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Electron and ion stored energy in the smallest tokamak

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Table-top size torus devices have advantages in study of innovative plasma confinement and control experiments. TOKASTAR-2 device is a table-top tokamak-stellarator hybrid device,[1] where position stabilization of tokamak plasma using local helical coils has been studied.[2] While the effect of local helical coils on the tokamak position is clarified, that on confinement property has not been understood due to difficulty in plasma density and temperature measurement in table-top tokamaks. Smaller dimension and lower density restrict applicable wavelength range of interferometer. Soft X-ray and diamagnetic measurement are difficult due to lower temperature. Electrostatic probe is suitable for temperature and density measurements, however robustness of the probe for heat flux causes disturbance on core plasma. In this presentation, electron and ion stored energy of TOKASTAR-2 tokamak plasma are evaluated using passive spectroscopies.

The table-top device TOKASTAR-2 in Nagoya University have nominal major and minor radii of R = 0.12 m and a = 0.05 m. Toroidal magnetic field was B ~ 0.1 T. A tokamak was generated and sustained by induction of center solenoid coils. Pre-programmed vertical field was applied during the ohmic heating, duration of which was 0.5 ms. Typical time trace of the plasma current is shown in Fig. 1.

We measured the electron temperature and density using line emission intensity ratio of neutral helium.[3] A tangential viewing chord was used. Following four line-emissions were measured; λ = 501.6, 667.8, 706.5, and 728.1 nm. Up to five shots were accumulated for the same wavelength. By comparing line intensity ratios of measured value with those calculated using a collisional radiative model,[4] the electron temperature and density were determined. Typical electron temperature and density were $T_e \sim 10$ eV and $n_e \sim 3\times10^{18}$ m^{-3}.

A high dispersion spectrometer was developed for measuring Doppler broadening of line emission.[5] The spectrometer equipped two output ports. Photomultiplier tubes were equipped at the output ports. One was installed with a narrow (50 μm) slit for wavelength scanning, the other with a broad (1 mm) slit for monitoring intensity of whole spectrum. Line emission from singly ionized helium ion, λ = 468.6 nm was measured. Up to 10 shots were accumulated for the same wavelength. Typical spectrum is shown in Fig. 2, where each signal is integrated in time range of 5.6 ms < t < 6.0 ms. Instrumental width of the spectrometer was evaluated using the nearest atomic line, λ = 471.3 nm using a hollow cathode discharge light source. Then Doppler width was deconvoluted from the spectrum using the instrumental width. The ion temperature $T_i = 0.8 \pm 0.3$ eV as expected for the electron heating plasma was successfully obtained.

Major and minor radii of circular tokamak were evaluated using poloidal array of magnetic pickup coils.[6] Kinetic stored energy for electron (ion) is evaluated from the volume inside the last closed flux surface, the electron density, and electron (ion) temperature.

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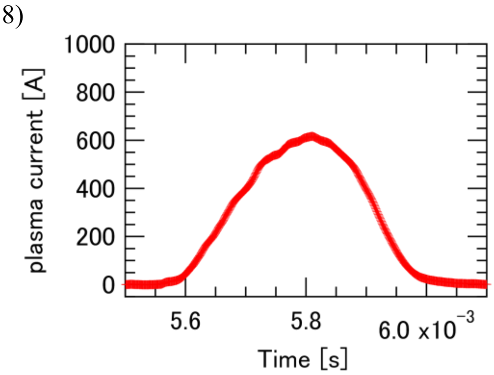

Figure 1. Typical time trace of plasma current (#18797).

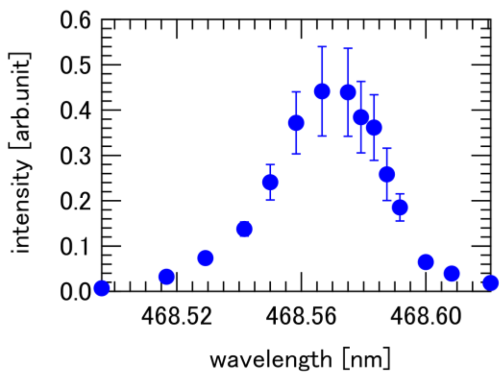

Figure 2. Spectrum of line emission from singly charged helium ion. Error bars corresponds to the root mean squared deviation among shots.