Short interval measurement of the Thomson scattering system at the pellet injection by using the event triggering system in LHD

R. Yasuhara, R. Sakamoto, G. Motojima, I. Yamada, H. Hayashi

National Institute for Fusion Science, Toki, Gifu 509-5292, Japan

Abstract: We have demonstrated Thomson scattering measurements of a short interval less than 1 ms by using the event triggering system with a multi-laser configuration. We have tried to measure this system at the pellet injection and obtained electron temperature and density profiles before and just after the pellet injection. Obtained profiles were dramatically changed after pellet injection with shot-by-shot measurements. This measurement technique will contribute understanding the physics of the pellet deposition.

Keywords: Thomson scattering, pellet injection, event trigger.

PACS: 52.50.Qt

1. Introduction

Thomson scattering (TS) measurements of a short interval less than 1 ms are strongly desired for a research on transient plasma events such as a pellet injection [1]. The time interval of electron temperature (Te) and electron density (ne) profiles is limited by the laser system. A joule class commercially based Nd:YAG lasers is pumped by flush lamp. A high repetition rate laser operation cannot be carried out by this pumping scheme. By researches in recent year the solid-state laser has demonstrated the Joule class output energy and over 10 Hz repetition rate with good beam quality by using laser diode [2-4] which can decrease the heat load dramatically from flush lamp scheme. However, high energy diode pumped laser system is not available commercially and is high cost now.

One of the practical solutions to realize a short time interval measurement is the burst mode operation with a multi laser configuration. Each laser in a multi-laser configuration can adjust the laser output timing independently. It allows a short interval burst mode measurement within the number of laser systems. MAST TS system has demonstrated such burst mode measurement of TS system [5] by using 8 probe lasers with the FPGA triggering system. They have obtained the Te and ne values from the transient plasma phenomena [6]. In LHD, we have three lasers for the probe laser of the TS [7]. Three burst pulses can use for a short time interval measurement. In addition, we have developed the coaxial beam combining technique to improve the spatial uncertainty of Te and ne values measured by each probe lasers [8]. By using multi-laser system with the coaxial beam combining

shot by shot TS measurement is available at the transient plasma phenomena in LHD.

In the paper, we report the detail of this burst mode measurement system and the result of the demonstration of this system at the pellet injection. This diagnostics method will contribute for cross-validation of the simulation and the experiment in transient plasma events.

2. Burst mode triggering system at the transient event

Figure 1 show the triggering system for the burst mode operation of the multi-laser TS system. TTL triggers from the tangent event such as the pellet injector or LHD timing system are used as master triggers of this system. Logic OR of this 2 line is the master trigger of the triggering system. Triggers for the three laser outputs are distributed by the DG645 which is the commercial pulse generator based on the FPGA system. The accuracy of trigger timing is less than 1 ns. It can generate the arbitrary timing trigger for the flash lamp and the Q-switch of three lasers. Then, the trigger timing duration between the Q-switch and the flash lamp should be fixed due to maintain the laser extraction efficiency. The shortest time interval of the multi-laser output for TS measurement is about a few micro second. This is depending on the data acquisition system of the LHD TS system.

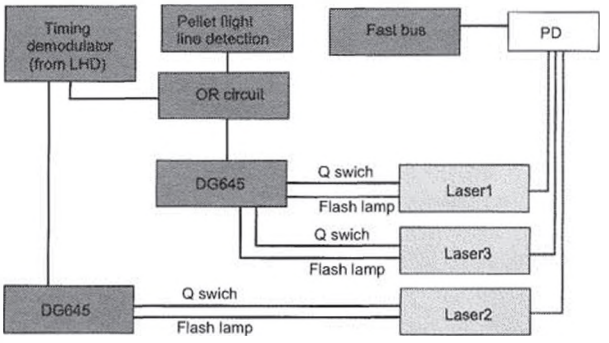


Fig. 1A schematic diagram of the event trigger system.

