§9. Double-layer Pellet for Diagnostics of Particle Transport

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An innovative method to measure particle transport both in parallel and in perpendicular to the magnetic field line for plasma confinement is proposed. The essential point is based upon the poloidally and toroidally localized particle source as a tracer. This can be realized with a double layer pellet which consists of small core as tracer such as lithium and the major outer layer of hydrogen or deuterium which is the same species as the bulk plasma. The relation between location of tracer particle deposition in the plasma and pellet size (or disturbance to the target plasma) is also shown with a parameter of pellet velocity. The results indicate that the method seems promising.

The basic principle of the diagnostics of particle transport by a double-layer pellet is as follows. Here, one typical example of configuration of a double-layer pellet is the core material of lithium as a tracer with the outer layer material of deuterium. Thus, the pellet is produced in a cryogenic system. The material of the core may be the other atoms such as Be, B, C and so on. Even heavier atoms are also applicable for some purposes. The material of the outer layer should be the same species as the target plasma. Such a double layer pellet is accelerated for injection into a plasma with typical velocity of 1 to several km / s. In the plasma edge region, only deuterium is ablated from the outer layer of the pellet. In some position, the outer layer will be completely ablated, and then, the core material starts to be ablated. In order to deposit the core material in the localized area, the typical diameter of the core is from 50 to 100 μm for the plasma temperature of keV range. In this case, the length of the flight during ablation of the core is around 1 cm, which will be shown later. This localization can be adjusted with pellet size and pellet velocity depending on the plasma parameters.

In this article, it is not the purpose to study the detail elementary atomic process and ablation mechanism, but to show the validity of the method of the new concept of diagnostics. It is essential that the ablation cloud of the core material is localized enough both poloidally and toroidally. In the very initial phase, the neutral gas cloud is dominant in the ablation cloud. Then, it becomes rapidly ionized to the charge state of 1. All the ionized particles will be trapped by the magnetic field lines, and they flow along the magnetic field lines. The ionization time of Li^{+1} ion is 4 -5 μs, and that of Li^{+2} ion is 10 - 20 μs. On the other hand, the time for lithium ions going around the torus once is typically 100 to several 100 μs. Thus, the time resolution should be better than 10 μs for this measurement. In the longer time range, the particles diffuse in the radial direction, which is usual particle diffusion. The particle motion in this phase may be also measured by a CXRS array, the other spectroscopic methods to observe line radiation and a soft-X array. The characteristic time in this phase is about 10 ms to several s. The two dimensional measurement is desirable for tracing the motion of the tracer particles. The two or more similar systems will give information about toroidal symmetry (nearing to three dimensional measurement). After reaching the separatrix layer, part of the tracer particles flow into the divertor region. In this region, the tracer particles with low ionization or neutral state may be measured by a laser fluorescence method in addition to CXRS and the other spectroscopic methods.

The schematic of the device for a double-layer pellet production is shown in Fig. 1. Accuracy of positions is very important, because several steps in moving a cryogenic disk for containing a pellet are needed. The patent of the method producing a double layer pellet was applied. In the test under room temperature, the accuracy of positioning was proved to be within 10 μm. To show accurate mechanical operation under the low temperature of about 6 K, a production of a solid hydrogen pellet having a central void with the diameter of 200 μm has been recently demonstrated experimentally.

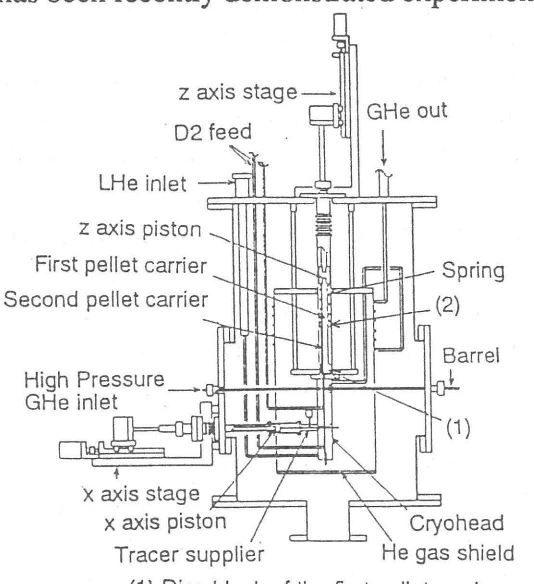

Fig. 1 Device for double-layer pellet production.