Development of 2-D Thomson Scattering Measurement Using Multiple Reflection and the Time-of-Flight of Laser Light

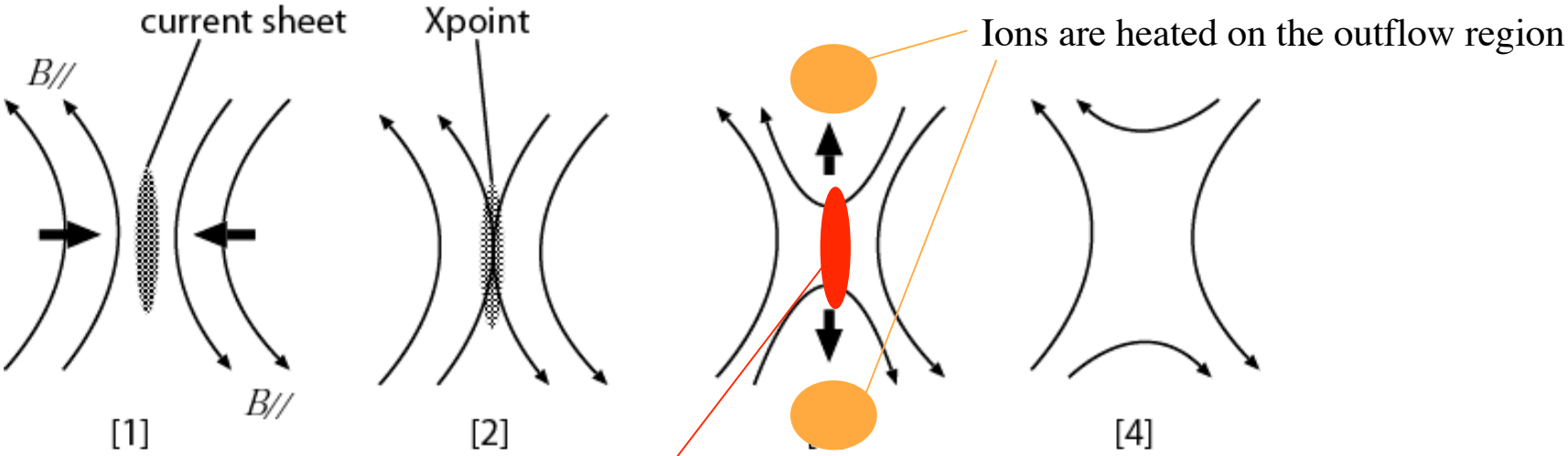
T. Sumikawa, K. Yamashita,
E. Kawamori, K. Narihara[1)], Y. Ono
Graduate School of Frontier Science, University of Tokyo
[1)]National Institute for Fusion Science

abstract

A new Thomson scattering diagnostic system has been developed
for measuring 2-D profiles of electron temperature and density in TS-4 spherical tokamak device.
Our new ideas are as follows:
(1) A number of mirrors are used to reflect YAG laser beam for multiple times to cover a whole r-z plane of the ST plasma.
(2) The time delay of the scattered light along the laser beam is used to save the number of detectors just like the LIDAR (Light Detection And Ranging) method. The measurements of Rayleigh scattering was made successfully on multiple measurement points, suggesting the basic ideas of 2-D Thomson scattering works correctly.

We need 2-D electron temperature profile

(1) to mesure the electron heating contour by the magnetic reconnection



Electrons are expected to be heated on the inflow region

We need 2-D electron temperature profile

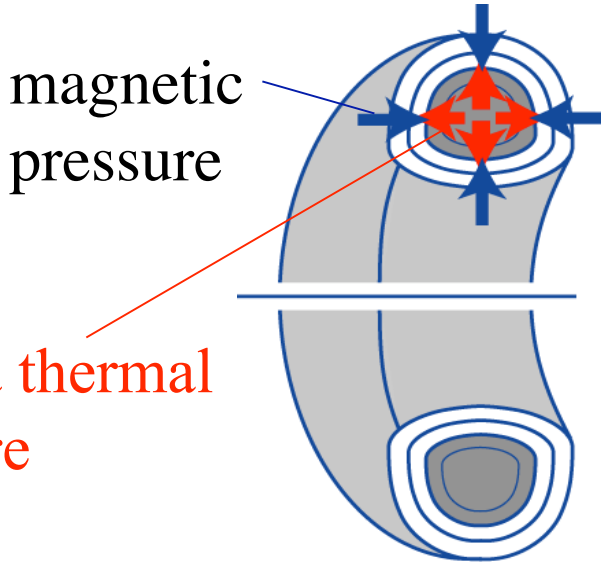
(2) to measure the pressure gradient of high-β ST by the plasma merging start-up

