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Development of the polarization controlled multi-pass Thomson scattering system for tandem mirror GAMMA10

タンデムミラーGAMMA10のための
偏光制御マルチパストムソン散乱システムの開発

Ryo Yasuhara[1], Masayuki Yoshiwaka[2], Ichihiro Yamada[1], Kazuo Kawahata[1], Hisamichi Funaba[1], Tsuyoshi Imai[2], Mizuki Sakamoto[2], Yousuke Nakashima[2], Masato Morimoto[2], Takashi Minami[3]
安原　亮[1]、吉川正志[2]、山田一博[1]、川端一男[1]、舟場久芳[1]、今井剛[2]、坂本瑞樹[2]、中嶋洋輔[2]、森本真人[2]、南貴司[3]

[1]*National Institute for Fusion science 322-6 Oroshi-cho Toki-city, GIFU 509-5292*
[2]*Plasma Research Center, University of Tsukuba, 1-1-1 Tennodai, Tsukuba-city, Ibaraki 305-8577, Japan*
[3]*Institute of Advanced Energy, Kyoto University, Gokasho, Uji-city, Kyoto 611-0011, Japan*
[1]核融合科学研究所 〒509-5292　岐阜県土岐市下石町322-6
[2]筑波大学プラズマ研究センター 〒305-8577 茨城県つくば市天王台1-1-1
[3]京都大学エネルギー理工学研究所 〒611-0011 京都府宇治市五ケ庄

The novel configuration of the multi-pass Thomson scattering (TS) system is proposed for the improvement of time resolution and accuracy of electron temperature by use of the polarization control technique. This configuration can realize a perfect coaxial multi-passing at each passes. Number of round trips is not limited by the optical configuration. Now, we are developing this new multi-pass TS system in GAMMA10. As the first step, a scattering signal has increased to 1.6 times by the double pass system.

1. Introduction

Thomson scattering (TS) diagnostics is one of the most reliable methods for measuring the electron temperature (Te) and density (ne) profiles in fusion plasmas. However, due to the small Thomson cross-section σ_{ts}=6.65×10^{-21} m^2, Thomson scattering is challenging for low densities plasma such as the GAMMA 10 plasma. The typical electron density, electron and ion temperatures of GAMMA10 are about 2 ×10^{18} m^{-3}, 0.1 keV and 5 keV, respectively, during application of P/B-ECH[1].

For increasing the scattering probability at low densities plasma, a multi-pass Thomson scattering scheme is effective. It allows the laser pulse to be focused several times onto the scattering volume, thus increasing the scattering photon number. Multi-pass Thomson scattering systems are demonstrated at many institutes. TEXTOR group has demonstrated the improvement of signal to noise ratio by use of multi-pass TS system which uses a pair of concave mirror for recycling photon[2]. JT60 TS group has constructed a double pass system by the use of phase conjugate mirror for reflection[3]. Although those systems have increased the reliability of TS system, they have the limit from the optical system. Each laser beam passes are different in a concave mirror type TS system (TEXTOR system). It should set the scattering volume near the focal point of a concave mirror, or need to calibrate for each different beam passes. A phase conjugate mirror requires the purity of laser bandwidth.

In this study, we propose a newly scheme of multi-pass TS system by the use of a polarization optics. This scheme can be modified from the basic single pass Thomson scattering system by adding the high reflection mirror for cavity mirror, lenses used for image relaying the laser beam and polarization control devices. It has a collinear beam line in the multi-pass cavity. The system design and experimental results of this multi-pass scheme have been reported at following sections.

