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Behavior of a field-reversed configuration translated into a quasi-confinement region

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Abstract: To demonstrate additional heating and control methods a new field-reversed configuration (FRC) machine called FAT (FRC Amplification via Translation) has begun operations. FAT has a field-reversed theta-pinch (FRTP) plasma source and a quasi-spherical confinement region. In the initial experiments on FAT, fast FRC translation and trapping with the translation speeds 70 to 210 km/s has been performed successfully. The typical elongation of the trapped FRC is approximately 4. The FRC could survive in its quasi-Alfvénic translation process without disruptive global instability, such as tilt.

1． Introduction

A field-reversed configuration (FRC) is a compact torus [1]. Because of its simply-connected configuration, the FRC can be translated axially, and trapped in a confinement chamber along an interconnecting guide field magnetic field. In the most promising reactor scenario, FRC is first formed by the field-reversed theta-pinch (FRTP) method, then translated into a confinement region where it is heated by neutral beam injection (NBI) to reach a burning state [2]. However, after rapid formation (a few micro-seconds) process by FRTP method, the FRC does not achieve adequate trapped flux to capture tangentially-injected NBI fast ions. Therfore additional heating and current-drive methods are necessary.

To examine additonal heating and control methods, the new FRC facility FAT (FRC Amplification via Translation) has begun operations. In the FAT experiments, the FRC formed by FRTP method is translated into the quasi-spherical confinement chamber. FRC translation has been applied on several other facilities, which produce globally stable FRCs. In the other facilities, aspect ratio of the confinement ragion (length / diameter) have grater than 3.5, while the FAT has 2.3.

2． Experimental setup

Figure 1 is a schematic of the FAT facility. The FRTP section consists of a transparent quartz tube (0.256 m in OD, 2 m in length) and a set of theta-pinch coils (0.36 m in maximum ID, 0.30 m in minimun ID, 1.6 m in coil length) made of copper. An FRC formed in the formation region experiences in its quasi-Alfvénic translation process. The motion of translating FRC is inferred by excluded flux method using magnetic probes and flux loops. In the formation region at z = -19.5 cm, He-Ne laser-interferometry and ion-Doppler-broadening spectroscopy systems are installed to measure the line-integrated electron density and ion temperature,

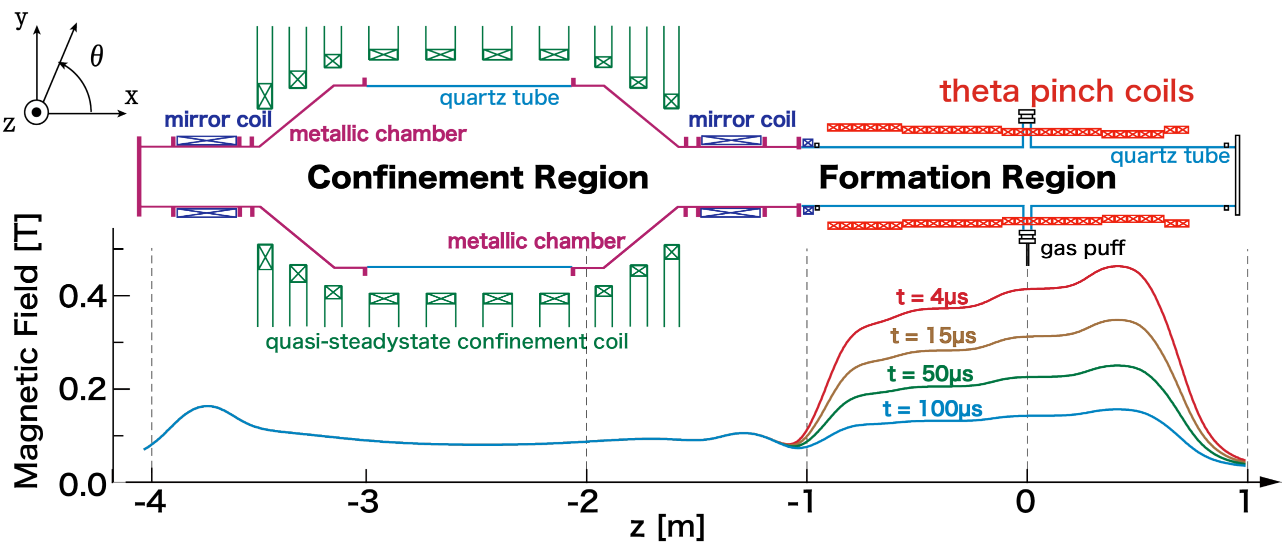

Figure 1. Schematic view of FAT facility with typical magnetic field.

