7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Diagnosing fast electrons interacted with kinetic waves on spherical tokamak

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Recently, ubiquitous feature of the interactions among high-frequency waves and fast electrons is getting spotlight both for the geomagnetic space and magnetic bottles for fusion energy development. Both cases share the same physics basis but have largely different characteristic scales of the systems. Resultantly, available diagnostics and relevant challenges are different. In this presentation, several problems of interest for laboratory magnetic confinement of fusion plasmas that is related to fast electrons is introduced. Then, recent works performed on the QUEST spherical tokamak (Kyushu Univ., Japan) for diagnosing fast electron behavior interacted with kinetic waves will be presented.

It is recognized that energetic/fast electrons confined in tokamaks and spherical tokamaks (STs) are highly anisotropic due to those low collisionality and become sources of kinetic instabilities. Burst of high-frequency kinetic modes have been recently observed in several tokamaks. Fast electrons in tokamaks and STs are attractive in terms of excellent absorber of electron cyclotron waves that are injected for plasma current drive but have a concern that they may lead to so-called runaway electrons (reaching relativistic speed without braking) and damage the plasma facing components. As a method of controlling such fast electrons to mild energies, pitch-angle scattering by kinetic modes are expected. If sufficient knowledge is obtained, there is a possibility of active control of fast electrons by externally exciting appropriate modes to exploit benefits of fast electrons while increasing the critical toroidal electric field for the generation of runaway electron (RE) beam. This function is especially important during a disruption (thermal and current quench). Several tokamaks and STs have been conducting research on it mainly in terms of RE issues. Although some experiments and simulations suggest that their effects are remarkable for RE beam physics, their understanding is still insufficient and more dedicated experimental studies are required. The difficulty of the relevant studies is in measuring a detailed structure of high-frequency kinetic modes, typically whistler waves, and dynamics of fast electrons in a denser hot plasma than the geomagnetic plasma.

So far, studies of the kinetic modes during disruptions are all based on the measurement of corresponding oscillations of the electromagnetic fields. On QUEST, along with various magnetic measurements, by developing a fast-response detector of hard X-rays, it was firstly found that the fast electrons confined in the magnetic bottle exhibited fluctuations with the same frequencies with the kinetic modes that were destabilized by high anisotropic electron velocity distribution (see Figure 1). This is the clear evidence of the interaction between the excited kinetic modes and driving fast electrons. In addition, we are close to diagnosing electron velocity distribution in a ST for the first time by developing a pitch-angle resolved fast electron probe; a direct particle measurement in a hot plasma, which has not been commonly performed in fusion plasma unlike in space plasma, was achieved using a novel high-speed particle measurement with canceling X-ray contribution. This new measurement and various results shown together will accelerate the understanding of the dynamics of fast electrons with accompanying kinetic modes and lead to attractive control of fast electrons in a magnetically confined laboratory plasma for fusion development.

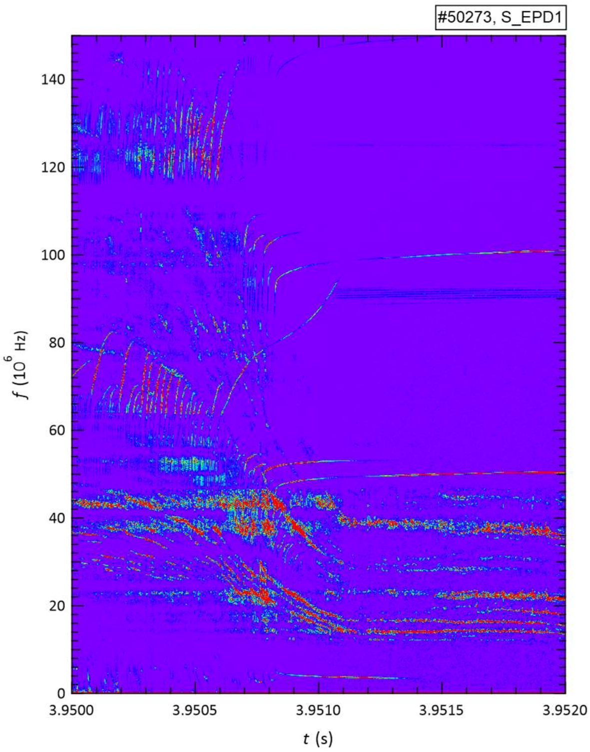

Figure 1. Fastly founded oscillations of fast electrons in a magnetically confined laboratory plasma on QUEST. The frequencies of high intensities correspond to those of the high-frequency kinetic modes, which are destabilized when the fast electrons are strongly accelerated by the inductive toroidal electric field.

This work was partly supported by JSPS KAKENHI Grant Number 21K03511 and partly by NIFS bilateral collaboration research program under grant no. NIFS22KUTR172.