P26

Design and demonstration of the double pass Thomson scattering measurement in LHD

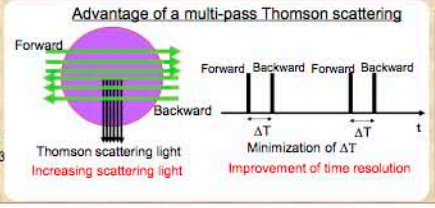
R. Yasuhara[1*], I. Yamada[1], E. Yatsuka[2], M. Yoshikawa[3], H. Funaba[1], H. Hayashi[1], H. Tojo[2], and T. Hatae[2]

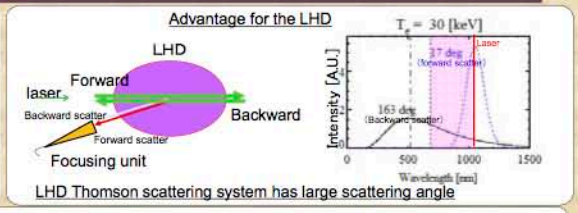
[1]National Institute for Fusion science 322-6 Oroshi-cho Toki-city, GIFU 509-5292
[2]Japan Atomic Energy Agency, Naka 311-0193, Japan
[3]Plasma Research Center, University of Tsukuba, 1-1-1 Tennodai, Tsukuba-city, Ibaraki 305-8577, Japan

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 $\sigma_{ts}=6.65\times10^{-21}$ m^2, Thomson scattering is challenging for low densities plasma such as the GAMMA 10 plasma (2×10^{18} m^{-3}) and a high temperature plasma at the LHD (~20keV).

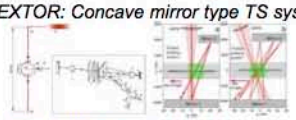




For increasing the scattering probability and the accuracy of electron temperature, a multi-pass Thomson scattering scheme is effective. It allows the laser pulse to be focused several times onto the scattering volume from backward and forward direction, thus increasing the scattering photon number into the detector.

Previous systems

In TEXTOR: Concave mirror type TS system



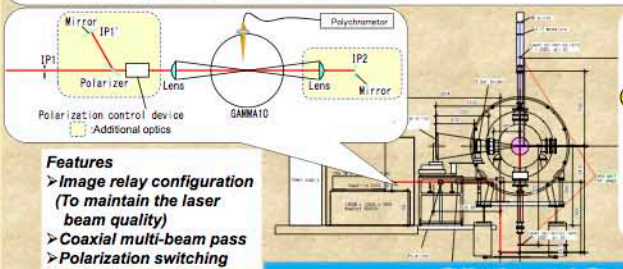
Each laser beam passes are different.
Multi-pass number is geometrically limited.
(M Yu Kantor, et al. Plasma Phys. Control. Fusion 51 (2009) 055002)

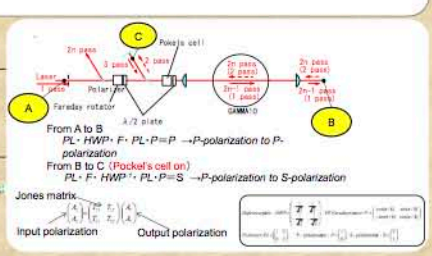
In JT60U: Phase conjugate mirror 2pass system

Cannot be used at over three passes.
A phase conjugate mirror requires the purity of laser bandwidth.
(T Hatae, et al. J. Plasma Fusion Res. 80(2004) , 87)

New method: Polarization controlled multi-pass system

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**.



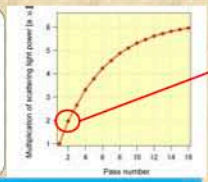


Features
- ***Image relay configuration (To maintain the laser beam quality)***
- ***Coaxial multi-beam pass***
- ***Polarization switching***

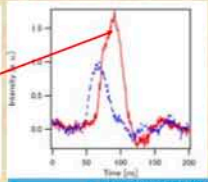
R. Yasuhara, et al., Rev. Sci. Instrum. 83, 10E326 (2012).

