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Observation of MBI and Pellet Injection Penetration on HL-2A

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Introduction

Pellet injection and supersonic molecular beam injection (SMBI) have been proved to be more efficient fueling techniques of magnetically confined fusion plasma devices compare to conventional gas puffing. Their penetration characteristics influence the plasma performance in these devices. On HL-2A tokamk, low temperature SMB cooled by liquid nitrogen has been applied for the first time. To study the characteristics such as the injection rate and deposition depth, tangential Hα detection arrays have been installed during the 2005 experimental campaign, these arrays can observe the trace-ray of pellet and SMB locally and avoid regional confusion in certain extent.

Experiment arrangement

The HL-2A is a divertor tokamak which can be operated at limiter or a single null-divertor configuration (the major radius R =1.65 m, the minor radius a = 0.42 m). In 2005 the toroidal magnetic field B_t, plasma current I_p and plasma duration have reached 2.65 T, 400 kA and 2960 ms, respectively. Figure 1 shows the experimental arrangement for the refueling port and the tangential Hα detection array in the HL-2A tokamak. Pellet and SMB move inward along the dashed line, and the photodiode array includes 46 channels which are arranged to detect different positions.

Experimental results

SMB injection is to enhance the penetration depth and the refueling efficiency. Aiming at penetrating deeper and refueling more efficient, low temperature SMB cooled by liquid nitrogen has been applied in 2005. To study the characteristics of the SMBI such as penetration depth, SMB with room and low temperature under different gas pressure have been used in the 2005 experimental campaign. Figure 2 shows the results measured by the tangential Hα array detection during low temperature SMBI . From the figure, it can be found that the maximal emission appeared on the 46th channel, and there are no channels which can observed deeper position than it. So, the low temperature SMB entered into the deeper position than r=17 cm. When the gas pressure is 5.5 bar, Hα signal of the sixteenth channel show the strongest emission, which means the SMB reached the position coincident with the channel, and the position is about r=31 cm. The SMB with high pressure (30 bar) arrived at the position (r=20 cm) coincident with the thirty-eighth channel. From the analysis of all other shots, it can be found that the larger the gas pressure is, the deeper the SMB would enter if they are under similar condition. The characteristics have also been observed by other diagnostics, such as ECE (electron cyclotron emission) and the microwave reflectometer. Figure 3(a) is an example of ECE result during the SMB injection at low gas pressure(5.5 bar). From the figure, it can be found that the largest change of the electron temperature caused by the SMBI happened at r=34 cm, which indicates the SMB deposited most on this place. From the results of reflectometer during the SMBI (5.5 bar), the electron density of the position r=30 cm changed most, it has the same meaning with the ECE that the SMB deposited most on this position. So, the experimental results by means of the different three diagnostics appeared to be similar during the SMBI at low temperature. From the ECE measurement, the maximal amplitude of the electron temperature perturbation was observed at r=30 cm during SMBI at high pressure, while the greatest influence was at about r=26 cm after the cold SMB (22 bar) injection. Figure 3(b) shows the results of the microwave reflectometer during the low temperature SMB injection when the gas pressure is 30 bar, the result shows that the SMB deposited most on the position r = 14 cm. From the analysis of ECE and reflectometer, the similar result would be found that the penetration depth of the SMB with high pressure is larger than the one at low pressure, and the low temperature SMB would penetrate deeper if it has the same pressure. The results appear to coincide with the results by the tangential Hα array detection.

In HL-2A experiments, the pellet velocity before entering into the plasma is measured by means of two channel laser-fibre system. The tangential Hα detector arrays could give reliable data to calculate the speed inside the plasma because the emission position can be localized precisely. Figure 4 shows the results measured by the tangential Hα detection array.

In figure 4, the left peaks of each channel show the track of the pellet along the minor radius. The pellet reached the location of 19.5 cm from the plasma core at about 810.76 ms, and reached 7 cm at 810.92 ms. The average velocity of the pellet was about 781 m/s. The pellet cloud almost kept as a whole on initial channels, but some small diamonds appeared from channel 12 and became more and more on the following channels. The process indicated the ablation activity of the pellet.

Summary

The penetration characteristics of pellet injection and SMBI in the HL-2A tokamak were analyzed by means of the tangential Hα detection array. The speed of the pellet can also measured by the detection system. The penetration depth of SMB was estimated by the signal of each channel. As was analyzed above, it can be summarized as below:

The pellet velocity measured by the array is about 700-800 m/s .

The penetration depth of SMBI with high gas pressure is larger than that with low gas pressure, and the first result of the low temperature has shown that SMB at low temperature penetrated deeper than that at room temperature. So, increasing the gas pressure and decreasing the temperature could enhance the refueling efficiency.