At first the multi-laser system is operated by the triggers from the LHD timing system for the stable laser operation. Before the some plasma event, the multi-system is stopped by stopping the LHD timing system and waited for the trigger from the events. In the case of the pellet injection, triggers from LHD timing system is stopped at 3.7 s of the LHD plasma shot for the waiting the pellet injection at 3.75 s. Finally, when the event provides the trigger, multiple laser light pulses are fired with the short time interval which is set by the DG645.

3. Multi-laser system

A partially high-reflectance coated mirror or the polarization beam combining technique [8] is adapted to form the bundle beam emitted from multiple lasers. By using the polarization beam combining, the laser beam axis is perfectly same. We can compare the ne profiles in time series of multi-laser. However, by using a partially high reflectance coated mirror laser beam axis is different between the multi-lasers. The laser beams are packed along a common beam axis at a regular interval of 1 cm by the packing mirror and a

partial overlap in the far field where they are focused on a common point inside the LHD vessel at the major radius of 3.65 m.

For the comparing the ne profiles in time series, we use the one laser for the standard laser. ne profiles measured by another lasers are normalized by the ne profiles measured by the standard laser. By adding this procedure, we can compare ne profiles by shot to shot of the multi-laser system. In near future, we planned to install the method of combining three or more laser beams by using a Pockels cell.

4.Synchronized measurement at the pellet injection

By using this short time interval measurement, we tried to measure at the pellet injection. Triggers from the pellet injector were used for the master trigger of the burst mode operation of the TS system. We have tested this synchronized measurement system for LHD TS system from 15th experiment campaign and confirmed the synchronized measurement of the TS system and the pellet injection. Figure 2 shows the Timings of the lasers for the Thomson scattering system relative to Hα emission light signal from the pellet ablation at the #113431 (16th experiment campaign). In this measurement, a pellet light gate signal with about 3.5 ms delay was used for the trigger of laser triggering sequences. A duration of two laser pulses after pellet injection was 200 μs. We have demonstrated the burst mode TS measurements within 1 ms after pellet ablation. Figure 3 shows Te and ne profiles from Thomson scattering measurements before and after pellet injection. Laser 2 put into the plasma before pellet injection (3.73358 s, red plots). After that, Laser 1 was injected after pellet injection (3.751974 s, green plots). After 200 μs of Laser 1, Laser 3 was worked for the measurement of Te and ne profiles (3.752175 s, blue plots). Finally, Laser 2 put into the plasma again (3.766912 s, orange plots). From the Fig. 3, we can see Te and ne profiles were dramatically changed after pellet injection with shot-by-shot TS measurements. This measurement technique will contribute understanding the physics of the pellet deposition.

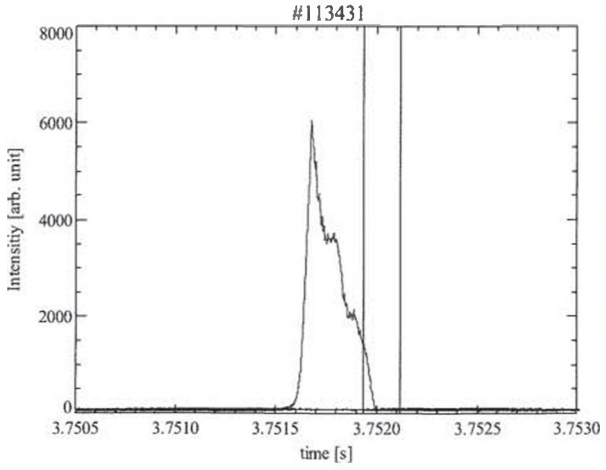
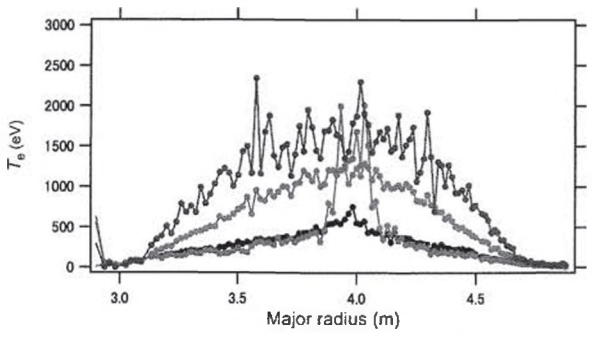


Fig. 2Timings of the lasers (blue lines) for the Thomson scattering system relative to Hα emission light signal (red line)from the pellet ablation.