Demonstration of the new multi-pass system (Double pass) using the GAMMA10 plasma

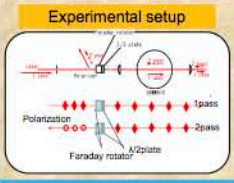
- **The multiplication of the scattering light as a function of a pass number from the result of the optical design.**
- **At the sixteenth pass configuration, scattering light was about six times larger than the single pass configuration.**

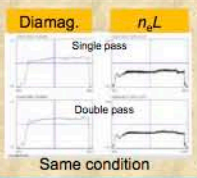


Estimation



Experimental result

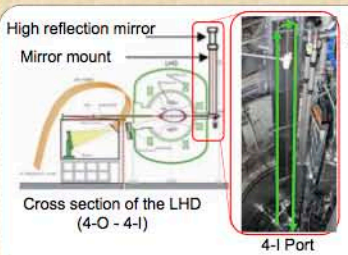




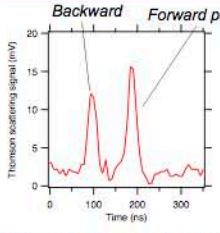
- **The integrated scattering signal of double pass configuration is 2 times larger than the signal of single pass configuration.**
- **As the result of improvement of SN, relative error of the electron temperature was reduced.**

M. Yoshikawa, R. Yasuhara, et al., Rev. Sci. Instrum. 83, 10E333 (2012).

For the LHD TS system



- **The double pass system demonstrated in GAMMA10 has installed to the LHD Thomson scattering system.**



- **We have successfully obtained the double pass Thomson scattering signal at the 16th campaign of the LHD experiment.**

Double-pass Thomson scattering signal

T_e from backward and forward TS signal

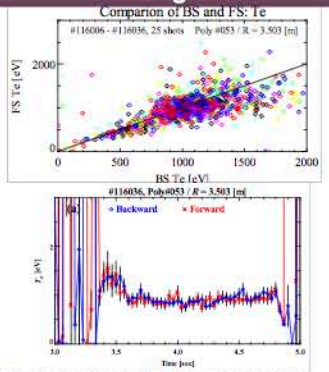


Fig. Comparison of T_e measured by the backward and forward scattering configurations.

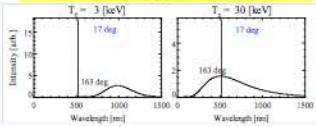
- **The forward scattering measurements show good agreement with those from the backward scattering.**
- **$T_\perp$ and $T_{//}$ was same at this experimental condition.**

Cf. → I. Yamada, R. Yasuhara, et al., P.24 (Mon).

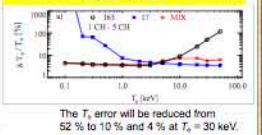
Open the new physics by using the multi-pass system

- **Forward scatter can be measured by use of the multi-pass system. This measurement improves the reliability of electron temperature at high temperature plasma higher than 30 keV.**

Estimation of forward(17 deg.) and backward(163 deg.) scattering spectrum



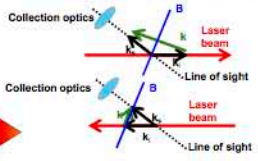
Relative error at forward and backward measurement

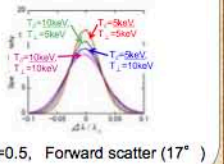


The T_e error will be reduced from 52 % to 10 % and 4 % at T_e = 30 keV.

- **By use of the multi-pass system we can get the information of the $T_\perp$ and $T_{//}$ spectrum separately.**

Calculated scattering spectrum of $T_\perp$ and $T_{//}$





ρ=0.5, Forward scatter (17°)

Conclusion

- **The novel configuration of the multi-pass Thomson scattering (TS) system is proposed by the use of the polarization control. This configuration can realize a perfect coaxial multi-passing at each passes.**
- **The polarization based double-pass system demonstrated in GAMMA10 has installed to the LHD Thomson scattering system. We have obtained the forward and backward Thomson scattering signals.**
- **We have evaluated the electron temperature from the forward Thomson scattering signals and confirmed the performance of the forward scattering measurements.**
- **We will try to measure the high temperature plasma and the anisotropic electron temperature.**

Acknowledgments
This work was supported by JSPS KAKENHI Grant No. 23760813 and Grant No. 25289341 and the NIFS Collaboration Research program (NIFS-KOAH025, NIFS11KLEH007).