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Development of Ion Beam Prob for the LATE Plasma
LATEプラズマのためのイオンビームプローブの開発

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An Ion Beam Probe is being developed to measure space potential distributions of the LATE(Low Aspect ratio Torus Experiment) plasmas which are formed and maintained solely by electron Bernstein wave heating and current drive. Ion sources of Na^+ , K^+ and Rb^+ have been made. Performance tests of the ion gun in the test bench and injection tests of ion beams in the LATE device have been carried out. Observed center positions of beams are almost consistent with calculated ones. But beams spread in the toroidal direction. It is a conspicuous problem in a low aspect ratio device. We are going to focus beams by using electrostatic quadrupole lens electrode. Energy analyzer is being designed.

1. Introduction

An ion beam probe (IBP) is a useful tool for the measurement of space potential in high temperature plasmas where insertion of Langmuir probes is impossible. It can measure not only space potential, but also other plasma quantities such as electron density and temperature, magnetic field and their fluctuations.

2. The LATE plasmas

In the LATE device, the spherical tokamak equilibrium configuration is formed solely by electron Bernstein wave heating and current drive and the plasma current is carried by a high energy electron tail[1].

Plasma parameters of typical discharges in the LATE device are following: plasma current $I_p \lesssim 10$kA, electron density $n_e = 10^{11} \sim 10^{12}\mathrm{cm}^{-3}$, and electron temperature $T_e \sim 70$eV when toroidal field $B_t = 480 \sim 720$ Gauss and vertical field $B_z = 15 \sim 125$ Gauss. Plasma major radius is 22.5 cm, plasma minor radius is 15.5 cm, and aspect ratio is 1.45.

3. Overall IBP System design

To investigate confinement and transport characteristics in such wave driven spherical tokamak plasmas, we are developing an IBP system for potential measurement. We use alkali metal ions (Na^+, K^+, Rb^+) with energy ~ 20 keV so that the Larmor radius of the secondary ion is large enough to escape from the plasma. Calculations based on the data of ionization cross section[2] show that the secondary beam currents of 22nA Na^{2+}, 130nA K^{2+} and 380nA Rb^{2+} may be detected respectively when 100 μA beams are injected and the length of sample volume along the primary beam is 1cm. These currents are sufficient for measurement.

Overall IBP system is shown in Fig.1 schematically. The injection beam line is set at the top port of the LATE device and the detection beam line is set at the bottom. The injection beam line consists of an ion gun, a beam profile monitor, a total beam current monitor, a toroidal sweeper and a poloidal sweeper. The ion gun consists of an ion source, a Pierce extraction electrode, and cylindrical lens electrodes. The beam ions are accelerated up to ~ 20 keV, here. The poloidal and toroidal sweeper change the injection angle on the poloidal plane and in the toroidal direction respectively. The detection beam line consists of a poloidal deflector, a toroidal deflector and an energy analyzer. The poloidal deflector and the toroidal deflector guide a secondary beam to the entrance aperture of the energy analyzer, and adjust the incident angle of the beam to the energy analyzer. The energy analyzer consists of a pair of parallel electrodes and split plates detector. The incident angle of the beam to the energy analyzer is 30 degree. This is the Proca-Green type energy analyzer[3,4] and it has second order focusing property.

