Stability analysis of runaway-driven waves in a tokamak

Pavel Aleynikov\textsuperscript{1} and Boris N. Breizman\textsuperscript{2}

\textsuperscript{1}ITER Organization, Route de Vinon-sur-Verdon, CS 90 046, 13067 St. Paul Lez Durance Cedex, France
\textsuperscript{2}Institute for Fusion Studies, The University of Texas, Austin, Texas, 78712 USA

Runaway electrons (RE) generated during disruption events in tokamaks have to be mitigated to minimize the detrimental impact from their massive losses to the wall, especially in ITER. RE-driven micro-instabilities, such as whistlers and magnetized plasma waves, can cause enhanced RE scattering and thereby alleviate the mitigation problem. This work presents a newly developed ray-tracing code COIN which enables stability analysis of runaway-driven waves in a tokamak. The code follows a wave-packet trajectory in a realistic plasma equilibrium and integrates the runaway kinetic drive and collisional damping of the wave. This approach captures convective aspects of wave amplification, such as the evolution of the wave vector due to plasma non-uniformity and internal reflection of the wave from the plasma boundary.

The ray-tracing code has been benchmarked for linear stability analysis of runaway electrons in realistic tokamak geometry. Whistlers and magnetized plasma waves are two primary candidates for high frequency kinetic instabilities. Radial non-uniformity of the tokamak plasma creates a cavity for these waves. A wave packet trapped in this cavity exhibits multiple conversions of these two modes into each other. Calculations of the instability threshold are consistent with previous experimental observations of the runaway-driven instability in several tokamaks (T-3, T-6, TFR, and T-10). The most unstable mode in this case is the magnetized plasma wave.

Based on the experimentally measured parameters of the runaway electron beam in DIII-D, the code predicts robust stability of such a beam with respect to high-frequency kinetically driven modes.

Preliminary calculations for ITER indicate that the minimal temperature for the whistler instability onset is $\sim 22eV$ in the case of a perfectly reflective plasma boundary.

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