DOI: 10.34854/ICPAF.52.2025.1.1.103

BENCHMARKING OF QUASI-OPTICAL AND FULL-WAVE MODELING OF MICROWAVE BEAM REFLECTION FROM THE ELECTRON CYCLOTRON RESONANCE REGION IN FUSION PLASMA *)

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Modeling the propagation, absorption, and scattering of electromagnetic waves in the electron cyclotron range within turbulent hot magnetized plasma confined in large-scale magnetic traps is successfully achieved through asymptotic approaches utilizing the VKB approximation. The applicability of the geometric optics framework is justified by the differences in characteristic spatial scales: the smallness of the wavelength and the scales of spatial dispersion relative to the inhomogeneity scales of the medium.

One of the most comprehensive approaches is the quasi-optical framework [1], which simplifies the original vector problem of wave propagation and absorption in slightly inhomogeneous media to a scalar initial value problem represented by a parabolic equation along a reference trajectory (reference beam). Notably, this approach allows for the simultaneous accounting of dissipation, diffraction, spatial inhomogeneity, and both spatial and temporal dispersion [2], but does not require the transverse beam scales to be small compared to the inhomogeneity scales of the medium. The quasi-optical framework has been successfully applied to model heating and current generation in toroidal [3] and axial-symmetrical magnetic confinement devices [4].

However, the resonant interaction of microwave radiation with hot weakly relativistic plasma can disrupt the VKB approximation, introducing new effects. One significant effect is the reflection of waves at oblique incidence in the resonance region, which may considerably limit the efficiency of electron cyclotron resonance (ECR) heating [5,6].

This paper addresses the accuracy and applicability limits of the quasioptics framework for ECR modeling problems and conducts a verification through comparison with full-wave modeling results of wave propagation in the vicinity of the second harmonic resonance in weakly relativistic plasma [7].

The work was supported by the Russian Science Foundation (grant № 19-72-20139)

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*) abstracts of this report in Russian