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Investigation of Electron Heating Mechanism for Strong Guide-Field Magnetic Reconnection

高ガイド磁気リコネクション現象における電子加熱機構の解明

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1. Introduction

1.1. Magnetic reconnection

Magnetic reconnection which changes the topology of magnetic field lines, provides a new equilibrium configuration of lower magnetic energy. It occurs everywhere in the universe, such as solar flares, coronal mass ejection, and interaction of solar winds with the Earth's magnetosphere and is considered to occur in the formation of stars plasmas [1, 2]. During this process, magnetic energy is converted to kinetic and/or thermal energy through acceleration and/or heating of charged particles. Despite the astrophysics, numerical and laboratory studies of magnetic reconnection, the energy conversion mechanism remain unsolved.

1.2. Thomson scattering diagnostics

Thomson scattering diagnostics became standard and reliable diagnostics for electron temperature and density on magnetic confinement device since 1969 [3]. The traditional Thomson scattering measurement system, however, can provide data for only one location during a single discharge.

1.3. Purpose of this research

This study focuses on investigation into the electron heating mechanism for strong guide-field magnetic reconnection in the UTST plasma merging experiment. We developed a novel slide-type two-dimensional Thomson scattering measurement system and then combined this system and magnetic field measurement to for disclose the energy conversion mechanism in the UTST plasma merging experiment [4].

2. Experimental setup

In the UTST plasma merging experiment, two initial spherical tokamaks (STs) is formed by PF coils in both upper and lower sections and then, these plasmas merge together through magnetic reconnection simultaneously with energy conversion of the upstream magnetic energy to the plasma kinetic and/or thermal energy.

We developed a novel slide-type 2D Thomson scattering measurement system which is a new concept of Thomson scattering diagnostic. This system can measure radial profiles by changing the radial position of whole 1D Thomson system which can measure the axial profiles of electron temperature and density in a single discharge.

3. Experimental results

We found the high electron temperature area was localized at the X-point ($\sim$ 2 [cm]), in sharp contrast with radially-elongated shape of the current sheet (($\sim$ 25 [cm]). This sharp electron peak, however, was not observed in the TS-3 experiment with more weak guide-field [5].

Since the reconnection electric field is parallel to magnetic field (mainly guide-field), electrons are obviously accelerated to guide direction which is parallel to the magnetic field. This parallel acceleration mechanism will play an important role for the electron kinetic energy increment, however, can not explain the electron heating measured by Thomson scattering, because the measured electron temperature is perpendicular to the magnetic field in the UTST experiment.

Meanwhile, the effective resistivity E_t/j_t at the X-point became much larger than the Spitzer resistivity η_{Spitzer} due to collision between charged particles when the fast reconnection phase started (the reconnection electric field peaked). Therefore, the anomalous resistivity due to non-collision effect became dominant in the fast reconnection phase and plays a key role for thermalization of the parallel accelerated electrons.

4. Summary

We developed a slide-type 2D Thomson scattering measurement system on UTST and successfully observed electron heating only at the X-point in the strong guide-field magnetic reconnection. These results indicate that the non-collision effect plays a key role for triggering the fast reconnection as well as thermalization of the accelerated electrons around the X-point in the strong guide-field magnetic reconnection.

References

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