Accepted Manuscript

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PII: S0584-8547(17)30273-2
DOI: doi:10.1016/j.sab.2018.02.017
Reference: SAB 5386

To appear in: *Spectrochimica Acta Part B: Atomic Spectroscopy*

Received date: 20 June 2017
Revised date: 27 February 2018
Accepted date: 27 February 2018

Please cite this article as: Dan Zhang, Anmin Chen, Xiaowei Wang, Ying Wang, Laizhi Sui, Da Ke, Suyu Li, Yuanfei Jiang, Mingxing Jin , Influence of the distance between target surface and focal point on the expansion dynamics of a laser-induced silicon plasma with spatial confinement. The address for the corresponding author was captured as affiliation for all authors. Please check if appropriate. Sab(2017), doi:10.1016/j.sab.2018.02.017

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Abstract

Expansion dynamics of a laser-induced plasma plume, with spatial confinement, for various distances between the target surface and focal point were studied by the fast photography technique. A silicon wafer was ablated to induce the plasma with a Nd:YAG laser in an atmospheric environment. The expansion dynamics of the plasma plume depended on the distance between the target surface and focal point. In addition, spatially confined time-resolved images showed the different structures of the plasma plumes at different distances between the target surface and focal point. By analyzing the plume images, the optimal distance for emission enhancement was found to be approximately 6 mm away from the geometrical focus using a 10 cm focal length lens. This optimized distance resulted in the strongest compression ratio of the plasma plume by the reflected shock wave. Furthermore, the duration of the interaction between the reflected shock wave and the plasma plume was also prolonged.

1. Introduction

Laser-induced breakdown spectroscopy (LIBS) is a technique that uses a pulsed laser to ablate and excite materials (usually solid). When a high-power laser pulse is irradiated onto the sample surface, the sample surface is evaporated and ionized by the initial shock of the laser pulse, forming a high temperature and density plasma [1]. In order to determine the composition of the elements in the sample, light emission from the plasma is analyzed with a spectrometer. Then, the material identification, classification, qualitative and quantitative analysis are carried out [2]. In recent years, LIBS technology has been widely applied to many fields due to its various advantages, such as rapid and remote application, in situ detection, low invasiveness, and multi-elemental diagnosis [3-8]. In essence, the spectral analysis of LIBS technology is the process of exploring the plasma plume produced from the sample.

In previously publications on laser-induced plasma, plume dynamics and many diagnostic methods have been proposed, such as shadowgraphy [9], digital holographic interferometry [10], interferometry [11-12], and emission spectroscopy [13], *etc*. Through these methods, it can be ascertained that the laser intensity [14], laser pulse width [15], air pressure [16], laser spot size [17], target material [18], and the focus point position [19-20] can significantly influence the expansion dynamics of plasma. For instance, Lagrange *et al.* used a KrF excimer laser with a wavelength of 248 nm to generate plasma and study the impact of laser fluence on the propagation parameters of