§22. Delta NL Feedback Control of Pellet Injection in LHD

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Multiple ice pellet injection is one of the effective technique to achieve high density plasma [1]. The timing of the pellet injection was feedback controlled by keeping line averaged density using a signal of CO_2 laser imaging interferometer[2,3]. After pellet injection, electron density reduces, then, using feedback, pellet is injected when line averaged density reduces to critical density, which is set by feedback controller of pellet injection. Although, averaged density is kept higher than critical density, edge density increases in time due to the increase of the fueling by the enhance of wall recycling, then, density peaking and central density reduces[3]. We tried new feedback control to keep density peaking keeping gradient of line integrated density instead of line integrated density. Here, we call new feedback control "delta NL feedback" and the previous feedback control called "NL feedback" .

Figure 1 shows cross section of CO_2 laser imaging interferometer. The system covers from R = 3.356m to R = 4.247m with 80 channels. Two signals of 80channels are used for the feedback control. For NL feedback control, the difference of the line integrated density at R = 3.842m (blue line in Fig.1) and 4.196m (Red line in Fig.1) are used. The tangent position of R = 3.842m is ρ = 0.2 and that of R = 4.193m is ρ = 1.1. The heterodyne beating signal of two chords are sent to analog phase counter[4]. Simultaneously phase shift due to mechanical vibration are subtracted from co-axial YAG laser interferometer[3]. Since plasma density at ρ = 1.1 is close to zero and density at ρ = 0 and 0.2 is almost same, the output of the signal of phase counter corresponds to central line averaged density. This signal is used as a source of feedback. While in delta NL feedback, the chord at R=3.842m (blue line in Fig.1) and R=3.373m (green line in Fig.1) are used. The tangent position of R = 3.373m is ρ = 0.7, thus, pellets are injected to keep gradient of line integrated density between ρ = 0.2 and 0.7 higher the setting value.

Figure 2 shows comparisons of time trace of two different feedback control. Using delta NL feedback, injection interval becomes larger compared with NL feedback. As shown in Fig.2 (a), density peaking are kept almost same region for each pellet injection by delta NL feedback, while change of density peaking is different depending on the injection. Minimum of central density is kept constant by delta NL feedback and decreases in time by NL feedback. These indicate delta NL feedback is better to keep density profile constant at setting density. Figure 3 shows difference of density profile before and after pellet injection. Constant density profile are obtained at just before pellet injection (blue lines in Fig.3(b)) at the timing of feedback set density. However, since minimum of line averaged and volume averaged density is almost constant by using both feedback as shown in Fig.2 (b) and (d), same effect of the delta NL feedback can be achieved by reducing setting density of NL feedback control lower.

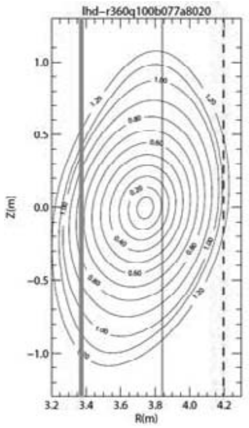

Fig.1 Cross section of CO_2 laser imaging interferometer. Magnetic flux surfaces are shows from ρ=0.1-1.2. Thick, thin and dashed lines are chord used for feedback control.

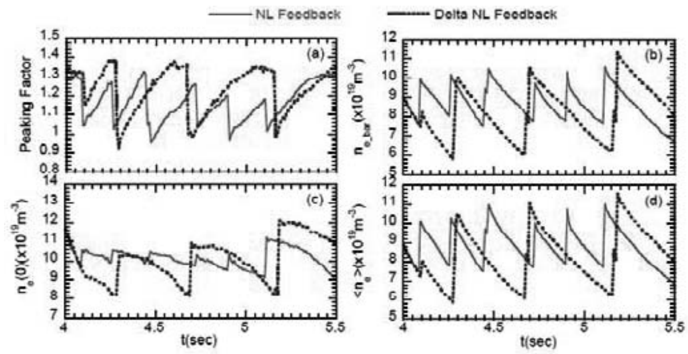

Fig.2 Time trace of different feedback control (a) density peaking factor, (b) line averaged density, (c) central density and (d) volume averaged density. The density peaking factor is defined as central density normalized by volume averaged density.

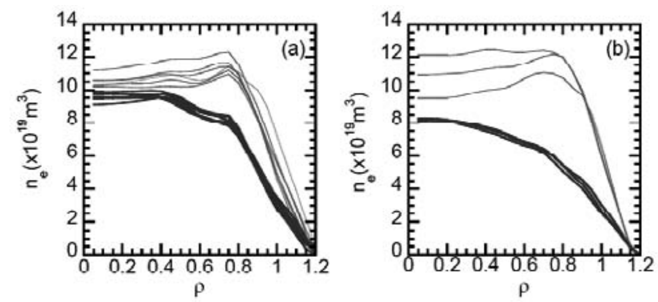

Fig.3 Density profiles of just before pellet injection (thick lines) and just after pellet injection (thin lines). (a) NL feedback and (b) Delta NL feedback

1) Sakamoto, R., et al., Plasma Fusion Res., **2**,047 (2007)
2) K. Tanaka et al., Plasma Fusion Res. 2 S1033 (2007)
3) K. Tanaka et al., NIFS annual report 2009-2010
4) Y. Ito et al., Fusion Engineering and Design 56–57 (2001) 965–968