2-D Reconstruction of Electron Characteristics Using Divertor Thomson scattering at the DIII-D National Fusion Facility

Achieving cold plasma conditions at the plasma-surface boundary are a critical operational requirement for future fusion tokamaks to preserve the integrity of wall armor under extreme particle and energy flux. The improved divertor Thomson scattering diagnostic at the DIII-D National Fusion Facility is unique in capability worldwide and has been applied to characterize electron parameters in 2-D from typical 'hot' plasma conditions (about 25 eV, or 300,000 °C) to high density 'cold' conditions (1 eV, or 12,000 °C) in order to elucidate the progression plasma parameters and the roles of conductive and convective flow in parallel energy transport. Imaging of electron temperature, density, and pressure profiles provide a valuable 2-D constraint on modeling for the challenging problem of operating a fusion tokamak device with a cold plasma boundary.

Limited lifetime due to wall erosion and damage to plasma-facing surfaces due to extreme power deposition (>10 MW/m^2 in steady state) are major impediments to next step fusion devices, even for the most resilient materials (graphite, tungsten). As a solution, a high density divertor was developed in which parallel momentum is transferred efficiently from the plasma to the divertor targets via neutral recycling atoms and not primarily energetic ions accelerated through the plasma sheath. Thomson scattering is an ideal diagnostic to measure the plasma conditions in this region. In this diagnostic, pulsed near-infrared laser light is scattered by the plasma to a spectrum dependent on the electron temperature (T_e) and the observation angle. Scattered light is monitored using fiber optics, and detected with high speed photo-diode detectors. By sampling the relative intensity of the scattered spectrum at various wavelengths, and measuring the absolute intensity of the scattered light on calibrated detectors, plasma T_e and density (n_e) in a small sampling volume (~1 cm^3) and temporal extent (10 ns) can be made while the plasma is swept along the measurement location. At DIII-D, the unique divertor Thomson scattering diagnostic has recently been refurbished and upgraded to include a state-of-the-art 7-channel filter set extending the T_e range to 0.5 eV – 5.0 keV, and resulting in the highest accuracy and precision achieved to date. These results help reveal the dominant physical processes at play, and provide strong constraints used for validation of numerical simulation in the transition to cold plasma-surface boundary operation in a fusion device.

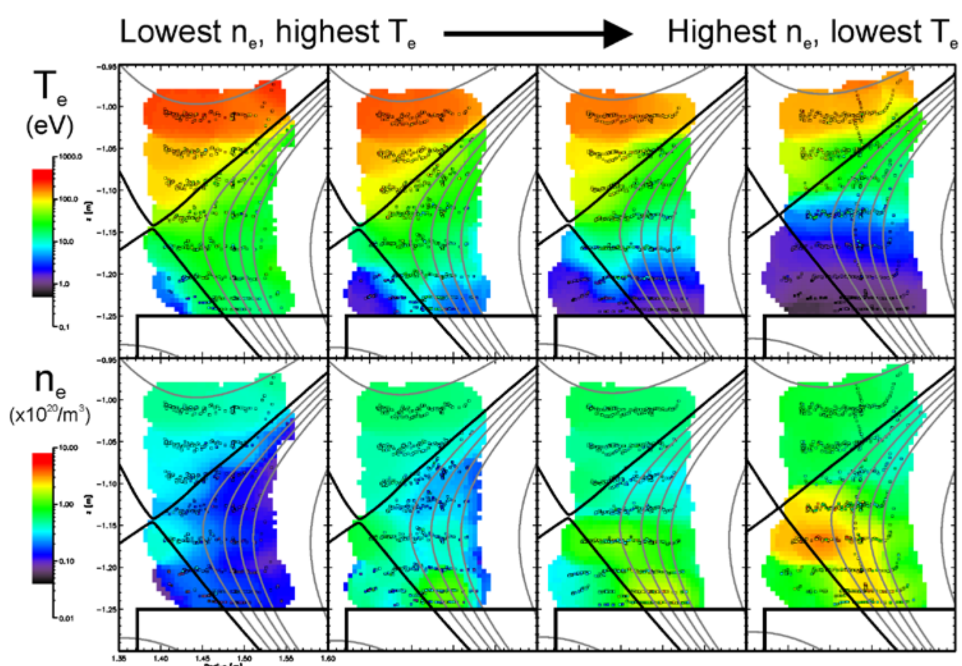

Figure 1: 2-D electron temperature (top row), and density (bottom row) for each of four plasma boundary densities increasing from left to right as measured by divertor Thomson scattering in DIII-D. Small squares indicate measurement locations mapped to the displayed magnetic equilibrium.