2. Design of the polarization controlled multi-pass system

A schematic diagram of the new multi-pass method of a polarization based system is shown in the figure 1. This system is based on the GAMMA10 Thomson scattering system which has successfully observed a electron temperature of the GAMMA10 plasma in 2010 [1]. Horizontal polarized laser light from the 2 J by 10 Hz Nd:YAG laser (Continuum, Powerlite 9010) is focused into a plasma by the first convex lens. After the interaction with plasma, laser light emits from the port window which has the anti-reflection coating and collimated by the second convex lens. A pair of lenses is a key component of this optical system. It makes the image relaying optical system from IP1 to IP2 to maintain the laser beam quality during the multi-pass propagation. The laser light is reflected by the mirror for the second pass and focused again into the plasma. A Pockels cell is used for a polarization control device. It switches horizontal polarization to vertical polarization during the double pass traveling of the laser light. The vertical polarized laser light is reflected by polarizer and end mirror at the image point of IP1'. The polarization of reflected laser light is changed again by Pockels cell for the traveling of third pass. Then laser light is confined between the mirrors at the IP2 and IP1' for the multi-pass.

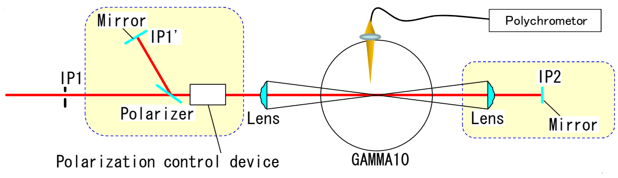

Fig.1. A schematic diagram of the new multi-pass method of a polarization based system.

To design the optical system of the multi-pass system, we have carried out the ABCD matrix analysis and the polarization analysis by the use of Jones matrix. Figure 2 shows the multiplication of the scattering light as a function of a pass number from the result of the optical design. This result indicated that scattering light signals are increased to two times larger at the double pass configuration. At the sixteenth pass configuration, scattering light was about six times larger than the single pass configuration.

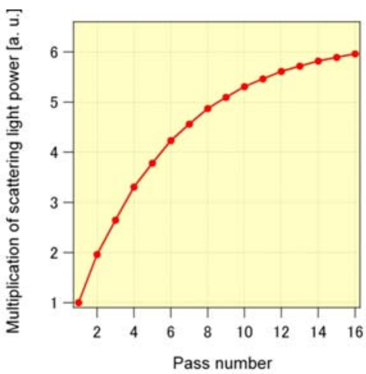

Fig.2. Scattering light power as a function of pass number

3. Experimental result

To evaluate the effect of the polarization based configuration, a mulitpass system without a polarization control device is installed in the GAMMA 10 system. This system can demonstrate the double pass scattering. Figure 3 shows double pass and single pass Thomson scattering signals. From the result, the scattering signal height of double pass configuration is 1.6 times larger than the signal of single pass configuration. It shows us the improvement of data quality of GAMMA10 Thomson scattering system and the feasibility of the proposed polarization based multi-pass system.

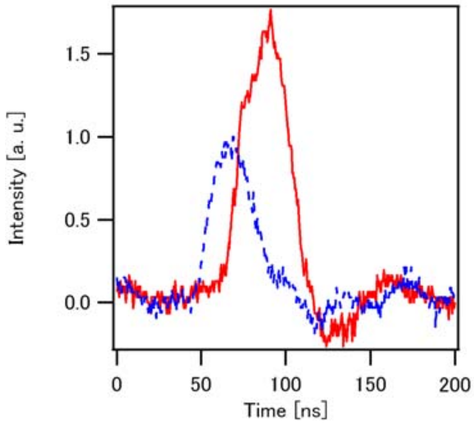

Fig.3. Double pass (solid line) and single pass (dotted line) Thomson scattering signals.

4. Summary

The novel configuration of the multipass Thomson scattering (TS) system is proposed for the improvement of time resolution and accuracy of electron temperature by the use of the polarization control technique. This configuration can realize a perfect coaxial multipassing at each passes. Number of round trips is not limited by the optical configuration but only by the optical loss. Now, we are developing this new multipass TS system in GAMMA10. In this presentation we will report a conceptual design, an estimation of TS signal at multipassing and preliminary results of the double pass experiment.

Acknowledgments

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