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High-frequency asymptotics of electromagnetic wave beams in magnetically confined plasmas.

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Electromagnetic wave beams constitute one of the major tools used in magnetic confinement devices (tokamaks, stellarators, ...) to heat, diagnose and control the plasma, and, in such applications, sufficiently fast codes for the calculation of the beam propagation, diffraction, and absorption are essential. From a computational point of view, the direct numerical solution of the relevant (linear) wave equation is hindered by the extremely small wave-length, as compared to the size of the computational domain. Besides, in contrast to computational electrodynamics, the precise resolution of the wave field is not needed: one is just interested in the energy flow and power deposition in the plasma. Under such conditions, high-frequency asymptotics is the ideal computational approach. On one hand, it allows us to separate wave oscillations, so that the extremely short scale of the problem is eventually removed from the equations for the construction of the asymptotic field. On the other hand, it yields naturally a description of the wave energy flow and power deposition in terms of a transport equation for the wave energy density. The numerical implementation is typically straightforward and leads to fast (even real-time) codes in arbitrarily complicated geometries.

This talk provides a review of the theory and implementation of high-frequency asymptotic solutions of the relevant pseudo-differential wave equation. First, the theory of geometrical optics is considered, as it fixes the basic ideas upon which other advanced techniques are built. The issue of caustic singularities is briefly addressed, and the limitation of standard geometrical optics outlined, leading to the advanced methods that have been proposed in order to overcome such limitations. The various methods are presented in a unified way based on a general asymptotic expansion of pseudo-differential operators. Particular attention is payed to the paraxial WKB and complex geometrical optics methods. At last, a number of open issues relevant to plasma physics are outlined.