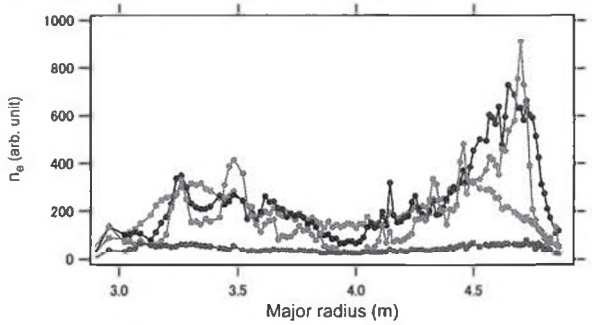


Fig. 3Te and Ne profiles from Thomson scattering measurements before and after pellet ablation.

5. Summary

We have demonstrated TS measurements of a short interval less than 1 ms by using the event triggering system with a multi-laser configuration. We have tried to measure this system at the pellet injection and obtained Te and ne profiles before and just after pellet injection. This measurement technique will contribute understanding the mechanism of the pellet deposition and the transient phenomena of the LHD plasmas.

Acknowledgments

This work was supported by a Grant-in-Aid for Young Scientists (B), Grant No. 23760813 from MEXT and is partially carried out under the LHD project financial support (Grant No. NIFS11ULHH005).This work was partly supported by the JSPS-NRF-NSFC A3 Foresight Program in the field of Plasma Physics (NSFC: No.11261140328).

REFERENCES

[1]. M. Valovi˘c, K. Axon, L. Garzotti, S. Saarelma, A. Thyagaraja, R. Akers, C. Gurl, A. Kirk, B. Lloyd, G.P. Maddison, A.W. Morris, A. Patel, S. Shibaev, R. Scannell, D. Taylor, M.Walsh and the MAST team, Nucl. Fusion 48 (2008) 075006

[2]. A. Bayramian, J. Armstrong, G. Beer, R. Campbell, B. Chai, R. Cross, A. Erlandson, Y. Fei, B. Freitas, R. Kent, J. Menapace, W. Molander, K. Schaffers, C. Siders, S. Sutton, J. Tassano, S. Telford, C. Ebbers, J. Caird, and C. Barty, J. Opt. Soc. Am. B 25(7), B57–B61 (2008).

[3]. R. Yasuhara, T. Kawashima, T. Sekine, T. Kurita, T. Ikegawa, O. Matsumoto, M. Miyamoto, H. Kan, H. Yoshida, J. Kawanaka, M. Nakatsuka, N. Miyanaga, Y. Izawa, and T. Kanabe, Opt. Lett. 33(15), 1711–1713 (2008).

[4]. S. Banerjee, K. Ertel, P. D. Mason, P. J. Phillips, M. Siebold, M. Loeser, C. Hernandez-Gomez, and J. L. Collier, Opt. Lett. 37(12), 2175–2177 (2012).

[5]. G. Naylor, Rev. Sci. Instrum. 81, 10E110 (2010).

[6]. K J Gibson, N Barratt, I Chapman, N Conway, M R Dunstan, A R Field, L Garzotti, A Kirk, B Lloyd, H Meyer, G Naylor, T O'Gorman, R Scannell, S Shibaev, J Snape, G J Tallents, D Temple, A Thornton, S Pinches, M Valovic, M J Walsh, H R Wilson and the MAST team, Plasma Phys. Control. Fusion 52 (2010) 124041

[7]. K. Narihara, I. Yamada, H. Hayashi, K. Yamauchi. Rev. Sci. Instrum. 72 (2001) 1122.

[8]. R. Yasuhara, I. Yamada, K. Narihara, H. Funaba, and H. Hayashi, Plasma and Fusion Research 7, 2402030 (2012).