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Fuel retention distribution in different locations of graphite tiles in HL-3

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In magnetic confinement fusion research, the Plasma Wall Interaction (PWI) process constrains the lifespan of the first wall and divertor target plates, and is closely related to core plasma contamination, disruption, etc., making it one of the important topics in current fusion research. Developing effective online, real-time, and quantitative wall diagnostic techniques is beneficial for gaining a deep understanding and quantifying the behavior of fuel retention and impurity deposition under high-confinement modes[1-3].

This work is oriented towards China's HL-3 Tokamak and uses situ deuterium retention diagnostic method consist of Laser induced desorption-Quadrupole mass spectrometry(LID-QMS) with Laser induced breakdown spectroscopy(LIBS)[4]. The results of the study show that: fuel gas (D) and impurity elements (such as hydrogen (H), silicon (Si), iron (Fe), chromium (Cr), etc.) retention in the poloidal and toroidal directions on the graphite tiles of HL-3 was found to be inhomogeneous, significant increase in fuel retention in the edge of graphite tiles, and the spatial distribution of impurities is similar to that of fuel retention. Subsequently, SEM and metallographic examination characterize the morphology of the ablation pits, yielding quantitative results for fuel retention. The laser properties presented in Figure 1(a) are obtained in laboratory with an imaging lens of 60 cm focal length with a distance of 50 cm (for 3 mm spot diameter) and 56 cm (for 2 mm spot diameter) between fibre end and target surface. As shown in Figure 1(b) where with consecutive laser pulses on the same spot, the LID signals decays from 9% in the second pulse to about 0.6% after 10 laser pulses. LIBS measurement results in 1.67×10^{20} D/m^2 after ms-laser irradiation in the same position, but the QMS signal of LIBS shows in 1.7×10^{22} D/m^2 without ms-laser, so that 98% of retained D was detected in 10 pulse by LID. Figure 1(c) shows that the effect of millisecond laser desorption on fuel retention by LIBS spectral diagnostics, Figure 1(d) and Figure 1(e) illustrate the distribution of fuel(D, H) and impurity elements.

The findings of this study provide data support for a deeper understanding of fuel retention and impurity distribution in Plasma-Facing Components (PFCs) under long-pulse steady-state operation conditions in magnetic confinement fusion devices. This work is supported by National MCF Energy R&D Program, Grant # 2019YFE03080300, National Naturel Science Foundation of China, Grant #11505040, and National Key Research and Development Program, Grant #2018YFE0303105.

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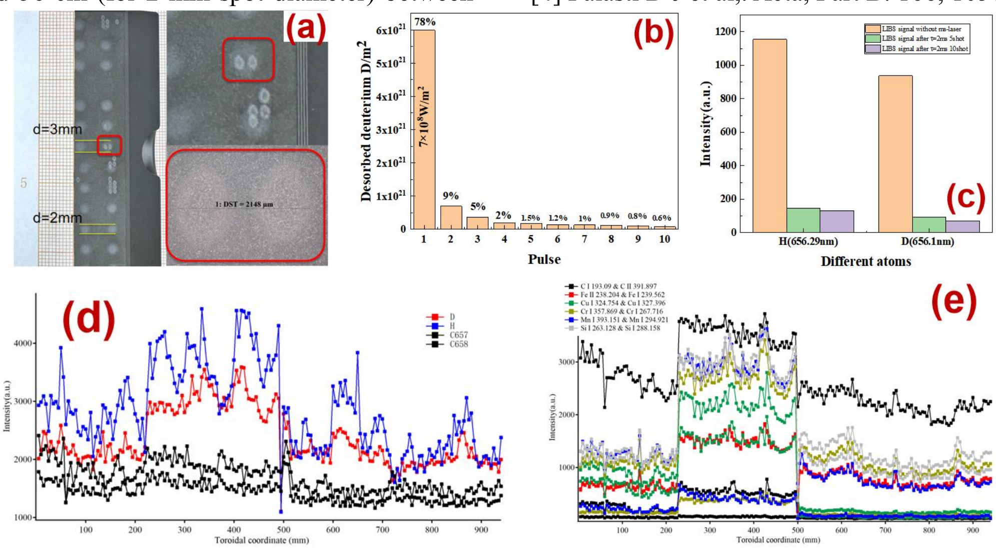

Figure1. (a)Spatial distribution of the Nd:YAG laser intensity after transmission through a 10 m long fibre of 600 μm core diameter; (b)Effect of perpendicular diffusion in successive laser pulses; (c)Spectral variation with different laser parameters; (d)Distribution of impurity elements in different positions; (e)Fuel distribution in different positions.