§2. Development of New Data Processing System for High Repetition Nd:YAG Thomson Scattering Measurement

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Objective of development of new data processing system The Nd:YAG Thomson scattering (YTS) system requires a high speed data processing, because the short laser pulse width ($\sim 10ns$) is required for improvement of S/N ratio. Until now, a charge to digital AD convertor (CDC) was commonly used as the data acquisition system of the YTS measurement. But this convertor is not necessarily the optimum one for the YTS. Recently, a high speed AD converter of 12 bits resolution and 500MHz sample rate (ADS5463, Texas Instruments inc.) had been developed, then we are developing the high speed YAG Thomson scattering AD Convertor (HYADC) that can directly convert the scattered light signal to the digital data[1)].

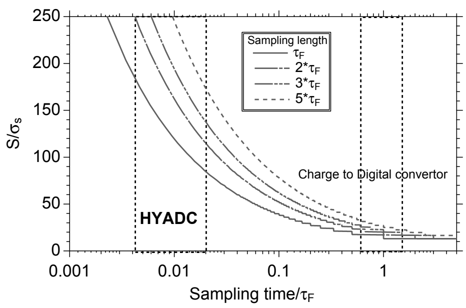

Fig. 1: **S/N estimation as function of sampling time normalized by τ_F for HYADC and CDC.**

Estimation of improved S/N ration by the HYADC using a signal processing model The improvement of the S/N ration is estimated by a signal processing model, which is developed by the DIII-D[2)]. The model estimates the S/N ratio for the pulsed light detected by an avalanche photo diode (APD) as follows.

$$\frac{S}{\sigma_s} = \sqrt{\frac{Qp}{F[\{\frac{2(t_G - D)}{D^2} - e^{-t_S}\}R_{Q_b} + 1] + (\frac{\delta S_0}{S})^2 Q_p}} \quad (1)$$

$$t_G = \frac{\tau_G}{\tau_F}, \quad t_S = \frac{\tau_S}{\tau_F}, \quad D = 1 - e^{-t_G}, \quad (2)$$

where τ_F is the decay time of the APD, which is determined by the resistance of the current to voltage conversion for the APD, the stray capacitance of the APD, the stray capacitance of the amplifier circuit. τ_G is the gate width of the integrator, τ_S is the time separation of the two gates. Q_p is the photoelectrons count which is produced by the laser pulse. F is the excessive noise factor of the multiplication of the APD. R_{Q_b} is the ratio of background signal to scattered light signal. $\delta S_0/S$ is the S/N ration in no signal. This model shows that the short gate width compared to the APD decay time improves the S/N ratio. Consequently, the short gate width with the large sampling rate reduce the measurement error, such as a quantization error, in small signal, then the measurement accuracy is improved.

The improvement of the S/N ratio is estimated by a next equation.

$$\left(\frac{\sigma_S}{S}\right)^2 = \frac{1}{N^2}\sum_i \left[\left(\frac{\sigma_{S_i}}{S_i}\right)^2 + \left(\frac{\delta t}{\tau_F}\right)^2\right], \quad (3)$$

where N is the sampling number, $\frac{\sigma_{S_i}}{S_i}$ is the S/N ratio of the single sampling and $\frac{\delta t}{\tau_F}$ is jitter of the sampling (2% is assumed). The result is shown in figure 1. It is noted that the estimation is carried out for the different sampling length, which is the time between the start and the end of the sampling. The S/N ratio of the HYADC is several ten times larger than that of the CDC due to the reduction of the sampling time. The long sampling length increases the S/N ratio of the HYADC, while the increase of the CDC is small. The S/N ratio as a function of the photoelectron count, which is detected by the APD, is also estimated in figure2.

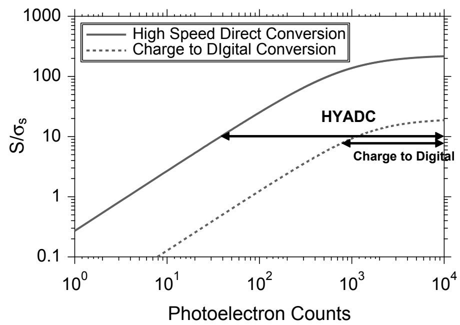

Fig. 2: **S/N ratio as a function of the photoelectron counts, which is detected by the APD**

Assuming that the minimum detectable S/N ration of the scattered light is 10, the detectable photoelectron count is reduced by 10 times compared to the CDC. Therefore, the measurable plasma density, which is proportional to the scattered light, is expected to be reduced by 10 times lower value than that of the CDC.

1) T.Minami, et al. 2014, Rev. Sci. Instrum., to be submitted.

2) C.L.Hsieh, J.Haskovec, T.N.Carlstorm, et.al. General Atomics Rep. GA-A20094 May 1990