

ミラー磁場中のアルベン波動の自発励起とイオンとの相互作用 Spontaneous excitation of Alfvén waves and their interactions with high-energy ions in a magnetic mirror configuration

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In laboratory fusion plasmas, high-energy ions are produced with DD and DT fusion reactions and are also created with high-energy neutral beam injection and electromagnetic waves for plasma heating. Special emphasis is given to plasma waves excited by such high-energy ions and their interactions with particles. For example, energetic alpha particles produced with DT fusion process can interact resonantly with shear Alfvén waves during slowing-down process, and excite plasma instabilities, that is, so-called Alfvén eigenmodes (AEs). Recently, enhancement of energetic ion transport caused by these instabilities has been remarked on its deleterious effects. When a small fraction of alpha particles is transported to the first wall in burning plasma devices, plasma facing materials can be damaged seriously. Many kinds of the experimental observations related to such wave-particle interactions are reported. In this report, spontaneously excited waves in Ion Cyclotron Range of Frequency (ICRF) and their interactions with high-energy ions in a mirror magnetic field configuration are presented.

The ICRF waves are frequently used for the plasma heating in laboratory fusion devices with the mirror magnetic field configuration. When the ICRF power and consequent wave energy levels are increased, it will become important to understand the detailed physics of wave-wave and wave-particle interactions. It is required to consider both linear and nonlinear processes for deposition of ICRF powers. In the ICRF heating experiments on the GAMMA 10 tandem mirror, the maximum ion temperature in the perpendicular direction has reached 10 keV and the temperature anisotropy (which is defined as the temperature ratio of perpendicular to parallel to the magnetic field line) becomes more than 10 in the central cell. Alfvén-ion-cyclotron (AIC) waves are spontaneously excited owing to such the strong temperature anisotropy. The excitation of the AIC wave is one of the common physical phenomena in space plasmas with an anisotropic velocity distribution. High energy ions, of which energy is more than 50 keV, have been observed along the magnetic field line at the open end of the mirror magnetic field configuration. The transport of high-energy ions along the magnetic field line owing to the loss processes other than the classical Coulomb scattering has been suggested. The existence of considerable energy transport along the magnetic field line owing to the AIC waves is discussed theoretically. The AIC waves in GAMMA 10, which has several discrete peaks in the frequency spectrum, are excited as eigenmodes. Their spatial structures are measured with a microwave reflectometer inside the plasma and magnetic probes in the peripheral region. Low-frequency fluctuations around 0.1 MHz, which is a differential frequency between discrete peaks of the AIC waves, are observed in the central cell. These fluctuations are also observed in the high-energy ion signal detected by a semiconductor detector installed at the end for measuring ions along the magnetic field line. Pitch angle scattering in the velocity space owing to the spontaneously excited Alfvén waves are indicated. The radial transport of high-energy ions owing to the low-frequency MHD instability has been observed, however, the transport across the magnetic field line owing to the AIC waves has not yet been detected.

Observations of spontaneously excited waves in ICRF in the large tokamak experiments are also reported as Ion Cyclotron Emissions (ICE). The fluctuations in ICRF are driven by the presence of non-thermal ion distribution in magnetically confined plasmas and plasmas with the strong anisotropy. Waves owing to fusion products of ³He and T ions are clearly detected in D-plasma and alpha particles in DT-plasma experiments.

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