§28. Pellet Injection Experiments into Toroidal Plasmas for Studying Plasma Transport in Stochastic Magnetic Field

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In Ultra-Low-q (ULQ) plasmas some interesting features such as anomalous plasma resistance and strong ion heating have been observed experimentally, and theoretical study related with ion viscosity has been carried out intensively. In addition, the production of high energy electrons has been experimentally observed in REPUTE-1 ULQ plasmas, similar with that in RFP plasmas. Production mechanism and radial transport of these high energy electrons gives a fruitful information on ULQ/RFP plasma dynamics; e.g., MHD/kinetic dynamo mechanism and stochastic transport due to electromagnetic fluctuations. While, a pellet injected into plasmas is strongly ablated by high energy electrons with their high heat flux. Here we have injected a low-Z plastic pellet into ULQ plasmas so as to study the behavior of high energy electrons.

Typical parameters and characteristics of REPUTE-1 ULQ plasmas are as follows; the major/minor radii of plasma are 0.82m/0.2m, respectively, and the plasma current is 100 – 200 kA with a stepwise change as a function of time. A small piece of plastic pellet with a size of 0.3 – 0.5 mm diameter is injected from the top in the REPUTE-1 device, and the trajectory of the pellet inside the plasma is measured by CCD camera system equipped at the horizontal port. Figure 1 shows the typical photograph of CCD camera with CI optical filter(538 nm band width). It takes about 3 milliseconds to cross the plasma column, because the pellet speed is typically 130 – 160 m/sec. In Fig. 1 we can see a clear deflection of the pellet trajectory to the toroidal direction opposite to the plasma current (i.e., the electron drift side). This suggests that a pellet is ablated selectively only from one side due to the high energy electrons with a large heat flux. The relation between the local intensity of CI line and the local deflection rate (i.e., the 2nd derivative of the pellet trajectory) suggests a strong correlation between each other. Around the plasma center a strong deflection of the pellet trajectory takes place, accompanied by the remarkable increase of the intensity.

Ice pellet injection experiments in RFP plasmas have been carried out in ZT-40M and RFX-20, and a strong deflection of the pellet trajectory has been observed. While, in comparing the ablation process between ice and low-Z pellets, the neutral gas shielding effect is quite small in low-Z pellet ablation, because of the large difference of the evaporation energy (typically, the evaporation energy of plastic pellet is roughly two orders of magnitude higher than that of hydrogen ice pellet), resulting in lowering a neutral gas density in low-Z pellet case. Especially in REPUTE-1 ULQ plasmas the direct evaporation due to the external heat flux such as high energy electrons becomes dominant. This directly affects on the pellet trajectory; e.g., the anisotropy of the heat flux yields the large deflection of the pellet, as shown in Fig. 1. In addition, the amount of the ablated particle number of low-Z pellet is at most 1 % of the bulk density, and the perturbation to the bulk plasma dynamics is quite small. The low-Z pellet is, therefore, a useful diagnostic tool for studying the high energy electrons in REPUTE-1 ULQ plasmas.

Here let us discuss on the heat flux carried by high energy electrons, by evaluating the deflection of the pellet trajectory shown in Fig. 1. We assume that the electron drift side of the pellet is selectively ablated by the heat flux of high energy electrons and the neutral gas spouts only from the electron drift side with the thermal velocity of the evaporation temperature. Neutral gas, therefore, yields the repulsion force acting on the pellet itself to the toroidal direction. Since the repulsion force to the pellet is calculated with the 2nd derivative of the pellet trajectory, we can estimate the heat flux of high energy electrons to be a few tens MW/m^2 around the plasma center. In addition, we might say that the population of the high energy electrons is relatively large around the plasma center. By the way, the heat flux evaluated from the pellet deflection is, roughly speaking, in agreement with that measured by the Electrostatic Energy Analyzer (EEA), where the strong anisotropy of the high energy electrons is observed, as well.

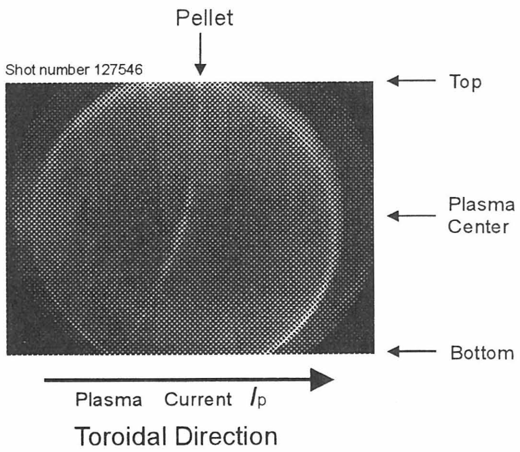

Fig. 1. Photograph of the pellet trajectory measured with CCD camera in REPUTE-1 ULQ plasmas. The pellet is injected from the top of the torus. The large deflection of the pellet trajectory opposite to the plasma current (i.e., electron drift direction) can be seen.