2-D ion Doppler broadening diagnostic system has been already established

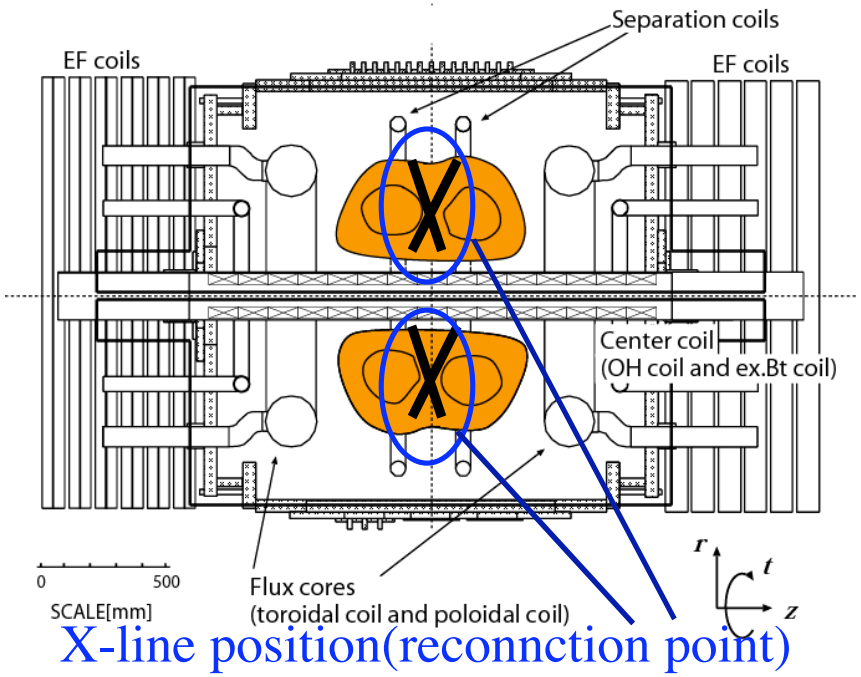
Plasma thermal pressure is given by

$$p = n_e k (T_e + T_i)$$

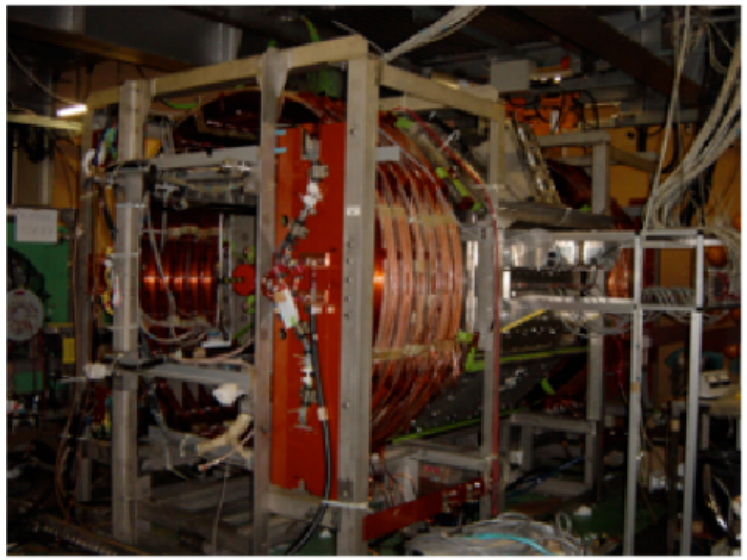
Obtaining by 2-D Thomson scattering diagnostic system



