Project Title: In-situ Laser Induced Breakdown Spectroscopy Measurements in PISCES-A
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The goal of the project was to develop a Laser Induced Breakdown Spectroscopy (LIBS) diagnostic that could be employed during the plasma exposure of targets in the PISCES-A linear plasma device to interrogate the surface as the plasma exposure progressed. The objectives of the measurements were twofold; first, to measure in real-time the composition of elements in the near surface ablated zone to enable a tool that could be used to validate material migration models of eroded material, and second, to measure the plasma fuel contained in the ablated surface to determine the static and dynamic inventory of gas in a target during the plasma exposure. The LIBS diagnostic was successfully deployed on PISCES-A and measured both elemental composition and gas accumulation in the near-surface ablated layer during plasma operations.

The elemental composition measurements utilized a helium (He) plasma incident on a chromium (Cr) target being clamped to the sample manipulator using a tantalum (Ta) ring. The measurements recorded the amount of Ta on the Cr surface as the ta ring eroded and redeposited on the Cr surface. These results and a description of the diagnostic setup were published in Review of Scientific Instruments (D. Nishijima, M. Patino and R. P. Doerner, "Development of a LIBS system for in-situ surface measurements during plasma exposure in PISCES-A", Rev. Sci. Instr. 89(2019)10J105) and presented at the 2019 High Temperature Plasma Diagnostic Conference. The results were also presented to the 2019 annual EUROfusion PMI meeting in Bratislava.

The gas retention measurements used a deuterium (D_2) plasma incident of a tungsten (W) target to determine the dynamic and static inventory in the W sample. The LIBS system has been upgraded to allow accurate and quick redirecting of the laser spot to precise locations on the plasma exposed surface. The laser beam path was modified, and a motorized, computer-controlled beam directing mirror mount (Zaber: T-MM2-KT04U) was installed right above a vacuum window of PISCESA. The upgraded system has been successfully operated: Accurate and quick redirecting of the laser spot via remote control is ensured, and around 300 laser spots are made on a sample surface with a diameter of 22 mm. Using the upgraded system, experiments have started to gain new and deep insights into dynamic retention of D in W during D plasma exposure (unfortunately, suspended due to the campus closure during the COVID-19 pandemic). A detected LIBS signal during D plasma exposure is considered to consist of three components: (1) dynamic and (2) static retention of D atoms in W, and (3) background D gas excited by the laser-induced plasma. Thus, the dynamic D retention component can be isolated by subtracting both static and background gas components from the total signal. The static and background gas components can be measured under the background gas after D plasma exposure. In addition, the static retention component can be obtained without the background gas. Based on this new idea, preliminary data was collected right before the campus closure, and the total signal is confirmed to be higher than the sum of static and background gas components, as expected. To obtain the D atomic density or fraction, the LIBS light intensity signal will be calibrated with the static retention component against ex-situ nuclear reaction analysis or secondary ion mass spectroscopy. This will enable us to quantify dynamic retention of D in W during plasma exposure. The upgraded system will also be useful to map the material deposition on the plasma-exposed samples. The intermediate progress of this work was presented at the 7th International Workshop on Plasma Material Interaction Facilities for Fusion Research in October, 2019.