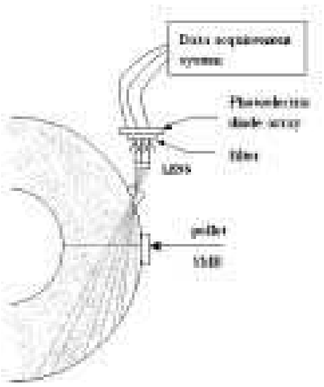

Figure 1: Overview of the experimental setup on a equatorial cross section of the HL-2A.

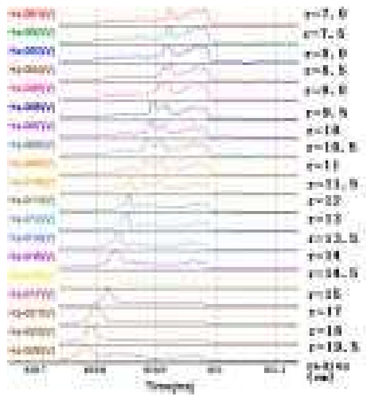

Figure 4: Pellet trace-ray and ablation measured by the tangential Hα detection Array. (shot 4513, n_e=1.3×$10^{13}$$cm^{-3}$)

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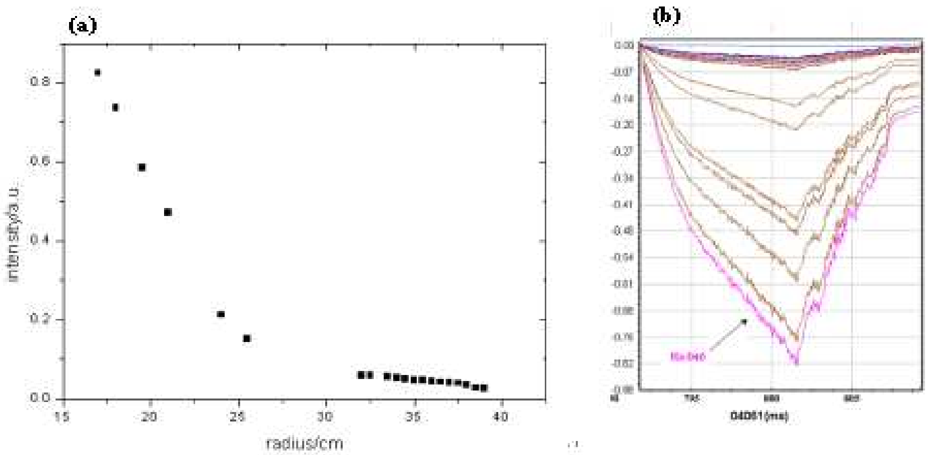

Figure 2: the largest change of Hα emission intensity happened at the location r=17cm (a) along the radius after the SMB injection (b) along time during the injection process

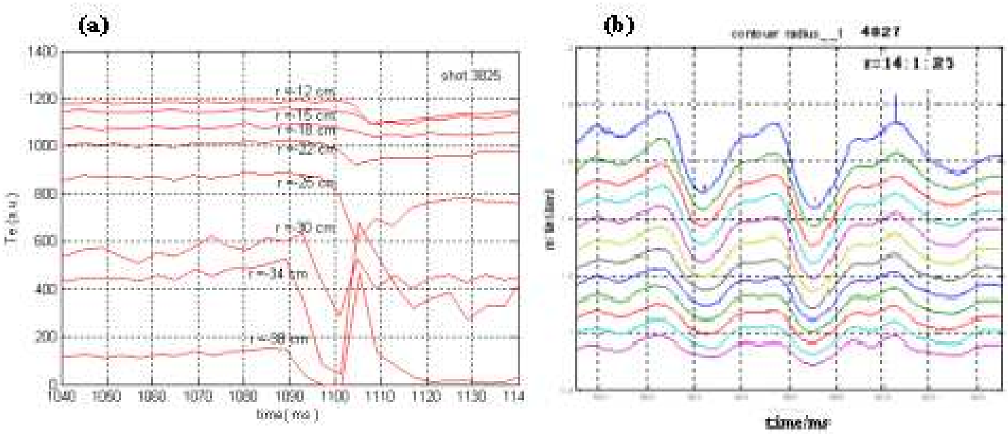

Figure 3: (a) Te pulse propagation during SMBI (5.5bar), the maximal amplitude perturbation was at r=34cm (b) n_e pulse propagation during low temperature SMB injection, the maximal amplitude perturbation was at r= 14cm.