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respectively. Collimator arrays to observe bremsstrahlung in the wavelength range of 550 ± 5 nm are installed to detect the global motion of translated FRCs. The most distractive instability in existing FRC experiments is the rotational instability with toroidal mode number n = 2 deformation. Observing along a chord parallel to the y axis is effective to detect the optical signal of rotating FRC.

Confinement chamber of FAT consisits of a transparent quartz tube (0.8 m in OD, 1 m in length), two metallic conical chambers and confinement coils. Decay of the confinement magnetic field (rise-time ~ 50 ms) is neglible because FRC lifetime is ~0.1 ms.

3． Experimental results

The first plasmas on the FRC experiment are successfully translated without disruption even through the violent process of translation into the quasi-spherical confinement chamber.

The translation speeds could be controlled in the range between 70 and 210 km/s. Figure 2 shows time evolution of separatix profile and volume on a typical FRC translation. Separatrix is a magnetical boundary of FRC, therefore the global behavior is observed from separatrix shape. However, the rotational instability with toroidal mode number n = 2 deformation cannot be detected by magnetic measurement in this case, because the magenetic probes and the flux loops detect mean values at each radial positions. Figure 3. shows time evolution of bremsstrahlung observed along a chord parallel to the y axis at z = -2.7 m. The onset time of toroidal deformation is approximately 70 μs in this operation. The rotation direction of FRC is the same as the ion diamagnetic direction.

The typical elongation (separatrix length / separatrix diameter) of the FRCs translated into the confinement chamber is roughly 4. On the other hand, the typical elongation of the FRCs in formation region is 6.

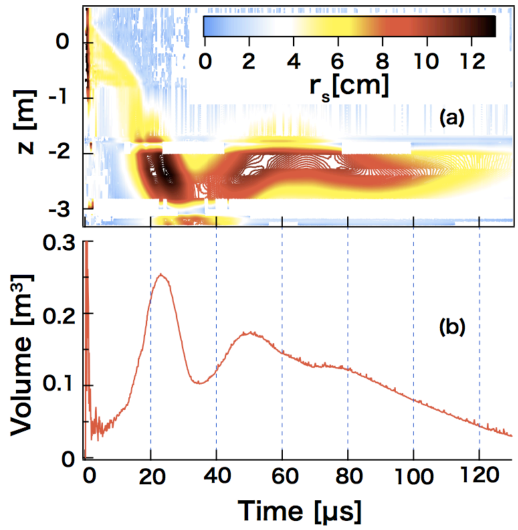

Figure 2. Time evolution of (a) separatrix profile. (b) separatrix volume.

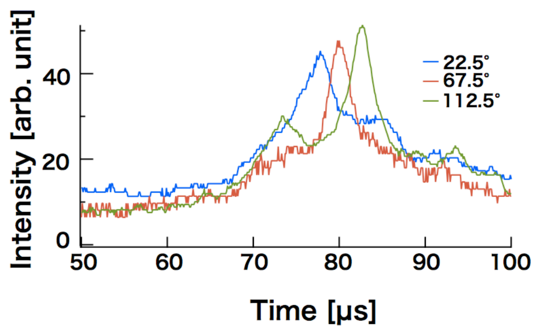

Figure 3. Time evolution of bremsstrahlung observed along a chord parallel to the y axis at z = -2.7 m.

4． Summary

The new FRC facility FAT has begun operations and performed FRC translation successfully. The translation speed could be controlled in the range between 70 and 210 km/s. The typical elongation of the translated FRCs into the confinement chamber is roughly 4.

As mentioned in introduction, to examine additional heating and control methods, construction of center solenoid for current-drive experiment on FAT in ongoing.

5． Acknowledgement

This work conducted as a part of the “Nihon University N. Reserch Project”.

6． Reference

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