A New Technique for Measuring Local Electric Field Fluctuations in High Temperature Plasmas[1]

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Measurement of electrostatic potential, or local electric field, turbulence is a critical missing component in validating nonlinear turbulence and transport simulations of fusion plasmas. A novel diagnostic for measuring local electric field [E(r,t)] fluctuations is being developed to address that need. It employs high-speed measurements of the spectral linewidth and/or line intensities of light emitted from an H^0 diagnostic neutral beam, while exploiting the line splitting from the Motional Stark Effect. The measurement is localized by the usual cross-beam geometry of beam-spectroscopy measurements. Specific vector components are selected by different viewing geometries. A midplane view of the beam can measure E_r and v_Z fluctuations via the varying Stark-broadened linewidth. In contrast, an off-midplane view using fluctuations in the π/σ intensity ratio can also measure E_r and v_Z fluctuations, albeit with a residual dependence on the local density fluctuations. The emphasis to date is on the midplane viewing system, because the optical access requirements are less. Linewidth fluctuation estimates based on simple turbulence scalings suggest that $\tilde{E}/E_{MSE} \sim 10^{-3}$ for the core plasma in present experiments. These fluctuations will likely need to be extracted via cross-correlation measurements with stronger local density fluctuation measurements. This approach is similar to that applied to local ion temperature fluctuation measurements on DIII-D.

Developments in both spectroscopic instrumentation and 2-D detector technology are exploited to satisfy the requirements of high throughput ($\sim$0.01 cm^2-ster), resolution (0.025 nm), and speed (500 kHz). A Spatial Heterodyne Spectrometer (SHS) is coupled to a high efficiency, low-noise, fast-framing CMOS camera to provide measurements of the Fourier transform of the line profile. The SHS design employs Volume Phase Holographic gratings to provide high efficiency and compact dimensions. The camera contains an integrated data acquisition and storage capability that readily couples to data archival systems. By making the window at the tokamak wall optically conjugate with the image field containing the interference fringes, the line broadening arising from the large collection lens can be virtually eliminated via corrective phase shifts across the fringe pattern.

A low-divergence ($< 0.5°$), 80 kV, 2.5 A H^0 diagnostic neutral beam is being developed for this system. The washer-stack arc ion source provides plasmas with $T_e \sim 20$ eV and $n_e \sim 5 \times 10^{17}$ m^{-3}, which is sufficient to sustain a 6 mA/cm^2 current density while maximizing the signal from the full energy component. The development plan includes tests with a magnetized target plasma in the laboratory and may include tests on the Pegasus ST experiment, followed by deployment to national tokamak experiments.

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