TS-4, plasma merging devise



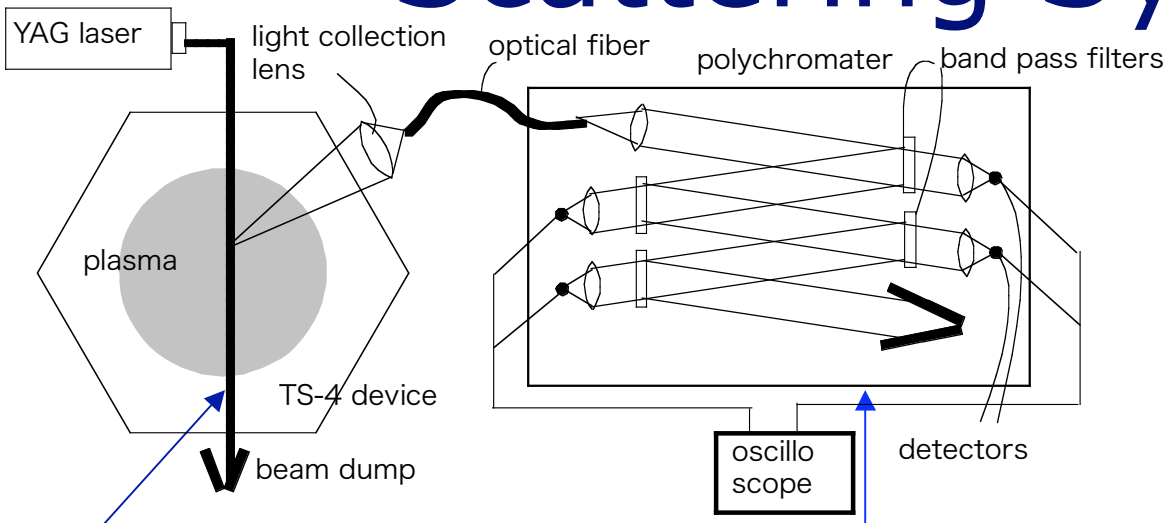
X-line position(reconnction point)

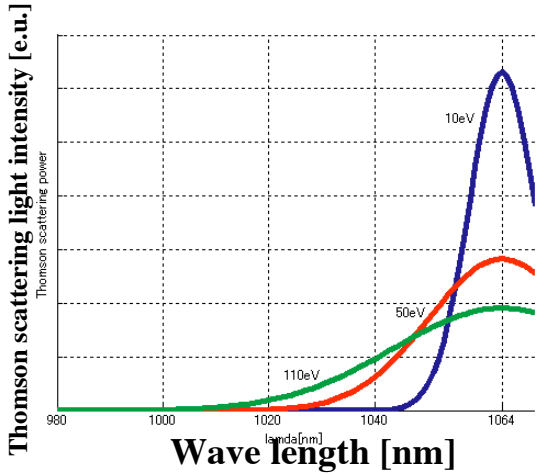


Appearance of TS-4

- A pair of torus plasma is made by TF and PF coils in the flux cores. When the a pair of plasma is merging on the mid-plane(z=0), magnetic reconnection comes off.
- We can make almost all kinds of Compact Torus (q_a~0.7-0.9).
- R=0.4-0.6m, R/a~1.5, B_{t0}~0.05T

Conventional 1-D Thomson Scattering System





Only 1-D profile is available

must prepare for polychromators as many as measuring points

Can we upgrade this system to the 2-D Thomson system cost-effectively?

How can we make the Thomson scattering diagnostic system 2-D?

