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The challenge of modelling wave propagation and damping in hot, magnetised plasmas in fusion machines

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Solving the relevant wave equation for wave propagation and damping in a hot, magnetised plasma in a fusion machine (tokamaks or stellarators) is routinely done assuming the wave phase varies little over a Larmor gyration. Although justifiable in a large number of relevant cases, this assumption is violated in very hot plasmas and equally breaks down for short wavelength branches. As a consequence models relying on a truncated finite Larmor radius expansion (yielding partial differential equations) are indicative at best when mode conversion is occurring or when RF created or fusion-born high-energy particles reside in the plasma.

Mode conversion effects, the polarisation changes they bring about and the impact of this on the wave absorption need to be assessed, hence wave equation solvers including this extra physics need to be developed. The relevant wave equation is of the integro-differential type yielding equivalent linear systems with full rather than sparse matrices. One such code presently already exists: the AORSA code [1] developed by Jaeger. This code solves the problem by brute force and hence requires many thousands of computer hours to solve the relevant equation. But in spite of its capacity, the grid it can consider to model 3D wave propagation (needed to capture the dynamics in a stellarator) is fairly crude (~60x60x60), excluding modelling the kinetic modes should they occur.

LPP-ERM/KMS has been working on finding *more economical ways* of solving the relevant equation, by semi-analytical treatment and by re-exploration of mathematical techniques to reduce the required number crunching. This has proven an extremely challenging exercise. Various methods were already tested: upgrades of finite element or finite difference schemes [2], semi-analytical treatment relying on tabulation of key quantities [3], the transfer matrix method [4] and the wavelet approach [5]. Tested methods typically work convincingly for simple test examples as well as for truncated Finite Larmor Radius (partial) differential equation models, but break down when addressing the actual equation of interest. More recently exploiting Fast Fourier transform and semi-analytical solving has been examined. A special treatment is required to ensure periodic base functions can be used. An overview of the progress of this - still ongoing - work is presented.

References

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