy switching between the spectral and spatial measurement modes.

1. INTRODUCTION

The formation of laser induced breakdown (LIB) refers to a plasma production by focusing an intense laser beam in a gas, liquid or solid target. Parameters of laser induced plasma depend on irradiation conditions, such as laser intensity, pulse duration, laser wavelength or ambient gas. To understand the process of laser induced breakdown it is required to obtain the detailed knowledge of the initial stages of various processes involving laser duration and irradiation, plasma formation and its expansion. The nanosecond laser pulse generates plasma through thermal and non-thermal mechanisms. Studying the plasma formation with a high temporal, spectral and spatial resolution is of a great interest and formation of laser induced breakdown plasma in air has been studied by many researchers [1-6], including references therein.

After the initial breakdown, plasma plume propagates towards the focusing lens [1,3]. The bright plasma core of the LIB plasma in open air is surrounded by a layer of cold, moderately ionized gas called the sheath [1]. Glow of plasma sheath, although fainter than the core, is also visible to the naked eye. An explosive plasma expansion induces optodynamic phenomena, i.e., the propagation of a shock, acoustical and ultrasonic waves.

In this paper we present an experimental system that is capable of both spatial and spectral measurements of laser-induced plasma with picosecond temporal resolution. We performed a simple modification of our spectrograph that enables easy switching between the spectral and spatial measurement modes. Later, we became aware that this modification was already proposed and successfully used in the study of Siegel et al. [7], where imaging device was ICCD camera.

2. EXPERIMENTAL SET-UP

Time resolved LIB system implemented in our laboratory is shown in Figure 1. In this study we use the fundamental output at of OPO pumping laser (1064 nm, pulse energy up to 270 mJ, pulse duration of about 5 ns) to create an optical breakdown in ambient air. Timing considerations regarding the laser pulse and streak camera synchronization are very important in our measurements, so we added a photodiode and digital oscilloscope to our experimental setup, Figure 1.

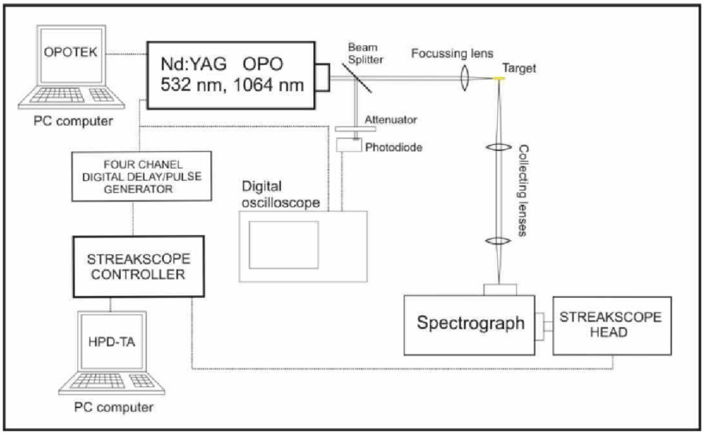

Figure 1. Setup for time-resolved laser induced breakdown measurements.

The optical emission from the plasma is collected by using a spectrograph and recorded with a streak camera. The streak images are time resolved thus enabling monitoring of temporal evolution of the ionic and atomic emission lines or spatial development of the plasma.

Our research of optical emission of plasma was limited so far to analysis of time resolved optical emission spectra acquired by the streak camera [8-10]. To make our study more comprehensive we saw the need for measuring the spatial distribution of plasma optical emission. So we improved the set up and accomplished requirement for easy switching between the spectral and spatial measurement modes of our streak camera system.

We performed a simple modification of our spectrograph that enables easy switching between the spectral and spatial measurement modes, see Figure 2. The spectrograph contains the triple grating turret. In the place of the 150 g/mm grating we mounted the plain mirror. Now, if position of turret corresponding to grating of 150 g/mm is selected, streak camera takes the image of the spatial distribution of the optical emission of the laser induced breakdown. The spectrograph entrance slit should be fully open to utilize as much as possible of the CCD camera active area. The calibration procedure showed that 1 mm on the target position corresponds to 72 pixels of the CCD camera.