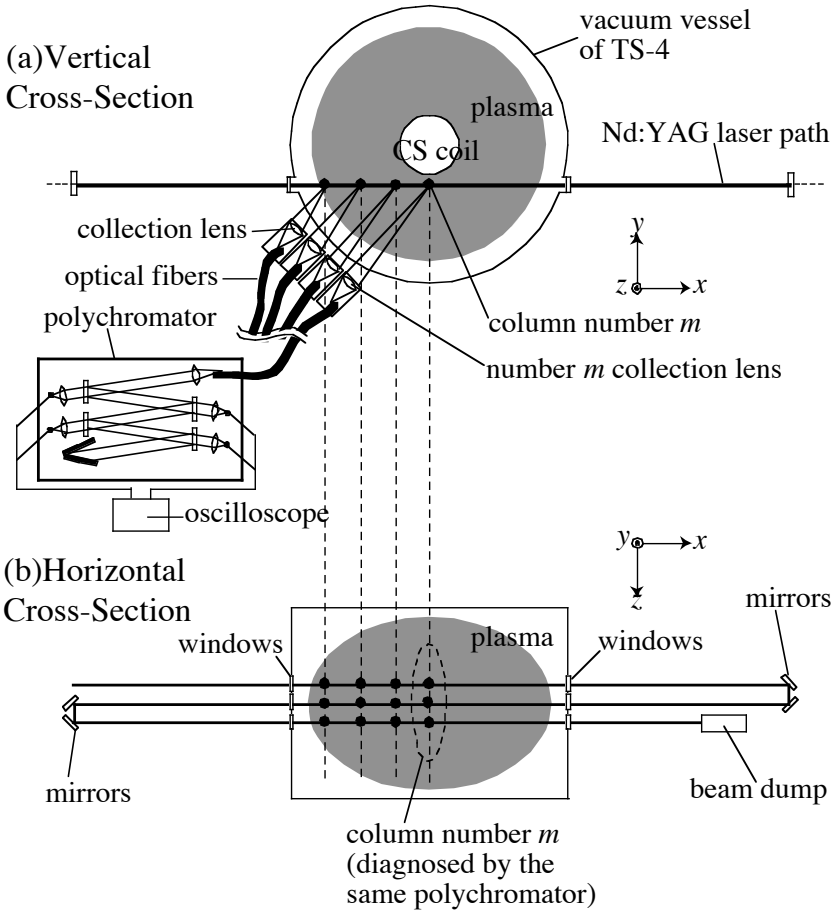
Our NEW ideas are…

1. Reflecting the laser path multiple times

then the laser beam covers the 2-D flatland of plasma

2. Using time-of-flight method

then we can reduce the number of polychromator



Description of components

1. Laser

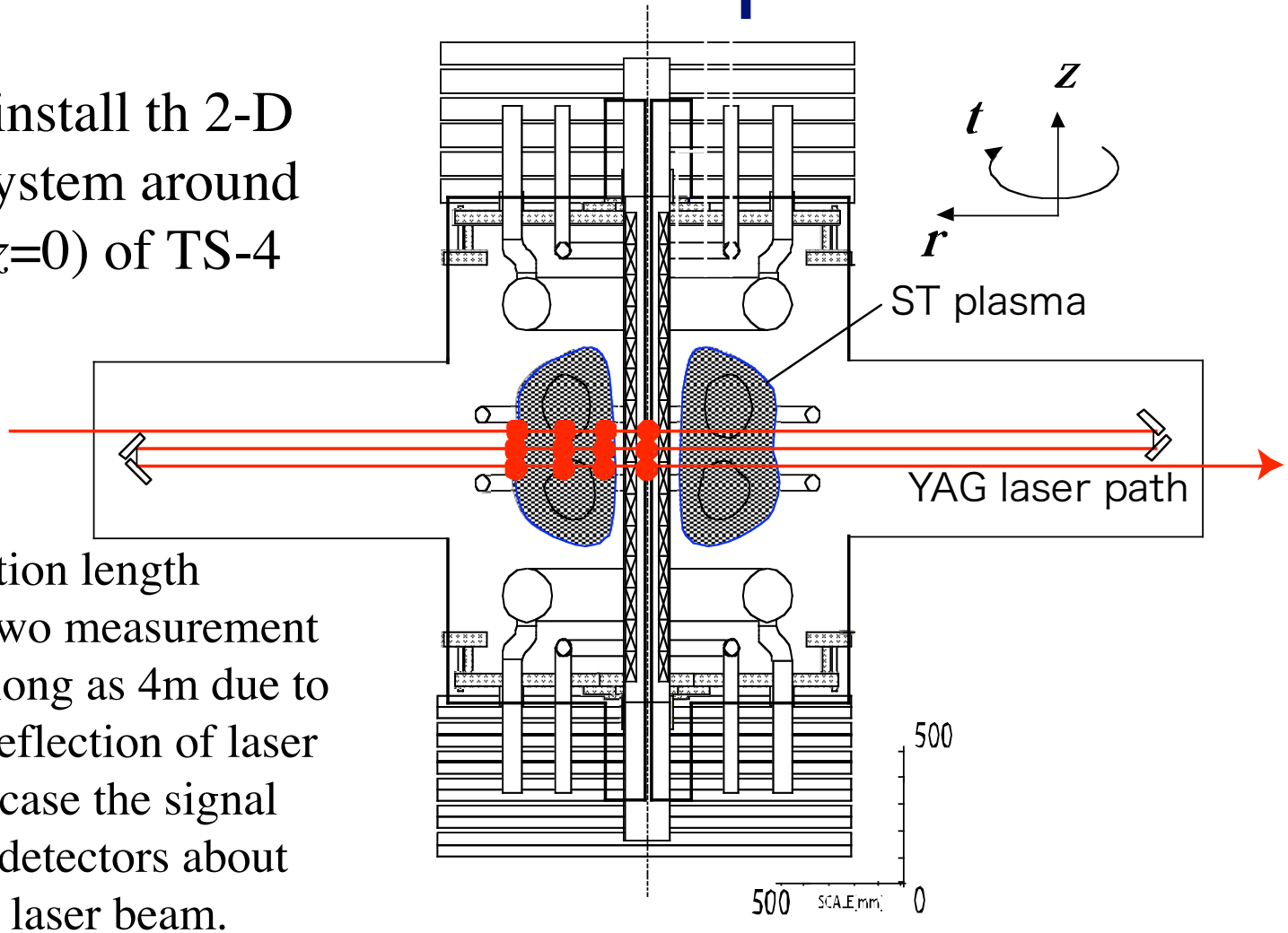
We use Nd:YAG pulse laser （Quantel,YG982E）
and its specification is as follows.

