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Study of Electron Acceleration during Magnetic Reconnection in UTST device
UTST装置における磁気リコネクション時の電子加速の検証

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Sharp soft x-ray burst was observed during magnetic reconnection in University of Tokyo Spherical Tokamak (UTST) experiment. Soft x-ray signal developed simultaneously with reconnection electric field and its intensity clearly depend on the strength of both toroidal electric field and guide field. These results suggest that the electrons near the X point are effectively accelerated in toroidal direction by the parallel electric field during plasma merging in the presence of the strong guide field.

1. Introduction

Spherical tokamak (ST) is a low aspect ratio tokamak and has been studied to support compact and economical fusion reactor. Central solenoid (CS)-less startup method is important for ST research due to the narrow coil space. ST merging startup method has been studied as one of the CS-less startup method in START, MAST (UKAEA), TS-3/TS-4 (Univ. Tokyo). High-power plasma heating through magnetic reconnection is expected to form high beta STs by merging method, but a small number of experimental studies have been carried out on the electron acceleration/heating during reconnection. In this paper, we present experimental investigation of electron acceleration, which I an unique feature of reconnection with strong guide field.

2. Magnetic Reconnection on strong guide field

Classical model of magnetic reconnection suggests that ions are heated in downstream area through thermalization of reconnection outflow accelerated by magnetic tension force and ion acceleration and direct ion heating during magnetic reconnection were widely researched. But the detailed mechanism of conversion of magnetic energy into electrons still remains unclear. In particular in strong guide field reconnection the electron behavior is paid attention now. In recent experimental result in MAST, extremely localized electron heating was observed near the X-point after magnetic reconnection [1]. The heating mechanism is unclear, but recent numerical work by 3-D PIC model suggests that electrons are effectively accelerated in toroidal direction by reconnection electric field in presence of the strong guide field [2]. These accelerated electrons may contribute to the result in MAST. The goal of this research is to verify the electron acceleration during magnetic reconnection with strong guide field.

3. Soft X-ray and Impurity

3.1 *Soft X-ray Measurement*

Surface barrier detector (SBD) was employed to observe soft x-ray emission by electron bremsstrahlung during magnetic reconnection. SBD is diode covered with aluminum rectifying contact on n-type Si and have good sensitivity over the energy range of soft x-ray (<20keV). Soft x-ray emission from the X-point region is detected by SBDs which have tangential line-of-sight with radius of 35 cm. Aluminum foil (0.8μm) is equipped in front of the SBD as x-ray absorption filter to eliminate photon with low energy.

3.2 *Visible Impurity Line Measurement*

Visible impurity line emission was observed by optical fiber and Photomultiplier Tube (PMT). Line of sight and spatial resolution is almost same to SBD.

4. Result

Fig.1 shows evolution of reconnection electric field, soft x-ray signal, and impurity line emission signals during fast magnetic reconnection. Sharp soft x-ray burst was observed only during magnetic reconnection with good correlation with reconnection electric field (Fig.1). This suggests that electron acceleration by toroidal electric field accounts for the soft x-ray emission.

Fig.2 shows fast camera image (CIII:467nm) during magnetic reconnection. Ring shape emission was observed around X point. Toroidally elongated structure of the emission region indicates that

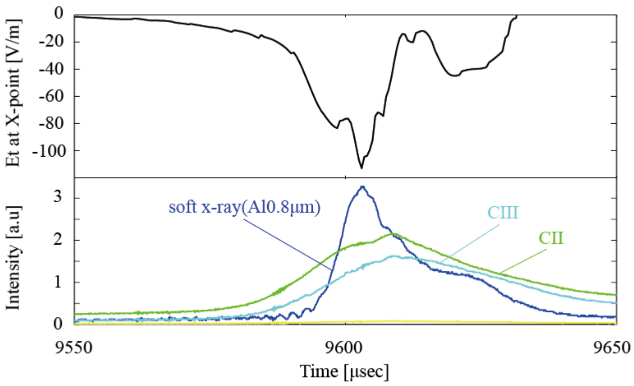

Fig.1. Time evolutions of SXR signals, visible impurity line emission and reconnection electric field

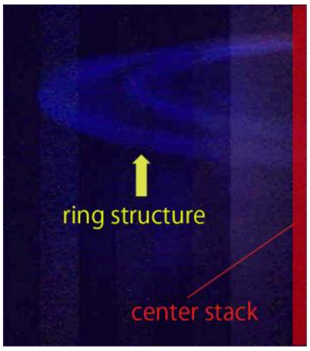

Fig.2. fast camera image during magnetic reconnection (CIII)

toroidal electron acceleration is responsible for excitation of carbon ions.Time evolution of CIII impurity form the X point region (Fig.1) shows slower time variation than that of soft x-ray, suggesting that lower energy electrons (<30eV) are produced for a longer period of time during magnetic reconnection. Fig.3 shows dependence of soft x-ray intensity on toroidal magnetic field. Soft x-ray intensity showed clear dependency on both toroidal electric field and guide field. These relusts suggest that the efficiency of the electron acceleration could be expressed by the effective electric field Et (Bt/Bp) near the X point region in analogy with torus plasma breakdown electrons near X point are effectively accelerated [3].

5. Summury

In the UTST experiment of high guide field reconnection, Evolution of the soft x-ray signal showed good correlation with reconnection electric field and its intensity showed nearly linear dependency on the strength of the guide field. These results suggest that the electrons near the X point are effectively accelerated along the toroidal direction by parallel electric field during magnetic reconnection in presence of the strong guide field. And furthermore, visible impurity line emission also showed temporal increase in brightness but with slower time variation. This result suggests that ionization/excitation of the impurity carbon Ions are provided by electrons with lower energy than those account for soft x-ray emission. Further quantitative research will be required to investigate energy conversion mechanism during magnetic reconnection to establish merging startup scheme of high beta STs.

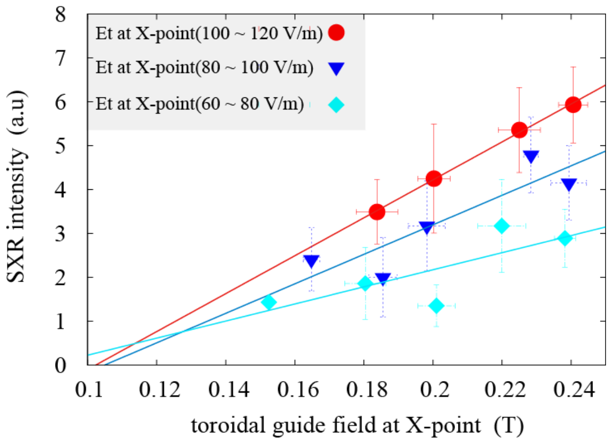

Fig.3. Dependence of SXR intensity on toroidal magnetic field(aluminum filters with thickness of 0.8μm)

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