Realtime raytracing of Electron Cyclotron waves for Neoclassical Tearing Modes control in The Divertor Tokamak Test facility

M. Guerini Rocco[1], D. Farina[2], A. Mariani[2], N. Rispoli[2], G. Granucci[23], L. Figini[2],

[1] *Department of Physics, University of Milano-Bicocca, Milan, 20126, Italy*
[2] *Institute for Plasma Science and Technology, National Research Council, Milan, 20125, Italy*
[3] *DTT S.C.a r.l., Frascati, Italy*

The next generation of magnetic confinement fusion reactors will require active control systems to maintain high performance and to protect the machine against potential damages resulting from plasma instabilities.

Neoclassical Tearing Modes (NTM) are magneto-hydrodynamic instabilities that can severely degrade plasma performance ultimately leading to a disruption. Electron Cyclotron Current Drive (ECCD) at the unstable magnetic surfaces, via the injection of properly aimed collimated mm-wave beams, is an effective mean to control and suppress NTMs [1,2].
Though, to be effective this operation requires a very precise alignment of the EC driven current with the NTM island (typically within 1% of the plasma radius) with fast response times (in the 1 to 100 ms range, depending on the plasma dynamics): conditions that are difficult to meet without the support of accurate modelling of the EC beam propagation and absorption in the plasma.

As part of the design of the ECCD-based NTM control system of the Divertor Tokamak Test facility (DTT) [3], we developed a realtime simulation software — based on carefully optimisations of the well-established ray and beam-tracing code GRAY [4] — that can supply the information needed by the EC launchers' actuators to stabilise the plasma.

In a test environment simulating the high performance plasma scenario of DTT, we show that our software is capable of performing well within the engineering constraints of the control system with negligible impact on the accuracy. Specifically, benchmarking against the full offline simulations, the realtime mode produces the same results with an average runtime of (11 ± 4) ms on commodity hardware.

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