- Repetition frequency: 10Hz
- Energy: 2.4J
- Pulse Duration FWHM: 10ns
- Beam Diameter: 12mm
- Beam Divergence 1/e2 Full Angle: <0.5mrad

Description of components

2. Laser beam path

■We will install th 2-D Thomson system around mid-plane(z=0) of TS-4 plasma.



■The separation length between the two measurement points are as long as 4m due to the multiple reflection of laser beam. In this case the signal arrives at the detectors about 13ns after the laser beam.

Description of components

3. Laser beam optics

■Mirror: We use dielectric multilayer mirrors whose reflectance is more than 99%. Its diameter is ϕ50mm large preventing the laser beam from hitting the edge of the mirror.

We use YAGCWlaser for laser path alignment because He-Ne laser transmits the mirror.

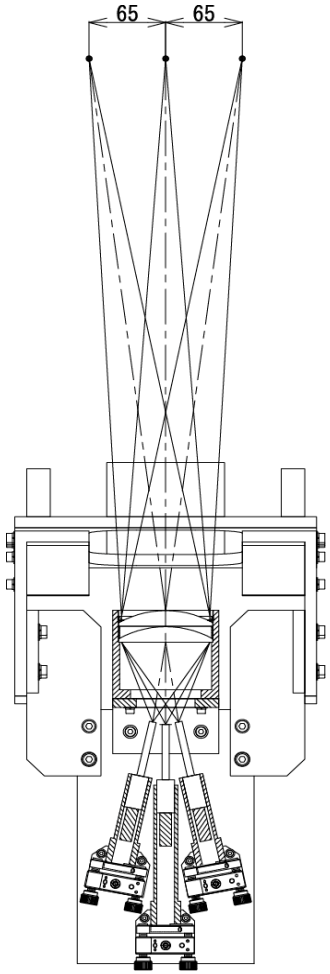
■Beam divergence: Laser beam of 12mm in diameter and 0.5mrad in divergence is focused by f=15m concave mirrror so that the beam goes straight.

■Window: We use anti-reflect coated windows to reduce stray light.

