Laser-induced breakdown spectroscopy for composition analysis of plasma facing components

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Laser-induced material analysis like Laser-Induced Breakdown Spectroscopy (LIBS) and Laser-Induced Ablation Spectroscopy (LIAS) offer preparation-free sample composition analysis. Thus these are promising techniques for in-situ monitoring of the fuel content in plasma-facing components (PFC [1, 2]) in fusion devices like Wendelstein 7-X (W7-X) or EAST. A deeper understanding of plasma-wall interaction processes like erosion, material transport and fuel retention is gained from this, what is essential for a long lifetime of PFC as well as for efficient operation of future fusion devices.

A setup for post-mortem analysis in an ultrahigh vacuum chamber is presented, which combines optical spectroscopy (LIBS) with residual gas analysis (LIA-QMS [3]) for quantitative sample composition determination. By using the third harmonic (λ = 355 nm) of a Nd:YVO_4-laser with a pulse duration of τ_p = 35 ps, pulse energies up to E = 30 mJ and a spot diameter on the sample of d = 700 µm, the heat penetration depth is smaller than the ablation rate. Thus a depth resolution in the order of Δh = 100 nm is achieved for graphite tiles from W7-X. After a hydrogen plasma campaign [4], the erosion/deposition pattern on graphite divertor and divertor baffle tiles of the last operation phase is analyzed. The LIBS system is used to measure the hydrogen retention depth-resolved in a series of toroidal and poloidal scans. Moreover, impurities like Na, Fe and O are analyzed. The hydrogen and oxygen measurements results are comparted simultaneously performed residual gas analysis, so that a calibration-free LIBS approach can be assessed.

Moreover, gained information will help to improve the design of in-situ systems in fusion devices like EAST or W7-X. In addition to LIBS, an in-situ system enables to perform spectroscopy on ablated particles, which penetrate into the plasma edge (LIAS). In preparation for this, a laser-induced ablation rate analysis of different layer structures is presented, which is needed for a quantitative analysis of the data from plasma spectroscopy.

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