Study of the optical thickness of laser induced plasma for improved material analysis via laser-induced breakdown spectroscopy

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In order to improve the precision of calibration-free laser-induced breakdown spectroscopy (LIBS) measurements, the existing database of Stark parameters needs to be significantly expanded. In this work, we have studied the optical thickness of laser induced plasma for several Al II lines to be used for LIBS plasma diagnostics.

1. Introduction

Laser-induced breakdown spectroscopy (LIBS) is an emerging technique used for quantitative elemental analysis of materials. Driven by the technological development of pulsed lasers, compact and high-performance spectrometers and detectors, LIBS is a promising ñtoolò for applications in many areas, such as quality control in industrial production, material recycling, environmental survey, interplanetary exploration etc. Even though the LIBS ability of performing precise analysis has been demonstrated for a significant number of materials, quantitative measurements are still difficult in many cases. This low precision is mainly due to the difficulty of calibrating LIBS measurements.

Calibration-free LIBS measurements procedure, developed in LP3, allows determination of the materials elemental composition by comparing the measured intensities of atomic spectral lines to the spectral radiance of plasma that is generally supposed to be in local thermal equilibrium [1]. The absorption coefficient Ǔ(ə), used for the calculation of plasma spectral radiance, takes into account the dominant spectral line broadening mechanisms. In order to achieve high precision of calibration-free LIBS measurements, a large database of Stark parameters needs to be available. The amount of Stark parameters data existing in the literature is very limited and they are often imprecise.

2. Study of the optical thickness

By employing optical emission spectroscopy to laser induced plasma one may measure Stark parameters of the spectral lines of any element present in the irradiated sample. Still, one should pay attention not to make erroneous measurements. Laser induced plasma is in most cases very dense, and for a number of spectral lines the plasma is optically thick. Self-absorption may lead to distortion of the spectral line profile, thus producing an apparently large line halfwidth and introducing a large error in the measured value of the Stark halfwidth coefficient [2]. This is why every spectral line needs to be checked on self-absorption, before proceeding to intensity and Stark halfwidth measurement.

In this work, we have employed the method of duplicating the optical path through plasma with a spherical mirror [2] in order to check the optical thickness of laser induced plasma for several Al II lines. Laser ablation of Al alloy was performed using a Nd:YAG laser (5 ns pulse duration, 266 nm wavelength, 3 mJ energy per pulse) in Ar at 50 mbar. This method enables us to quickly verify if the observed spectral line is self-absorbed. Measured values of plasma transmission coefficient, presented in Fig. 1, indicate the presence of self-absorption for three Al II lines. The experimental results are compared to the spectrum calculated using calibration-free LIBS procedure [1]. Furthermore, temporal evolution of the plasma transmission coefficient has been studied for all observed Al II lines in order to find the optimal conditions for Stark halfwidth measurements.

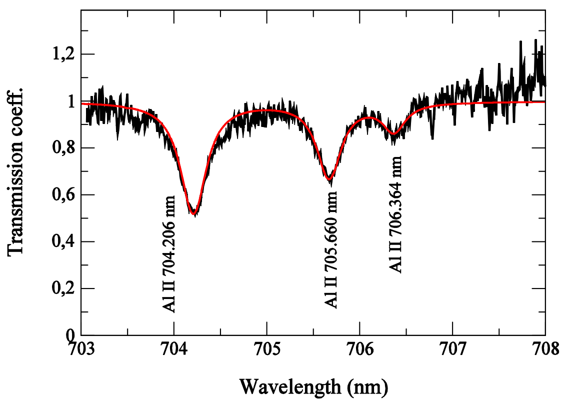

Fig. 1: *Plasma transmission coefficient for three Al II lines.*

Finally, Stark halfwidths have been measured for the Al II spectral lines for which favorable optically thin plasma conditions have been found.

References

[1] J. Hermann, Patent WO 2010/052380 (A1).

[2] N. Konjevic, Phys. Rep. 316 (1999), 339.