Use of VUV Spectroscopy in Validation of DIII-D Boundary Science During Radiative Divertor Operation*

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A VUV spectrometer viewing the peak plasma radiation near the vessel wall components (Divertor SPRED) was installed in the DIII-D tokamak to resolve discrepancies between measured and predicted radiated power. Next step, reactor-scale magnetic confinement fusion devices are expected to exhaust most of their plasma heat radiatively rather than conductively to avoid exceeding the engineering limits of the vessel wall components [1]. In these radiative divertor conditions, the plasma flowing along the field lines towards solid surfaces is cooled from electron temperatures above T_e ~ 70 eV down to sub eV, and the electron density is increased from a few $n_e \sim 10^{19}$ m^{-3} to about $10^{20} - 10^{21}$ m^{-3}. A rich phenomenology of multiple atomic and molecular physics processes from excitation to recombination with strong impurity radiation convert the plasma heat to radiated power. However, 2D fluid codes, used for predicting these conditions in the next step devices, do not generally predict radiation accurately for existing devices [2, 3]. The newly installed divertor SPRED is capable of measuring directly the intensity of the dominant resonant radiating lines, such as Ly-α (1215 Å), CIV (1550 Å), and NV (1238 Å). The spectrometer also covers the spectral region of molecular Lyman-Werner bands. Together with the bolometer measuring the total radiated power and the divertor Thomson scattering system measuring n_e and T_e, these measurements provide direct constraints for most of the key ingredients of radiated power calculations in these models.

Similar to previous studies with divertor SPRED in DIII-D, in strongly radiative conditions induced by deuterium injection, the resonant CIV (1550 Å) line dominates radiated power near the X-point in the divertor, while Ly-α radiation dominates near the target [4]. In plasmas with strong nitrogen injection, NV (1238 Å) provides the strongest contribution to radiated power near the X-point. While 2D simulations capture qualitatively many of the radiative features seen in the experiment, there are still significant quantitative discrepancies, which will be elaborated.

References

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