Description of components

4. Light collection optics

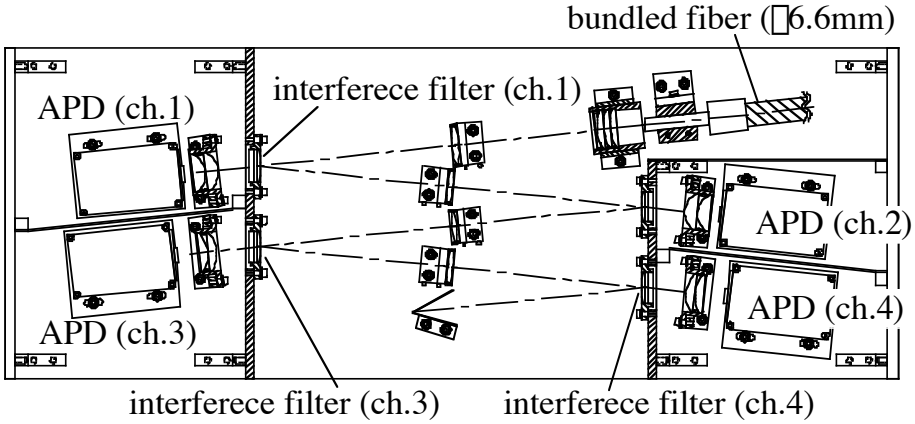
- Gauss-type objectives designed and fabricated by OKlab, Tokyo.
- Diameter of the lens is □80mm, giving solid angle of 1.94×10^{-2} sr.
- Each surface of the lens is anti-reflection-coated, giving the overall transmittance of 99%.
- Scattered lights caught by same lens are detected in the same polychromator.



Description of components

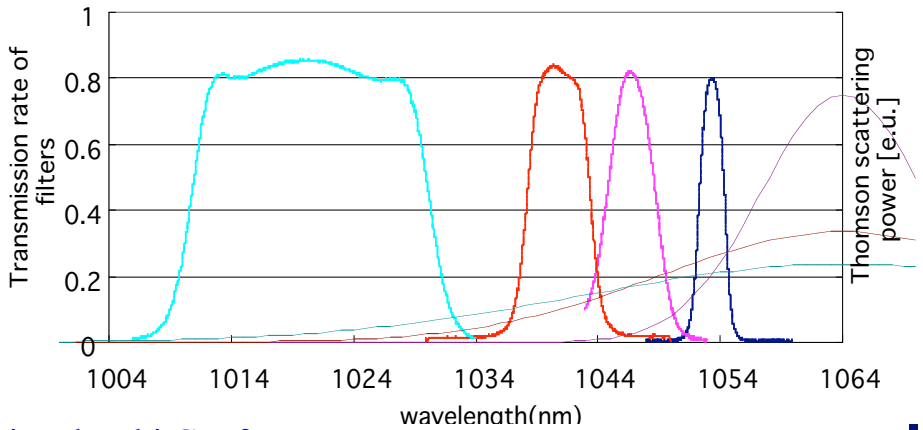
5. Polychromators

- We made filter polychromator.
- We use 4 interference filters with high transmission in a pass band and high blocking power at the YAG wavelength(>10^5).
- Each filter's pass band shown on the right table is suitable for measuring 20-200eV electron temperature.



1	1056-1052nm
2	1052-1045nm
3	1045-1035nm
4	1035-1005nm

Transparent characteristics of interference filters and Doppler broadening of the Thomson scattering specrum



