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Development of a Scrape-off Layer Plasma Simulator Using a Magnetic Mirror Device in KAIST (KAIMIR)

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To support fusion reactor development, it is essential to mitigate high heat flux on the divertor while maintaining high confinement in the core region. Understanding the physics of scrape-off layer (SOL) plasmas, including interactions with the core region, is thus a key research area. Linear devices have been widely used to simulate SOL plasmas due to their high aspect ratio geometry, replicable in cylindrical configurations[1]. These systems offer a cost-effective and accessible platform for conducting dedicated experiments.

We have developed a SOL plasma simulator using KAIMIR, a magnetic mirror device at KAIST[2]. KAIMIR consists of three main regions: source, central, and expander. In this configuration, the expander region represents the near-divertor region, while the central region serves as the upstream region. Plasma is generated in the source region by a washer gun, achieving central plasma densities on the order of 10^{19}-10^{20}m^{-3}, suitable for SOL plasma simulation.

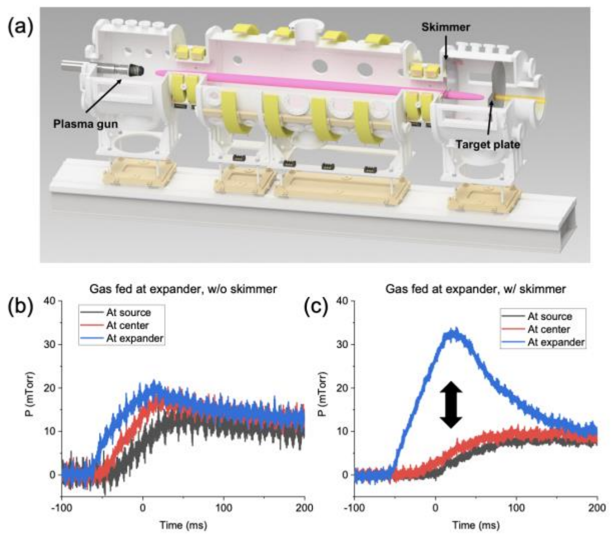

Figure 1 (a) KAIMIR device with skimmer (b) Temporal evolution of neutral pressure in each region by gas puffing at the expander without skimmer (c) Same as (b), but with skimmer.

Our primary focus is the simulation of radiative divertor condition, where heat flux to the divertor is reduced via enhanced radiation resulting from neutral gas injection. To replicate this condition, we installed an additional neutral gas puffing system in the expander region. However, gas puffing can influence neutral pressure not only in the expander but also in the source and central regions, thereby altering upstream plasma conditions. To independently control the neutral pressure in the expander, a skimmer was installed at the entry to the expander region, as shown in Figure 1(a). This modification effectively reduced vacuum conductance into the expander and enabled independent pressure control, as demonstrated in Figures 1(b) and (c).

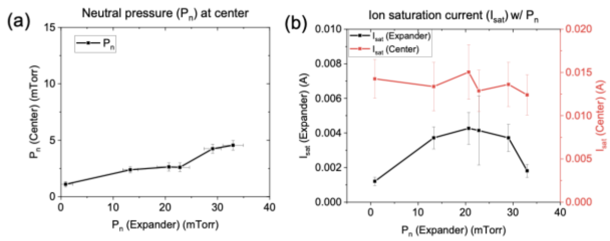

Figure 2 (a) Neutral pressure in the center region while varying expander pressure (b) Ion saturation current with expander pressure (red : at center, black : at expander region).

Experiments were performed to investigate the influence of neutral gas puffing in the expander on plasma parameters in both the central and expander regions. With the implemented upgrades, we were able to maintain neutral pressure variations in the central region within 3 mTorr while varying expander pressure beyond 30 mTorr, as shown in Figure 2(a). Figure 2(b) presents ion saturation current measurements, proportional to ion particle flux, in both central and expander regions. The central region exhibited stable current levels within their experimental uncertainties, whereas the expander region showed a non-monotonic response: the current initially increased, likely due to enhanced from the injected neutrals, but began to decrease when the expander pressure exceeded 20 mTorr. This reduction may suggest a transition from the attached to detached state, driven by increased radiative losses. Further experimental data and detailed analysis will be presented and discussed.

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References

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