LIBS analysis of geological and fusion-relevant materials and development of Spatial Heterodyne Spectrometer

Abstract

Surpassing the throughput/etendue disadvantage of dispersive kinds of spectrometers, a hybrid spectrometer is used based on interference- the Spatial Heterodyne Spectrometer (SHS) for capturing emission signals from LIBS and Raman. The design of SHS is similar to a Michelson Interferometer, with mirrors replaced by reflective diffraction gratings. The experiments related to SHS were conducted in BAM, Berlin, and Comenius University, Bratislava. The LIBS results from the SHS were almost comparable to those of the standard echelle spectrometer (Resolving power = 9000). The camera exposure and the laser power were optimized systematically to reduce the background emissions and to attain well-defined Raman bands. The Raman results from SHS showed a slight non-linear displacement in the band position when compared with a handheld spectrometer. The Raman results for the marble sample were attainable with and without a microscopic objective.

A similar SHS setup was developed at the Comenius University, with a different detector and a cheaper and larger linewidth laser. The consequence of the larger linewidth laser proved unsatisfactory towards Raman spectroscopic detection, as also observed with an high-resolution commercial spectrometer, where considerable fluorescence was detected. However, the spectrometer designed successfully captures the Hg-emission spectra, as a result, the current thesis focuses on the experimental parameters' effect on the Hg emission lines for various cases. Additionally, the current work also explores the possibility of miniaturizing the SHS, and their technical challenges with miniaturization are mentioned.

Alternatively, various relevant samples in today's research, like, geological and thermonuclear fusion relevant were explored and reported for the LIBS analysis in the following sections. The geological section comprises of study of lepidolite samples in the Ar gas and air ambiances, and CF-LIBS analysis is used to quantify the constituents, however, as a first analysis without refinement. As future work, the analysis made either in a vacuum chamber or within a closed chamber would benefit from the interference of other atmospheric gases into the spectra, thereby increasing the accuracy of the CF-LIBS results. For the LIBS studies of the walls of the thermonuclear fusion reactors, D and He were studied with various gaseous impurities in the Be matrix. Relevant publications are attached for detailed results; however, a brief background is provided.

The future of the SHS and miniature SHS is to study with lower linewidth lasers in continuous mode of operation or with pulsed lasers and ICCD combinations. The influence of the detector pixel parameters could be studied in detail with different detectors and corresponding exit optics. Engineering various robust designs for the miniature SHS, their comparisons, and a systematic study would be beneficial for furthering the field of miniature SHS, and also their in-field applications.