Numerical diagnostic results and design aspects of the DIII-D millimeter-wave imaging reflectometer

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Abstract. A numerical millimeter-wave imaging reflectometer (MIR) synthetic diagnostic is employed to guide the design of an MIR system for the DIII-D tokamak, benchmarked against data from demonstration discharges, and utilized to determine the range of resolvable fluctuation wavenumbers and amplitudes. A two-dimensional full-wave reflectometer (FWR2D) code as well as optical simulation is combined to assess the numerical imaging quality. The dependence of the imaging quality on errors in three optical factors: the focal position, spot size, and angle of incidence of the receiver sightlines, as well as wavefront curvature of the probe beam are investigated. The MIR optical system installed at DIII-D employs a curved receiver antenna array to optimize the matching between the receiver wavefront and the cutoff layer to achieve optimized imaging quality. Numerical diagnostic results indicate that the MIR optical system installed on DIII-D can accurately resolve poloidal fluctuations with mean wavenumber k_Θ up to 2π cm^{-1}, and fluctuation amplitude from $\tilde{n}/n$ = 0.1% to 5%. In addition, the numerical study results are compared to two DIII-D experimental discharges, which include plasma with a density ramp and a rigid vertical jog. Qualitatively, excellent agreement is achieved between the experimental and numerical results. Furthermore, the numerical diagnostic results revealed a previously unknown vertical displacement of 5.5 cm between the midplane of the optical system and the midplane of the DIII-D vacuum vessel, indicating that numerical imaging can provide validation to the experimental results and help to elucidate anomalies in the experimental data.

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