

Synthetic Doppler-backscattering diagnostic based on reduced models of plasma-wave interactions: recent progress and next steps

Valerian H. Hall-Chen¹, K. Barada², V.P. Bui¹, Y. Chow¹, S. Chowdhury², N.A. Crocker², J. Damba², K.R. Fong^{1,3}, M. Giacomini⁴, P. Hill⁴, J.C. Hillesheim⁵, Y.H.M. Liang¹, T. Macwan², L.B.S. Marsh¹, C.A. Michael², R.J.H. Ng¹, R. Otin⁶, F.I. Parra⁷, B. Patel⁶, E. Poli⁸, Q.T. Pratt², T.L. Rhodes², J. Ruiz Ruiz⁹, P. Shi¹⁰, Z.K.I. Tan^{1,3}, N.Q.X. Teo^{1,11}, J.W. Tumbokon^{1,3}, J. Wang¹, X. Wang¹, T. Xing¹, A.K. Yeoh^{1,9}

¹IHPC, Agency for Science, Technology and Research (A*STAR), Singapore

²UCLA ³NUS ⁴York ⁵CFS ⁶UKAEA ⁷PPPL ⁸MPI ⁹Oxford ¹⁰ASIPP ¹¹NTU

e-mail (speaker): valerian_hall-chen@ihpc.a-star.edu.sg

Turbulent transport limits the performance of modern fusion devices. Understanding this turbulence is key to designing and optimising the next generation of fusion energy systems. However, measuring turbulent fluctuations is difficult due to the spatial and temporal resolutions required. Doppler backscattering (DBS) is one of the few diagnostics capable of measuring turbulent density fluctuations. Direct quantitative comparison between such measurements and gyrokinetic simulations of the same is challenging. Such comparison requires a model of plasma-wave interactions, acting as a synthetic diagnostic. Full-wave synthetic diagnostics are computationally intensive while ray tracing is unable to quantitatively account for instrumentation effects such as beam focusing and mismatch attenuation.

In this talk, we present an overview of our synthetic DBS diagnostic, which is based on beam tracing and the reciprocity theorem, and implemented in the Scotty code platform. Scotty is capable of predictively and quantitatively calculating DBS instrumentation effects in tokamak and stellarator geometries, and runs in under ten seconds. We will summarise our recent work on the validation of Scotty on DIII-D and MAST-U, followed by its use as a bridge between gyrokinetic simulations and DBS in these two tokamaks. We will then cross-compare Scotty with beam-tracing code TORBEAM and finite-element frequency-domain full-wave code ERMES. Finally, we will show preliminary comparisons of beam tracing with full-wave simulations.

Acknowledgements: This work was funded by A*STAR (Green Seed Fund C231718014, YIRG M23M7c0127, and a SERC Central Research Fund). This material is also based upon work supported by the U.S. Department of Energy, Office of Science, Office of Fusion Energy Sciences, using the DIII-D National Fusion Facility, a DOE Office of Science user facility, under Awards DEFC02-04ER54698 and DE-SC0019352. This work was also in part supported by a grant from the Engineering and Physical Sciences Research Council (EPSRC) [EP/R034737/1].

Disclaimer: This report was prepared partly as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.