EXPERIMENTAL AND SIMULATION STUDY OF PLASMA DETACHMENT IN THE LINEAR PLASMA DEVICE MPS-LD

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1. BACKGROUND

Plasma detachment is a commonly used divertor operation regime that can effectively reduce the plasma temperature and heat flux near the target. However, divertor physics involves complex processes such as plasma transport, atomic and molecular collisions, and plasma-wall interactions. In tokamak experiments, isolating the effect of a single parameter is challenging, and diagnostics are also difficult, limiting our understanding of detachment. The accuracy of numerical models heavily depends on validation with experimental data, and discrepancies exist between tokamak experiments and simulations in addressing key issues such as energy radiation [1]. Therefore, there is an urgent need to create relevant conditions in laboratory settings and conduct experimental studies. Linear plasma devices generate high-density plasmas using plasma sources and confine them with magnetic fields to form intense plasma beams, providing an excellent platform for studying tokamak divertor plasmas. The **M**ultiple **P**lasma **S**imulation **L**inear **D**evice (MPS-LD) [2] is a newly constructed large linear device at Dalian University of Technology, China. This report introduces the MPS-LD device and recent progress in detachment investigation.

2. EXPERIMENT AND SIMULATION

MPS-LD device consists of four regions: the plasma source region, heating region, target region, and sample exchange region. The first three regions are 3 meters in length, with diameters of 0.4 meters, 0.4 meters, and 0.6 meters, respectively. MPS-LD is equipped with 11 conventional copper magnets, each independently powered, allowing flexible control of various magnetic field configurations by adjusting the current and magnet position. The maximum axial magnetic field strength reaches 0.4 Tesla. MPS-LD utilizes a helicon plasma source to generate high-density plasma, with an RF power of 20 kW and a frequency of 13.56 MHz [3]. The device is also equipped with an ion cyclotron resonance heating system, operating at a power of 10 kW and a frequency of 0.9 MHz [4]. Figure 1 shows a typical discharge waveform of the MPS-LD device.

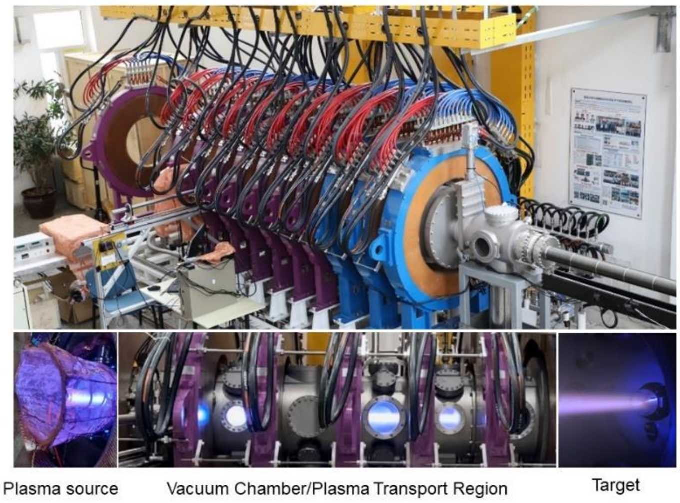

Figure 1. MPS-LD device and typical argon plasma discharge Photo

A variety of diagnostic systems have been developed for MPS-LD, as shown in Figure 2. It includes three sets of Langmuir probes, a Thomson scattering system, a spectrometer, an retarding potential analyzer (RPA), an infrared camera, a high-speed camera, and thermocouples. These are used to measure basic parameters such as electron temperature, electron density, ion temperature, the heat flux of the target plate, and ion composition, providing data for experimental analysis and comparison with numerical simulations.

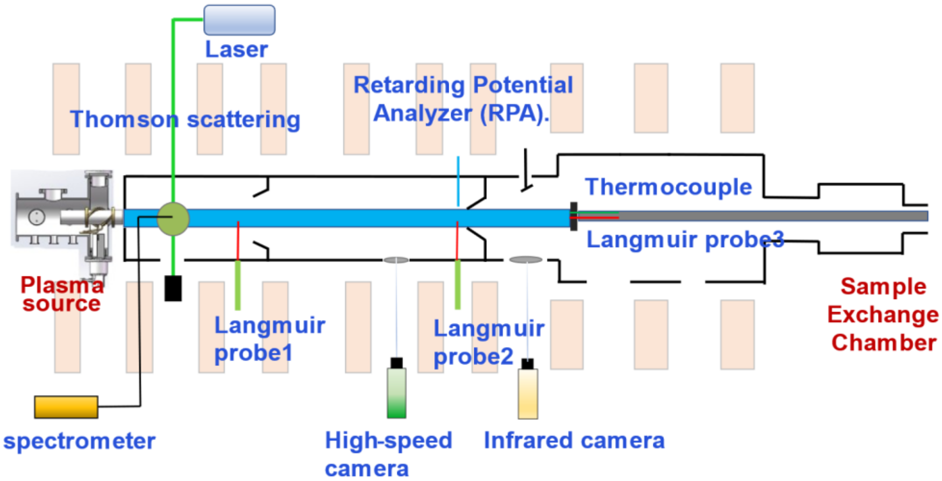

Figure 2. Diagram of the Diagnostic System in MPS-LD Device

MPS-LD device has conducted plasma discharges using various gases, including argon, helium, and hydrogen. This work primarily focuses on the experimental and simulation study of plasma detachment. Hydrogen discharges were used to investigate plasma detachment by varying the electron density and ion temperature through discharge power and ion heating power scans. Inert gas was injected at the target to enhance radiation and induce detachment. Plasma density and temperature in upstream were measured using probes and Thomson scattering. Plasma conditions and deposited heat flux on the target plate were obtained using probes, infrared camera, and thermocouples. Spectroscopic diagnostics provided data on collisions and ion composition. Based on these measurements, simulations were conducted using SOLPS-ITER [5] and BOUT++ [6,7], with results showing good agreement with experimental diagnostics. Further analysis examined the impact of key collisions on energy radiation and detachment. Additionally, material irradiation studies were performed to investigate the effects of impurities on material erosion and fuel retention.

ACKNOWLEDGEMENTS

This work is supported by National Key R&D Program of China No. 2024YFE03160000，and National Natural Science Foundation of China under Grant No. U2441223.

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