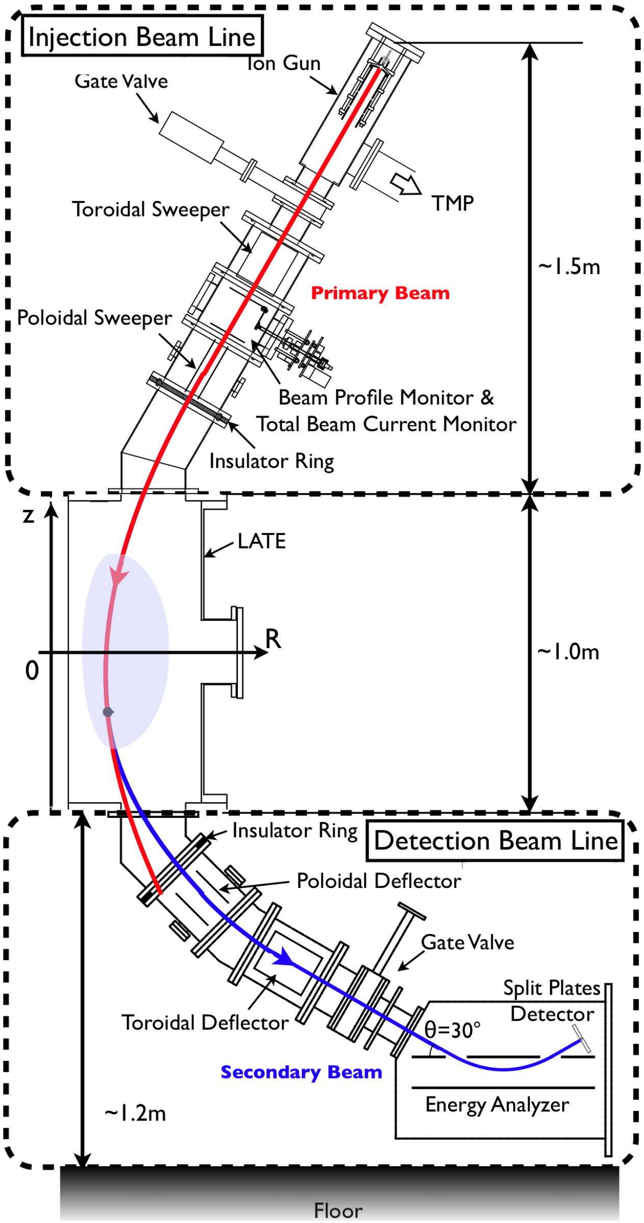

Fig. 1: Overall IBP System

4. Components developments, tests and present status

Firstly, we have made ion sources of Na^+, K^+ and Rb^+, and have tested the ion gun's performance in the test bench. Ion current more than 100 μA is extracted. Beam diameter is less than 3 cm at 206 cm away from the ion source. This place corresponds to z ~ 10 cm in the LATE device.

Secondly, the injection beam line is installed into the LATE device, and following tests are carried out. The cross section of beams at z = 1.5 cm is examined by the linear movable detector, and the cross section of beams at the entrance of the poloidal deflector is examined by the matrix plates detector (4×6 = 24ch). The observed positions of beam center are compared with calculation ones by sweeping the poloidal sweeper voltage. Both are consistent with each other when the beam energy is ~ 14 keV. But when the beam energy becomes lower, the difference appears. It becomes ~ 2 cm at the entrance of the poloidal deflector when the beam energy is ~ 8 keV.

Thirdly, the detection beam line and the matrix plates detector(8 × 3 = 24ch) instead of the energy analyzer are installed into the LATE device, and following tests are carried out. Injected primary beams are guided by the poloidal deflector to the matrix plates detector and the cross section of beams is examined. The observed positions of beam center changes by the applied poloidal deflector voltage, which is consistent with the calculation. These test results show that the beam controlling system meets the minimal demand level for the measurement.

However, the beam spreading in the toroidal direction is observed. While the beam diameter in the poloidal direction is ~ 1.5 cm, the beam diameter in the toroidal direction is more than 6 cm. It is a conspicuous problem in a low aspect ratio device. So, we are going to focus beams by using electrostatic quadrupole lens electrode.

5. Summary

The IBP system to measure space potential distributions in the LATE plasma has been designed. The injection beam line and the detection beam line with the matrix plates detector have been installed into the LATE device and have been tested. Results show that observed center positions of beams are almost consistent with calculated ones. But beams spread in the toroidal direction due to a low aspect ratio. We are going to focus beams by using electrostatic quadrupole lens electrode.

References

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