Description of components

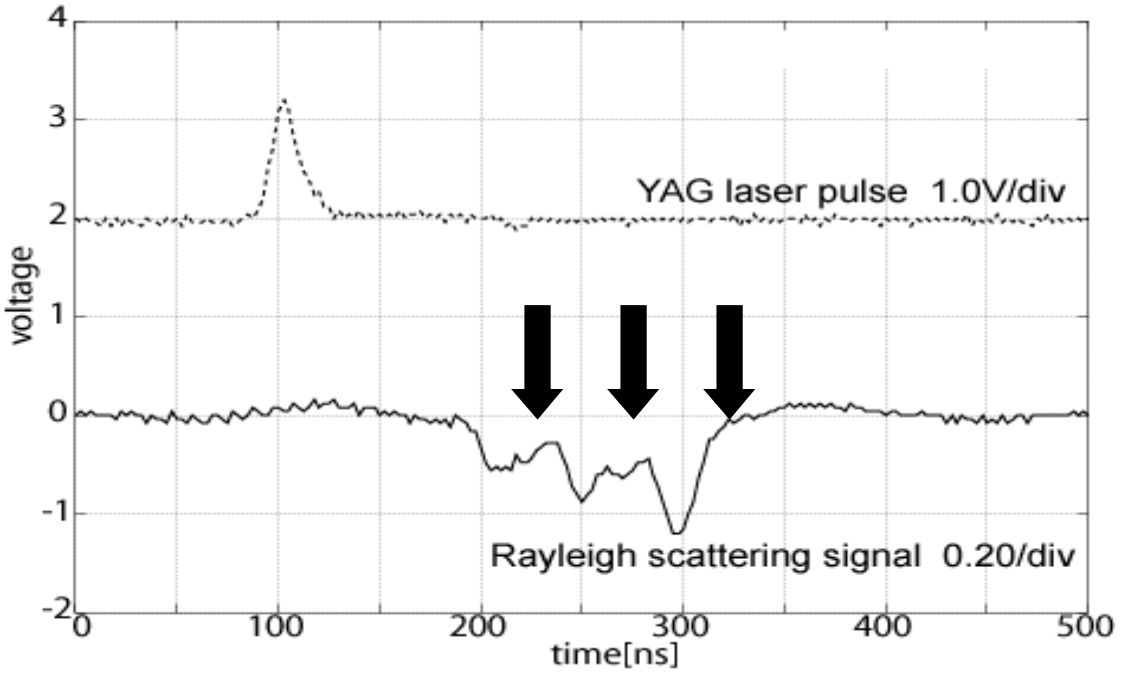
6. Dectectors and electronics

We use Silicon and InGaAs Preamplifier Modules as the light detectors. They are by Hamamatsu Photonics and their specification is as follows.

- type: S8890-30
- Band width range: 100MHz
- Active diameter: 3mm
- Responsibility: 47kV/W
- NEP: 0.3pW/(Hz)$^{1/2}$

Performance of the System

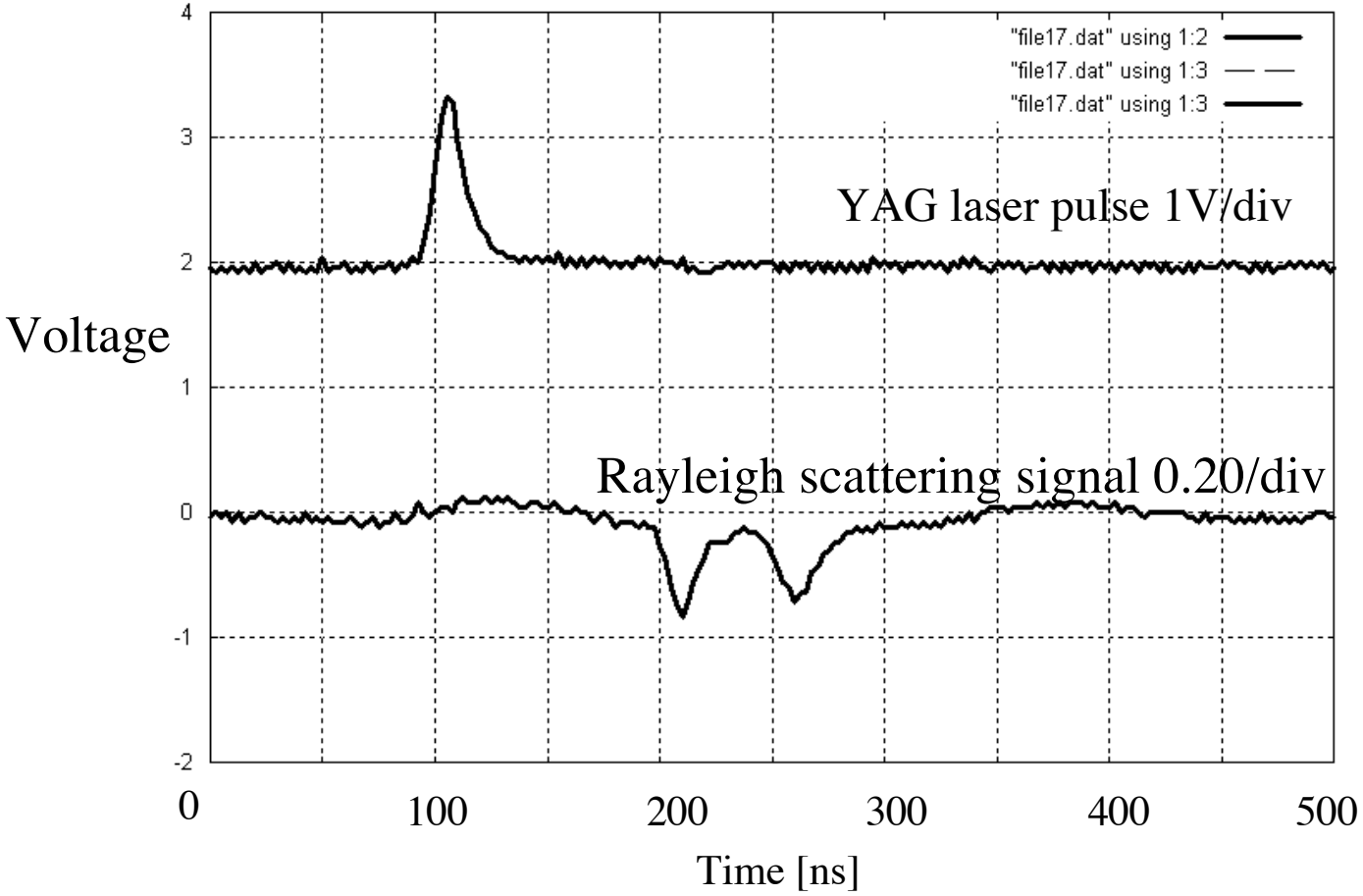
The Rayleigh scattering signals:ch. 1-3 were detected successfully by the proposed time of flight method.



