5th Asia-Pacific Conference on Plasma Physics, 26 Sept-1Oct, 2021, Remote e-conference

Development of laser-based wall diagnostics for the characterization of plasma-wall interaction on EAST tokamak

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Plasma–wall interactions (PWI) related to fuel retention, material erosion and redeposition on the first wall play an important role in nuclear fusion devices. Since *ex situ* post-mortem analysis including XPS RBS, SIMS and NRA cannot meet the requirements of the *in situ* characterization of PWI behaviors in the future fusion device with active cooled plasma-facing components (PFCs), especially in radiative environment. There is an urgent need to develop *in situ* diagnostics to characterize PWI and to further improve plasma performance. Laser-based methods are proposed to be promising candidates and incredibly important for ITER and nuclear fusion devices in the future, as they have the capability to monitor the fuel inventory and material migration without the break of vacuum to allow the monitoring of PWI processes in real-time[1].

In this work, in order to measure the PWI *in situ* for improving the plasma performance of long-pulse and high-performance operation on Experimental Advanced Superconducting Tokamak (EAST), we present the successful development of two laser-based wall diagnostics of laser-induced breakdown/ablation spectroscopy (LIBS and LIAS) for assessing fuel retention and material deposition on the first wall of EAST[2,3]. The *in situ* LIBS system on EAST has to be a routine diagnostic which provides the distribution of fuel retention and impurities co-deposition on the first wall in real-time between discharges and during wall conditioning processes. Approximately 2.0 μm Li layer was identified by LIBS after 200 min Li evaporator wall conditioning on the first wall. The thickness of the deposited layer increases with operation time but not linearly. The ratio of H/H+D in the deposited layer has been estimated as 34%~38%, which is much higher than the value (<5%) in the plasma phase. Moreover, the H/(H+D) ratio was measured by LIBS under different conditions indicating that LIBS could be a valuable diagnostic to predict the wall condition in EAST tokamak. LIAS diagnostic relies on localized ablation by an intense laser beam and subsequent excitation and ionization of the ablated species in the plasma edge region. It was applied during plasma operation, and the dynamic retention on graphite and tungsten as plasma-facing materials are compared during limiter configuration, showing more than three times higher short-term retention in graphite than in tungsten. A saturation effect of the deuterium retention on graphite as the plasma-facing component on the first wall high field side was determined for ion fluences of $F \geq 3 \times 10^{18}$D+/cm^2. The results demonstrate the potential of LIAS for real-time characterization of dynamic fuel retention. In the 2021 campaign, a new endoscope system for LIAS and LIBS to characterize PWI which can scan upper tungsten divertor has been designed. The upgraded system will be a unique diagnostic and the results will be presented at the conference.

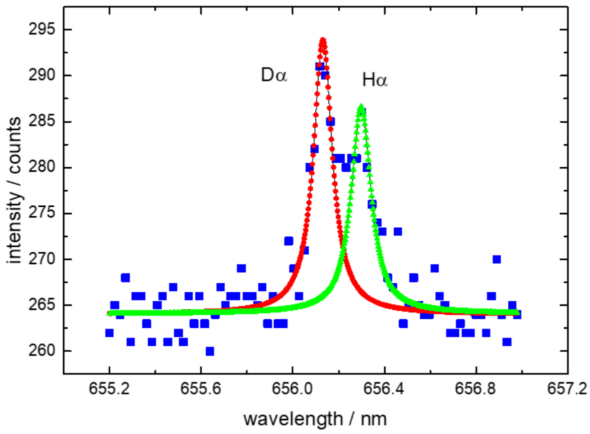

Figure 1. The fuel retained in the deposition layers.

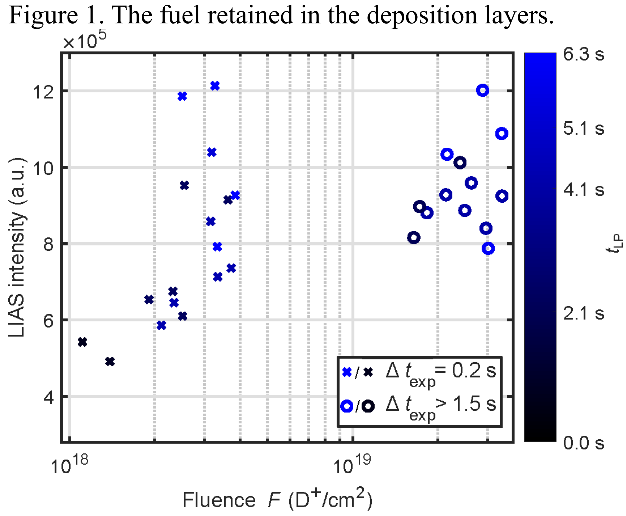

Figure 2. Deuterium signal over ion fluence measured by a Langmuir probe for an analysis of graphite as PFC.

This work was supported within the SINO-GERMAN project by the DFG and the NSFC under Grant No. 11861131010, and National Magnetic Confinement Fusion Science Program of China under Grant No. 2017YFE0301300.

References

[1] V. Philipps et al, Nucl. Fusion. 53, 093002 (2013)
[2] Z. H. Hu et al, Phys. Scripta. 014046, T170 (2017)
[3] Z. H. Hu et al, Fusion Eng. Des., 135 (2018)