Assessment of heat flux and plasma detachment in the Small Angle Slot divertor of DIII-D using new surface eroding thermocouple array


University of Tennessee – Knoxville, 1412 Circle Drive, Knoxville, TN 37996, USA
a Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, USA
b General Atomics, 3550 General Atomics Court, San Diego, CA 92121, USA

E-mail address: ddonovan@utk.edu

The Surface Eroding Thermocouple (SETC) is a novel diagnostic qualified to obtain fast local heat flux measurements in DIII-D [1]. A new array of SETCs covering the plasma facing surface of the Small Angle Slot (SAS) divertor was installed and operated in 2019 [2, 3]. This new SETC array has provided high-resolution measurements of the heat flux footprint in the SAS divertor and was used to characterize the heat flux profile and study divertor detachment during the 2019 DIII-D campaign. The direct surface heat flux measurements enabled by SETCs provide new insights into divertor physics and divertor optimization for future fusion reactors.

The new SETC array provides high-speed (~10 kHz) and high spatial resolution (<1 mm) data collection in the SAS divertor during attached plasma operation with strike-point sweeping. The size and shape of the heat flux footprint in SAS varies significantly with the position of the outer strike point (OSP) in SAS. In contrast, the heat flux footprint does not vary substantially with the OSP position in the open, lower divertor of DIII-D. The ion \( \nabla B \) drift direction is observed to strongly affect plasma profiles along the divertor target. When the ion \( \nabla B \) drift direction points away from SAS, it appears that the \( E \times B \) drifts enhance the neutral build-up at the outer corner and cause a drop in plasma temperature, as measured by target-embedded Langmuir probes. When the ion \( \nabla B \) drift direction points towards SAS, the \( E \times B \) drift would push the particles towards the private flux region and decreases the particle flux near the outer corner of the SAS divertor. Consequently, the peak heat flux was lowest when the OSP was near the outer corner of SAS for both the ion \( \nabla B \) drift directions, as measured by the SETCs.

The new SETC array was also able to detect the onset of plasma detachment in SAS and measure the resulting heat flux reduction. For an H-mode plasma with the ion \( \nabla B \) drift direction away from SAS, the divertor plasma transitions to a detached state at a main plasma density below \( 4 \times 10^{19} \text{ m}^3 \), which is much lower than the detachment density \( (6 \times 10^{19}\text{ m}^3) \) with the ion \( B \times \nabla B \) drift direction towards the SAS divertor. This is consistent with recently published Langmuir probe measurements [4]. Lastly, results will be discussed comparing puffing D\( _2 \) gas directly into the SAS divertor vs. the main chamber, and the corresponding effects on detachment will be analyzed. Generally, the heat flux profile and divertor detachment in SAS are strongly affected by divertor closure and the ion \( \nabla B \) drift direction.


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