TO THE PROPERTIES OF LASER-INDUCED PLASMA

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Abstract: Laser-induced breakdown spectroscopy (LIBS) is an analytical technique that uses a laser-induced plasma to perform elemental analysis of a sample. It is a versatile and non-destructive method that can be applied to various materials, including solids, liquids, and gases.

1. Introduction:

LIBS offers several advantages as an analytical technique. It is rapid, often requiring only a few seconds to analyze a sample. It is also non-contact and non-destructive, which means it can be used to analyze samples in their natural state without requiring any sample preparation. Additionally, LIBS can be performed remotely, making it suitable for applications such as space exploration or hazardous environments.

The basic principle of LIBS involves focusing a laser pulse onto the surface of a sample, causing rapid heating and vaporization of the material. This creates a high-temperature plasma plume consisting of ions, atoms, and electrons. The plasma emits characteristic radiation in the form of atomic and molecular emission lines when the excited species return to their ground state. These emission lines correspond to the elemental composition of the sample.

The emitted radiation is collected and passed through a spectrometer, which disperses the light into its constituent wavelengths. A detector then measures the intensity of the emitted light at specific wavelengths, allowing identification and quantification of the elements present in the sample. The resulting spectrum provides information about the elemental composition and concentration of the sample.

2. Challenges and limitations of LIBS:

While LIBS has numerous applications and advantages, it also presents certain challenges and limitations:

Plasma Instabilities: Laser-induced plasma can exhibit instabilities, such as filamentation or irregular plasma shapes. These instabilities can affect the consistency and reliability of experimental results. Careful control of laser parameters is required to minimize these instabilities

Heating and Damage: High-power laser pulses used to generate plasma can cause heating and damage to the target material or surrounding environment. Excessive heating can alter the sample's properties or even lead to its destruction. Proper selection of laser parameters and appropriate cooling techniques are essential to mitigate these issues.

Spectral Interferences: In spectroscopic applications, spectral interferences can occur when the emitted radiation from the plasma overlaps with other emission lines or background noise. This hinders accurate identification and quantification of elements. Careful calibration and advanced data analysis techniques are required to address spectral interferences.

Matrix Effects: In analytical applications, the matrix effect refers to the influence of the sample composition on the plasma generation and emission characteristics. Different sample matrices can affect the plasma temperature, electron density, and particle composition, leading to variations in the measured signals. Compensating for matrix effects requires proper calibration strategies and reference materials.

"The matrix effect makes the preparation of high-quality standards important," said Steven J. Rehse, an associate professor in the Department of Physics at the University of Windsor, "It also makes it more difficult to sample highly heterogeneous samples like complex minerals or complicated powders like dirt or soil." [1]

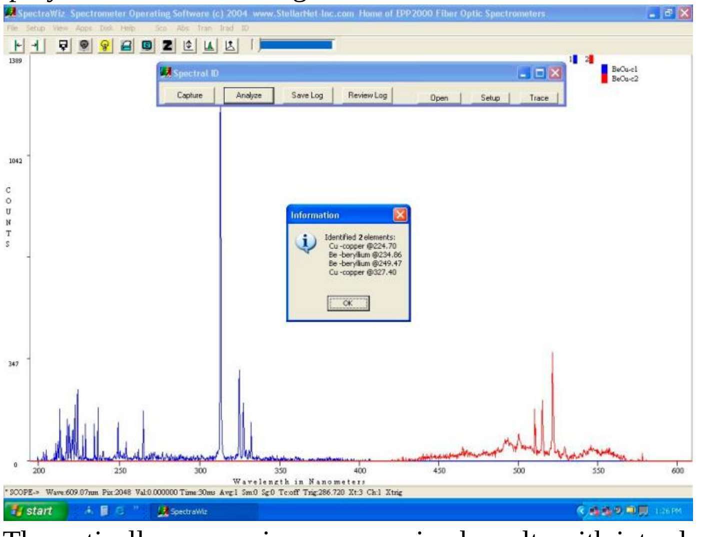
Quantitation and Reproducibility: Achieving consistent and reproducible results with laser-induced plasma can be challenging due to the complexity of plasma dynamics and various experimental parameters. Careful control of laser parameters, sample preparation, and experimental conditions is crucial to ensure reproducibility.

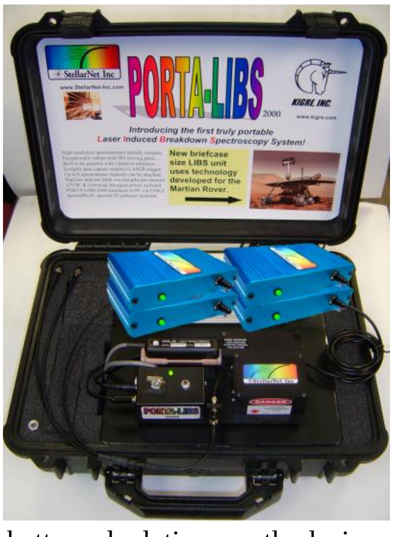
Before LIBS can become available on a large scale we have to solve issue with same sample groups having variation in spectral signal. Resulting in Laser Induced plasma Spectroscopy spectra for the same experiment on different instruments having nonidentical results.

For this issue, an assistant professor at Johns Hopkins University, Ishan Barman, suggested to move from reproducibility issue and try to use LIBS only as a "robust screening tool". As a screening tool, the relative variations-due to laser fluctuations, environmental and matrix effects, and self-absorption-would cease to have as much of an impact [1].

Improving Equipment: development of new compact, accurate device for LIBS experiments. This will improve resulting accuracy and time needed for process. Currently we posses Porta-Libs-2000 device, which consists of laser emitter, sample frame-box and spectrometer that is connected to terminal with installed software to view results.

Signal-to-Noise Ratio: Laser-induced plasma signals can be relatively weak, especially for trace element analysis or when detecting low-concentration species. The signal-to-noise ratio can limit the sensitivity and detection limits of the technique. Advanced detection systems and signal processing methods are employed to enhance the signal-to-noise ratio.





Theoretically, we can improve received results with introducing better calculations methods, improving software and creation of standardized data library. Such methods wont's require improving hardware (CCD detectors, optical transfer cables, laser emitter) that would lead to much higher price and unavailability to reserchers.

Conclusion:

Addressing these problems requires a combination of experimental optimization, advanced instrumentation, and data analysis techniques. Despite these challenges, laser-induced plasma remains a valuable tool in various scientific fields and continues to be an active area of research and development.

References:

[1] Analysis of the State of the Art: LIBS, **Spectroscopy-06-01-2015,** Volume 30, Issue 6, https://www.spectroscopyonline.com/view/analysis-state-art-libs