Acceleration of charged particles by crossing RF or micro waves in an external magnetic field, Resonant Moments Method (RMM)

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Abstract

A mechanism for enhanced acceleration of charged particles using crossing radio frequency or micro waves propagating at different angles with respect to an external magnetic field is investigated. This mechanism consists in introducing low amplitude secondary waves in order to improve the parallel momentum transfer from the high amplitude primary wave to charged particles. In Refs. [1-2] it has been pointed out that it may be more effective to accelerate electrons when the waves propagate obliquely to the external magnetic field. The idea considered here is similar although no constraint is imposed on the refraction indices of the primary and the secondary waves.

The theoretical analysis of the acceleration mechanism is based on the Resonance Moments Method (RMM) in which moments of the velocity distribution are computed by using an average over the resonant layers $(RL)_i$ only instead of a complete phase-space average. The quantities obtained using this approach, referred to as Resonant Moments (RM), suggest the existence of optimal angles of propagation for the primary and secondary waves as long as the maximization of the parallel flux of charged particles is considered The secondary wave tends to maintain a pseudo-equilibrium velocity distribution by continuously re-filling the RL. Indeed, the combined effect of the two-waves and the magnetic field yields a stochastic motion which, though very different in nature, have some similar consequences as a collisional thermalisation of the particles population. Moreover, the synchronization between the waves and the gyro-motion of the particles is, on average, more favorable for transferring momentum to the particles.

Our suggestions are confirmed by direct numerical simulations of particle trajectories for a populations of 10^5 electrons. The parameters for these simulations are relevant in today tokamak plasma. In particular, the primary wave corresponds to the second harmonic of the cyclotron frequency and the secondary wave to the third harmonic extraordinary mode which are used for instance in the TCV tokamak experiments [3]. Our simulations confirm that the secondary perpendicular wave is the most effective for a stochastization of the particles trajectories and, consequently, to maintain a pseudo-equilibrium. Although measures of the distributions clearly show a departure from a thermal equilibrium, the stochastization effect of the secondary wave yields a clear increase (up to one order of magnitude) of the average parallel velocity of the particles. It is a quite promising result since the amplitude of the secondary wave is ten times lower the one of the first wave.

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