§10. Real Time Signal Output of CO_2 Laser Interferometer for the Feedback Control of Pellet Injection in LHD

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The high density operation was the one of the advantage of helical device, where no density limit exists unlike Greenwald density limit in tokamak. In LHD, high density around 10^{20} - 10^{21}m^{-3} was achieved by the ice pellet injection[1]. In order to sustain such a high density constant, repetitive pellet injection were tried. The repetition rate should be controlled with the appropriate injection timing by using feedback control system. For this purpose, the real time output of the CO_2 (wavelength 10.6μm) / YAG (wavelength 1.06μm) laser imaging interferometer[2] was developed. This two wavelength system is in order to compensate the phase shift due to the mechanical vibration . The system is originally developed for the density profile measurements at high density (<10^{20}m^{-3}), where the existing far infrared laser ((wavelength 119μm)) fails to work. Two channel of CO_2 laser interferometer (CO_2 Int.) and YAG laser interferometer (YAG Int.) were used for the feedback control.

Figure 1 is the system of the signal processing. For the real time feedback control, analog phase counter[3] are used for both CO_2 and YAG laser int. The beating signals are filtered then phase difference between probe and reference channel is electrically calculated by phase counter for YAG and CO_2 Int.. Then, the phase shift of mechanical vibration measured by YAG Int. is subtracted from the phase shift of CO_2 int. Figure 2 shows the chord position of probe and reference channels of the discharge of Fig.3 and 4. Although the magnetic axis shifted, the probe chord at R=3.843m of CO_2 Int. passed around the axis and monitored central line averaged density. Figure 3 shows an example of feedback control of repetitive pellet injection. As shown in Fig.3 (b), the output of CO_2 int. are consist of phase shift due to electron density and vibration, while the output of YAG Int. shows only vibration components. A clean signal was obtained after vibration subtraction. Feed back control started after t = 4.3s. As shown in Fgi.3 (b), the pellet was injected when the line averaged density decreased down to 1.4 x10^{20}m^{-3} keeping density from 1.4 to 2.1 x10^{20}m^{-3}. System works without any phase jumping in spite of NBI break down at t=5.8 and 6.4s. Figure 4 (a) shows time history of central, volume averaged density and peaking factor, which was defined as the ratio of two. Although the volume averaged density was kept constant, central density decreased gradually resulting the reduction of peaking factor. Figure 4 (b) shows comparison of density profiles just before and after pellet injection at former (t=4.802, 4.812s) and latter (t = 6.129-6.139) timing of the discharge. These are obtained from the CO_2/YAG Int.. At later timing, the density decreased at ρ<0.6 and increased at ρ >0.6. The density profile became less peaked. This is due to increase of the edge recycling. In order to keep central density constant, strong pumping is necessary to reduce recycling.

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

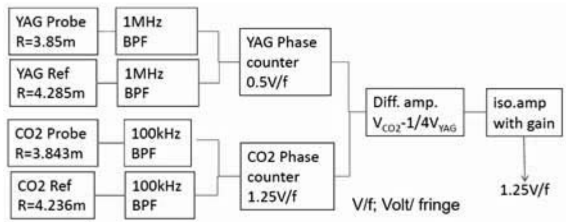

Fig.1 Schematic diagram of real time output of CO_2/YAG Int.

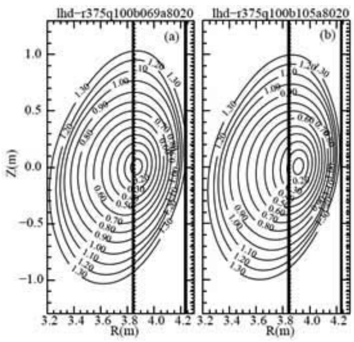
Fig.2 Chord position of CO_2/YAG Int. for real time output. Plain and dashed lines indicate chord position of CO_2 and YAG Int. at the highest and lowest peaking timing

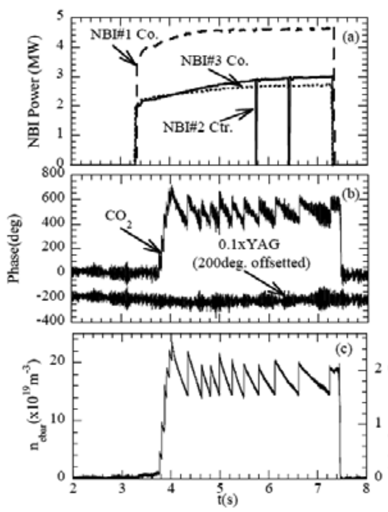

Fig.3 Time trace of (a) NBI injection power (b) CO_2 and YAG phase counter output (c) line averaged density after vibration compensation.

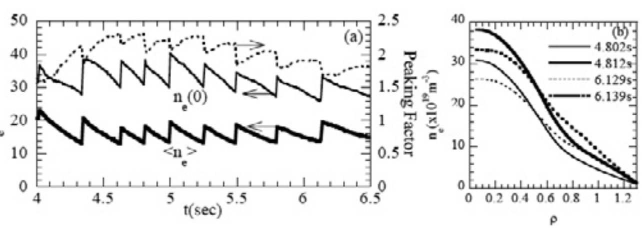

Fig.4 (a) time trace of central, volume averaged density and peaking factor (b) density profile at beginning and later timing of discharge