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X-mode Beam Tracing in a 2D Slab for Doppler Backscattering

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The Doppler backscattering diagnostic (DBS) is one of the few diagnostics able to measure intermediate-scale turbulent density fluctuations. The spatial and wavenumber resolution of DBS, as well as its sensitivity to density fluctuations at different locations, depend strongly on the width and curvature of the Gaussian beam emitted by the DBS antenna. Quantitatively accounting for these effects is key for accurately determining properties of the density fluctuations from DBS measurements.

Using beam tracing, we analytically calculate the propagation and diffraction of X-mode DBS probe beams in 2D slab geometry with a linear density gradient, in the limit where the cyclotron frequency is much lower than the beam frequency. We then use the reciprocity theorem to calculate the DBS filter function and its effect on the measured turbulent density fluctuation spectrum, finding that X-mode DBS measurements in this geometry are qualitatively similar to that of O-mode (J. Ruiz Ruiz et al, JPP, in preparation), albeit with an additional contribution to the instrumentation function. We then find the effect of having a small-but-finite toroidal launch angle, which results in 3D propagation with a non-zero mismatch angle. This mismatch angle has been known to decrease the backscattered signal and DBS practitioners typically seek to minimise it, though this is not always possible. We study how mismatch angle evolves and its effect on focusing the probe beam. Finally, we determine the effect of mismatch on the measured turbulence spectra.

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