Simultaneous 2D imaging of temperature and density fluctuations using the DIII-D combined ECE-Imaging/ Millimeter-wave Imaging Reflectometer diagnostic*

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Abstract. A new millimeter-wave imaging reflectometer (MIR) has been installed alongside the existing electron cyclotron emission imaging (ECEI) instrument on the DIII-D tokamak. While ECEI is a multi-channel radiometer that measures the spontaneous millimeter-wave emission from the plasma, allowing diagnosis and visualization of electron temperature fluctuations, MIR is a radar technique which utilizes millimeter waves to probe density fluctuations in the plasma. These imaging diagnostics work together to diagnose important quantities such as the amplitude and wavenumber of coherent fluctuations, correlation lengths and de-correlation times of turbulence, plasma flow velocity, and the cross phase between density and temperature fluctuations. During its first year at DIII-D, the optical system of MIR was extensively characterized in the absence of plasma, validating the expected radiation patterns from beam propagation analysis with those measured in the laboratory. The combined ECEI/MIR system was deployed during plasma experiments, from which simultaneous images of edge T_e and n_e fluctuations induced by MHD were obtained. The MIR component of this simultaneous MIR/ECEI suite consists of twelve vertically separated sightlines coupled to the plasma by an innovative optical design that keeps both on-axis and off-axis channels focused at the cutoff surface. Four illumination frequencies (corresponding to four radial channels) can be tuned in 500 μs over a range of 56 to 74 GHz, allowing control over the radial channel spacing and radial coverage. Synthetic diagnostic simulations with the full-wave reflectometry code (FWR2D) have played an integral role in the design of the MIR instrument as well as the interpretation of MIR data. During its initial experimental campaign on DIII-D, discharges in which the density is varied and the plasma is rigidly shifted permit tests of the receiver depth-of-field and vertical alignment of the optical system. Measurements during H-mode discharges will be presented, which show a rich spectrum of fluctuations in the interval between type-I edge-localized modes (ELMs). Simultaneous MIR/ECEI measurements indicate several bands of modes ranging from highly-coherent, high-frequency modes early in the ELM period to low-frequency, broadband turbulence leading up to the following ELM. Characteristics of the fluctuations, such as their poloidal wavenumber and flow velocity, are readily inferred. Innovations planned for the current and upcoming experimental campaigns are aimed at facilitating active tracking of cutoff surfaces as the density and plasma position evolve during the discharge. In the short term, the number of probe frequencies will be doubled to eight, and the millimeter-wave source generation scheme will be upgraded to allow for greater flexibility and control.

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