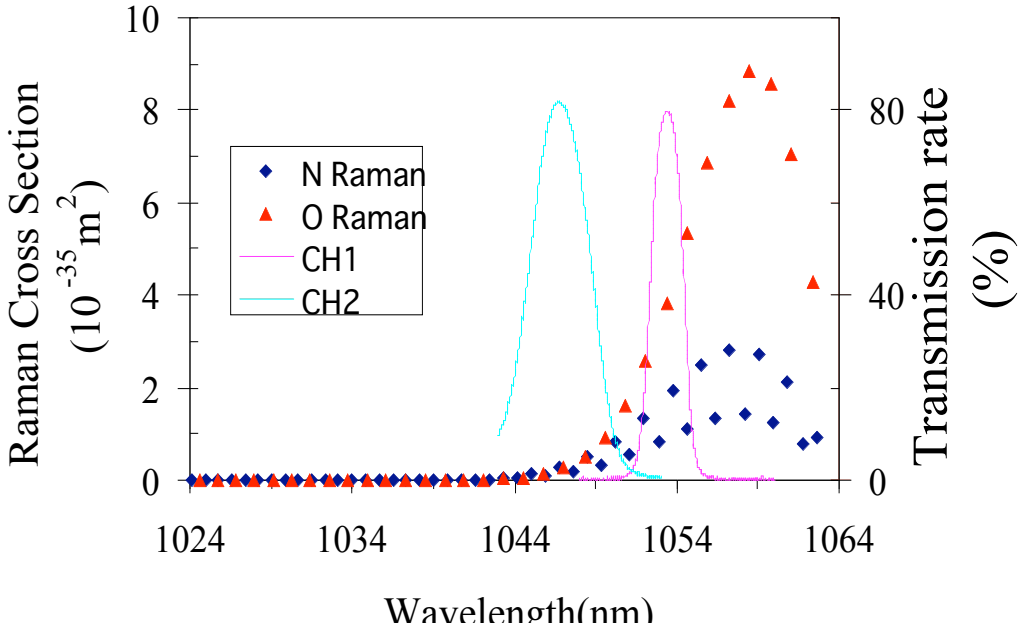
The basic ideas of 2-D Thomson scattering was confirmed to work correctly.

Performance of the System

Rayleigh scattering (2 points)



Suggestion of calibration using Raman scattering



- gas : air (N_2:80%, O_2:20%)