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Whistlers, Helicons, Lower Hybrid Waves: the Physics of RF Wave Absorption Without Cyclotron Resonances[1]

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In hot magnetized plasmas, two types of linear collisionless absorption processes are used to heat and drive noninductive current: absorption at ion or electron cyclotron resonances and their harmonics, and absorption by Landau damping and the transit-time-magnetic-pumping (TTMP) interactions. This tutorial discusses the latter process, i.e., parallel interactions between rf waves and electrons in which cyclotron resonance is not involved. Electron damping by the parallel interactions can be important in the ICRF, particularly in the higher harmonic region where competing ion cyclotron damping is weak, as well as in the Lower Hybrid Range of Frequencies (LHRF), which is in the neighborhood of the geometric mean of the ion and electron cyclotron frequencies. On the other hand, absorption by parallel processes is not significant in conventional ECRF schemes. Parallel interactions are especially important for the realization of high current drive efficiency with rf waves, and an application of particular recent interest is current drive with the whistler or helicon wave at high to very high (i.e., the LHRF) ion cyclotron harmonics. The scaling of absorption by parallel interactions with wave frequency is examined and the advantages and disadvantages of fast (helicons/whistlers) and slow (lower hybrid) waves in the LHRF in the context of reactor-grade tokamak plasmas are compared. In this frequency range, both wave modes can propagate in a significant fraction of the discharge volume; the ways in which the two waves can interact with each other are considered. The use of parallel interactions to heat and drive current in practice will be illustrated with examples from past experiments; also looking forward, this tutorial will provide an overview of potential applications in tokamak reactors.

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