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Adiabatic nonlinear waves with trapped particles: III. Wave dynamics

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The evolution of adiabatic waves with autoresonant trapped particles is described within the Lagrangian model developed in Paper I, under the assumption that the action distribution of these particles is conserved, and, in particular, that their number within each wavelength is a fixed independent parameter of the problem. One-dimensional nonlinear Langmuir waves with deeply trapped electrons are addressed as a paradigmatic example. For a stationary wave, tunneling into overcritical plasma is explained from the standpoint of the action conservation theorem. For a nonstationary wave, qualitatively different regimes are realized depending on the initial parameter S, which is the ratio of the energy flux carried by trapped particles to that carried by passing particles. At $S < 1/2$, a wave is stable and exhibits group velocity splitting. At $S > 1/2$, the trapped-particle modulational instability (TPMI) develops, in contrast with the existing theories of the TPMI yet in agreement with the general sideband instability theory. Remarkably, these effects are not captured by the nonlinear Schr\"odinger equation, which is traditionally considered as a universal model of wave self-action but misses the trapped-particle oscillation-center inertia.

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