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Present status of development in optimal high speed AD conversion system for Nd:YAG Thomson scattering diagnostic

Nd:YAG トムソン散乱計測に最適な高速 AD 変換装置開発の現状

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A new High speed Nd:YAG Thomson scattering AD Convertor (HYADC) that can directly convert the detected scattered light signal into a digital signal is under development. The HYADC is expected to improve a signal to noise ratio of the Nd:YAG Thomson scattering measurement. A prototype of the HYADC was developed and it successfully converts a test signal into digital data by sampling frequency of 500MHz. A function of the FPGA on the HYADC work correctly as designed.

1 Introduction

Nd:YAG Thomson scattering (YTS) system requires a high speed data processing, because a short laser pulse width ($\sim 10ns$) is required to improve the signal-to-noise ratio (SNR)[1]. A charge to digital convertor (CDC), which integrates the detected signal and converts it to digital data, was commonly used as the data acquisition system of the YTS measurement. However, the CDC is not necessarily optimal for the YTS. Therefore, we are developing a new ADC dedicated to the YTS method, called High speed YAG Thomson scattering ADC. The HYADC is being designed to directly convert the scattered light signal into the digital data. As the scattered signal is converted by a single chip (ADS5463, Texas Instruments inc.) with 12 bits resolution and a 500 MHz sample rate[2].

2 Advantages of the HYADC

An increased amount of sampled data of the HYADC compared to the CDC improves the SNR. A precise background light reduction also can be performed using the digitized data detected just before the laser injection[3]. The model simulation of the HYADC shows the SNR of the HYADC is several orders of magnitude larger than that of the CDC. When the minimum detectable SNR of the scattered light is ten, the detectable photoelectron count is reduced ten-folds compared to the CDC. Therefore, the measurable plasma density, which is proportional to the scattered light, is expected to be ten times lower than that of the CDC.

The HYADC can also analyze the short pulse interval laser injection of the multi-pulse Nd:YAG Thomson scattering measurement. Even when the signal is overlapped, the HYADC can separate both signals. Previous direct AD converters adopt a time-interleaving technique, making it a complicated structure and expensive. Moreover, because the time-interleaving technique requires several AD converter chips, accuracy of the conversion is degraded because of the dispersed characteristics of chips. However, because the scattered signal is converted by a single chip, the HYADC is a simple and compact structure; additionally, it has the improved conversion accuracy and is affordable compared to the previous direct converters.

A high sampling rate ADC increases the data volume recorded in the memory, thus increasing the storage cost for a long plasma discharge. To resolve the storage problem, the limited scattered light signal from immediately prior to just after the pulsed signal was recorded by a hardware procedure because the pulse width of the scattered light signal is very short ($\sim 200ns$) compared to the plasma discharge time. The hardware procedure records solely the signal corresponding to the period of scattered light produced, with the data in which the scattered light is not produced deleted. Consequently, the data volume that is stored in data storage is estimated to be reduced to below 0.01% compared to the volume that is required when the whole data is recorded in the storage.

3 Development of the HYADC

The circuit diagram of the HYADC prototype is shown in Figure 1. The circuit has two analog to digital channels, which consist of two AD converter, two amplifiers, an FPGA and a physical layer chip for Ethernet communication. The almost all the logical circuits are integrated into the single FPGA. The present status of the development is as follows.

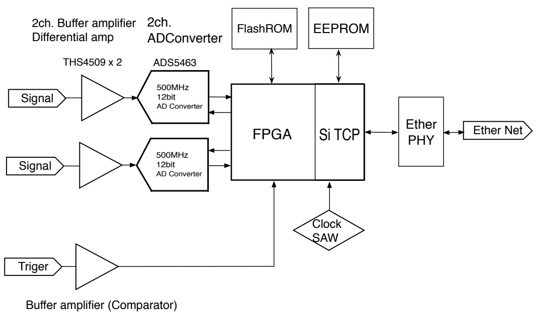

Fig. 1: Circuit diagram of The HYADC.

The design of the FPGA already has been completed: the structure of memory, register, acquisition from AD convertor and the data transfer system to a host computer are designed. The HDL description of logical circuit, logical synthesis, and circuit layout for the FPGA has also been completed. An experimental prototype of the HYADC that is shown in Figure 2 is developed using evaluation boards for an initial test purpose. Test signal is successfully converted by a sampling frequency of 500MHz, and we confirm that the designed FPGA works correctly. Design of a substrate arrangement has been completed, then we are constructing the actual prototype of the HYADC. The prototype will be tested using the Nd:YAG Thomson scattering system of LHD and Heliotron J.

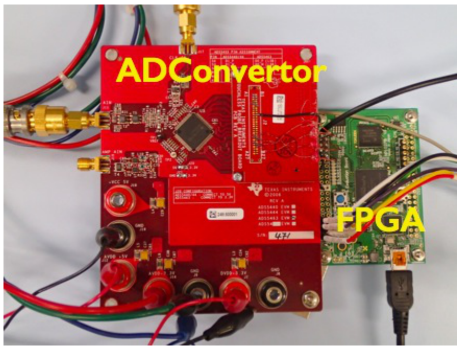

Fig. 2: Picture of the HYADC prototype using evaluation boards.

4 Summary

The HYADC is designed to directly convert the scattered light signals into the digital data using the high speed and resolution pipeline type ADC. The HYADC is expected to improve the SNR of Nd:YAG Thomson scattering measurement by ten-folds. The prototype of the HYADC is under development. The schedule of the development is on time. The first performance evaluation using the prototype will be carried out in the fiscal year of 2014.

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