A Novel, Cost-Effective, High-Channel-Density Multi-point Thomson Scattering System for Diagnosing High Temperature Plasmas on the Pegasus Toroidal Experiment*

D.J. Schlossberg, J.L. Barr, G.M. Bodner, M.W. Bongard, M.G. Burke, R.J. Fonck, J.M. Perry, J.A. Reusch, C. Rodriguez Sanchez

A novel Thomson scattering system has been designed, deployed, and exploited at the Pegasus Toroidal Experiment to provide high spectral and spatial channel density at relatively low cost and complexity. This is enabled by technological advances in Volume Phase Holographic (VPH) gratings and Intensified Charge Coupled Device (ICCD) cameras that allow for simultaneous acquisition of the Thomson scattered spectrum at multiple spatial locations on a single camera. These in turn allow use of a low-maintenance, frequency-doubled Nd-YAG laser for measurements in the visible region (532-592 nm) to provide SNRs comparable to that obtained with more conventional near-IR systems.

The cornerstone of the system is a high-efficiency, 0.87 mm^2-ster spectrometer. VPH gratings provide 70-95% transmission for unpolarized light over wavelength ranges of interest. Easy substitution of gratings with different dispersions allows optimization of the measurable T_e range. On-chip binning of the ICCD reduces signal-to-read-noise ratios, enabling photon-noise limited detection with 16 spectral and 8 spatial bins. The system is capable of multi-pulse acquisition with a frame repetition time of ~60 ms, though newer ICCD technology can provide ~15 ms frame rates with the same binning scheme. Finally, the system is cost-effective in that all spectral bins for eight spatial channels (or four on-laser and four background channels for active background subtraction) are included on one detector with a simple, integrated data acquisition system. This leads to ready scaling of the spatial resolution of the diagnostic through the addition of more spectrometers, as has been demonstrated at Pegasus where three spectrometers are now in operation.

Stray laser light from non-ideal reflection and transmission of the laser is removed with a custom in-vessel conical shaped baffling system and time-of-flight rejection of stray light from the beam dump. Reflected laser light from the dump is removed by the fast gateable image intensifier of the ICCD. A typical 15 ns gate captures the ~10 ns FWHM laser pulse but excludes reflected light. Additionally, the detector is shielded from plasma background light during its readout by a fast mechanical shutter, increasing the SNR.

This system has been used to study both Ohmic and Local Helicity Injection (LHI) discharges in Pegasus, providing measurements at plasma densities as low as $n_e \sim 5 \times 10^{18}$ m^{-3}. Recent results in L-mode show T_e increasing steadily throughout the discharge, up to 150 eV. H-mode discharges have core temperatures >200 eV. Surprisingly, LHI discharges have similar temperatures to L-mode discharges and peaked temperature and pressure profiles. Future activities will involve more detailed confinement studies as well as optimizing the collection fiber mounting structure to provide more versatile and complete spatial coverage of the plasma.

*Work supported by US DOE grant DE-FG02-96ER54375.