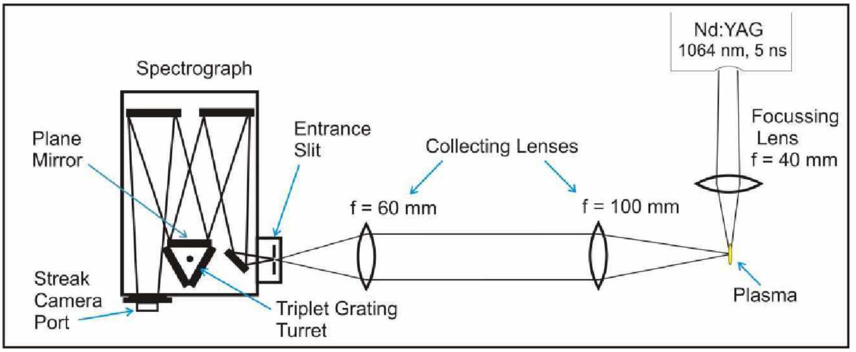

Figure 2. A simple modification of our spectrograph that enables easy switching between the spectral and spatial measurement modes.

3. RESULTS AND DISCUSSION

The streak image of the laser induced plasma (excitation at 1064 nm, energy of 51 mJ, peak intensity of 1.3 10^{11} W/cm^2) is shown in Figure 3. The time axis is vertical, with zero on top of the image. The spatial axis is horizontal. The development of the plasma is seen on the streak image as vertical development (corresponding to a passing of time) of a narrow horizontal section of plasma optical emission, seen through the camera slit, along the direction of propagation of the laser beam. In other words, two dimensional (2-D) streak image corresponds to only 1-D spatial image, represented by rows of image matrix, the other dimension being the time. White points indicate the edges and peak values of plasma brightness, detected by our image processing algorithm.

Our analysis of data provided by streak image presented in Figure 3 shows that instantaneous-velocity of plasma is about 150 km/s at the beginning, and decrease towards about 25 km/s after 16 ns. At about 20 ns plume stops expanding.

4. CONCLUSION

We have the presented the possibilities of spatial measurements of the laser induced plasma development in air by using the streak camera equipped with spectrograph, after simple modification of spectrograph turret. The presented method is suitable for plasma sheath velocity measurements from the very beginning of the laser induced breakdown by using a picosecond time resolution of our streak camera.

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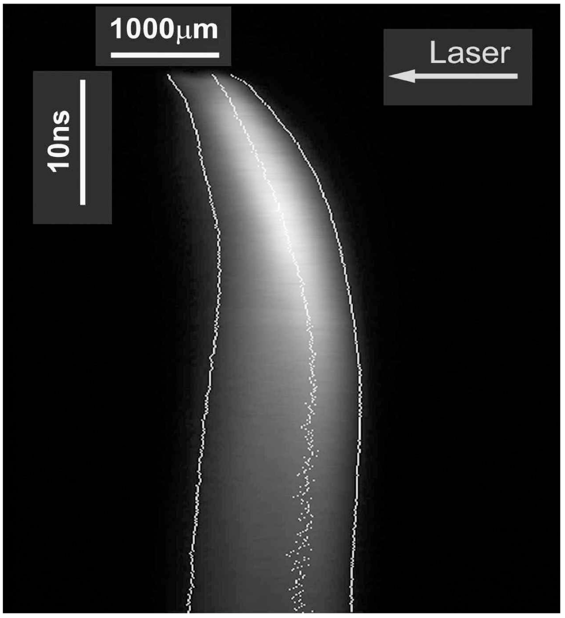

Figure 3. Streak image of the laser induced plasma (excitation at 1064 nm, energy of 51 mJ). The detected edges and peak values of brightness of the plasma plume are indicated by white points.

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