9th Asia-Pacific Conference on Plasma Physics, 21-26 Sep, 2025 at Fukuoka

Conceptual design of a Doppler Backscattering diagnostic for the EXL-50U spherical tokamak

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The EXL-50U spherical tokamak was built by Energy iNNovation to develop technologies for proton-boron fusion in spherical tokamaks [1]. We present a conceptual design of the Doppler backscattering (DBS) diagnostic for the EXL-50U spherical tokamak. DBS is a diagnostic capable of measuring electron scale turbulence, which is especially important for transport in tokamaks. Starting from a set of physical design constraints, such as port window availability and in-vessel space, we used SCOTTY [2], an in-house beam tracing code, to predict the location of the cutoffs and the corresponding scattering wavenumbers for several EXL-50U plasma scenarios. We find that we are able to measure scattering locations of $0.15 < \rho < 1$, with corresponding turbulent wavenumbers of $2.47\ \text{cm}^{-1} < k_{\perp} < 9.49\ \text{cm}^{-1}$. We then determine the optimal toroidal launch angles to ensure that the probe beam's wavevector is perpendicular to the magnetic field at the cutoff location, thereby maximising the backscattered signal. This matching is crucial due to the EXL-50U's high magnetic pitch angle, $\sim 35^{\circ}$ at the outboard midplane. Given our results, we propose the use of toroidal steering and tunable frequency channels to ensure beams are well matched. We propose a quasioptical system that covers the U-band range (40 – 60 GHz).

References

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[2] V. H. Hall-Chen, Scotty, https://github.com/beam-tracing/Scotty (2022).