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Editorial

Towards Laser-Based Calibration-Free Quantification of Trace Elements

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It is told that Theodore Maiman called the first operating laser source he and his co-worker Charles Asawa realized 60 years ago [1] a "solution in search of a problem". Merely three years later, first experiments have shown the broad range of possible applications for laser irradiation such as a tool in materials processing [2] or an excitation source in emission spectroscopy [3]. The latter application, laser-induced breakdown spectroscopy (LIBS) is thus one of the oldest laser applications and can be regarded as a very basic utilization of direct laser–matter interactions. With incident laser irradiation, a certain portion of the solid, liquid or gaseous sample material is transferred into the plasma state, either by initial melting and subsequent vaporization or by phase explosion, i.e., the direct transition of solid matter into the gaseous condition of aggregation. In the course of recombination processes, the laser-ignited plasma emits characteristic atomic lines. The detection and evaluation of the light emitted by the plasma thus allows the determination of the chemical composition of the sample material. This approach, LIBS, is a well-established, robust, and reliable analytical technique and is applied in various fields such as process control in industry [4], forensic investigations [5] or materials science and research. In the latter case, LIBS is even performed on Mars by the ChemCam module of the Mars rover, Curiosity [6].

The first commercial LIBS apparatus was produced in 1967. Since that time and thanks to the development of pulsed laser sources in the 1980s, this technique was refined and optimized rapidly. However, accurate calibration using appropriate standards was crucial for a long time in order to perform quantitative measurements—as usual for analytical measurement techniques. In 1999, Cucci and co-workers suggested an approach for calibration-free LIBS [7] and since that time, several works have shown that an extensive understanding of the laser–matter interactions during the ignition of the plasma allows for quantitative measurements without any calibration. For instance, high laser fluences need to be applied in order to achieve stoichiometric ablation [8] so that the plasma composition corresponds to the sample's composition. It can then be determined without any calibration by an accurate modelling of the laser-induced plasma and its properties such as electron density or temperature and the comparison of the theoretical model and the actually measured plasma emission. It has been shown that this approach allows for the characterization of multi-elemental thin films [9]. Here, even better analytical performances than the established methods for thin film analysis were obtained. Most recently, further sensitivity improvement by a sequential measurement process has led to notable enhancement of the detection limit and the possibility of calibration-free quantification of trace element contamination [10,11].

Even though the possibility of laser-based calibration-free quantification of trace elements was shown by this work, many efforts have to be undertaken in order to provide widely used measuring systems. However, the first steps have been completed and it can be assumed that—freely adapted from Maiman's famous citation—such analysis is a solution for many problems. Furthermore, it is an excellent example for both the utilization and the characterization of laser–matter interactions.

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