§52. Development of a Bright Polychromator for Thomson Scattering Measurements

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A Thomson scattering is a standard technique for electron temperature and density measurements. Since the scattering cross-section is very small, an efficient system is necessary to measure low density plasmas. Non-inductive start-up of spherical tokamak (ST) is one such case, where the plasma is generated by RF waves, and the densities are as low as 10^{17} [m^{-3}] in recent experiments.

Recent development in fiber fabrication technology enables a large NA fiber. We constructed a Thomson scattering system for the TST-2 spherical tokamak device, using an optical fiber with NA=0.37. However, the polychromator, on loan from the national institute for fusion science, were designed for an optical fiber with NA=0.22. Therefore, we have designed a new polychromator not only for the TST-2 Thomson scattering system, but also for the system which will be used in the QUEST spherical tokamak device. We are planning to use a multiple path scattering scheme (based on a confocal spherical mirror cavity), from which a train of scattering pulses is expected. By resolving each pulse, we can distinguish parallel and perpendicular temperatures.

After ray-tracing calculations, satisfactory design was found (Fig.1). The polychromator has six detectors as the six wavelength channels. Lenses made of high refractive index glass SF11 (n=1.76 @1000 nm) are used.

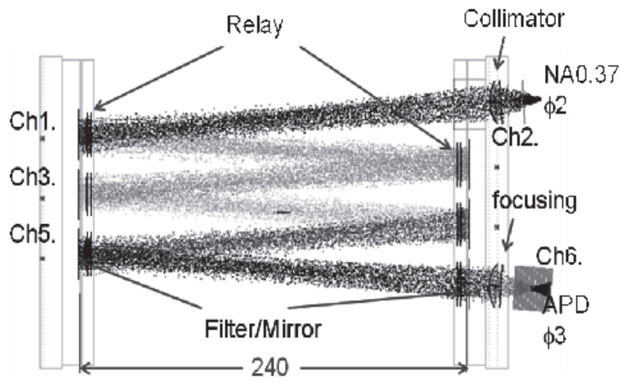

Fig.1 Layout of the optics and rays in the polychromator.

Several issues should be addressed to use high refractive index glass. One is AR coating and the other is the chromatic aberration. Due to the high refractive index, the normal incidence reflectivity for bare SF11 is 8 %, while that for BK7 is 4 % at 1000 nm. However, the mono-layer MgF_2 AR coating on SF11 yields very small reflectivity of about 0.2 %, because of the amplitude matching condition for the refractive indices. The chromatic aberration effect is not serious, because the target electron temperature is relatively low. The ray tracing calculation shows that the efficiency varies by +/- 1 % in the wavelength range 900 - 1050 nm. When we calculate a quantity similar to the Abbe number in the infrared range, the value is very large, and the chromatic aberration is negligible as a result.

In order to measure low density plasmas, a fast and low noise detection system should be developed. As a detector we selected an APD (Hamamatsu photonics, S8890-30). A two stage noninverting amplifier composed of two low noise operational amplifiers was made as the preamplifier. The response of the detector unit was measured by detecting a YAG laser pulse. The FWHM of the pulse waveform is 10 ns, which is sufficiently short for the multiple-path scattering scheme (Fig. 2). The signals start to saturate when the amplitude exceeds 2.5 V, which corresponds to the detected photon number of 40000.

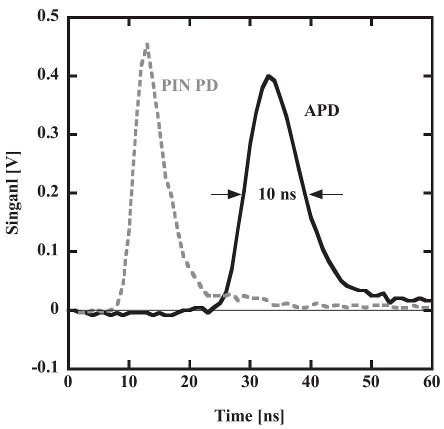

Fig. 2 Signal waveform of the prototypical APD detector system (solid curve) illuminated by a YAG laser pulse. Signal waveform of a PIN Si photodiode monitor (dashed curve) is also plotted.

Figure 3 shows the relative error as a function of detected photon number. Open circles represents the (relative) standard deviation of 10 similar YAG pulse measurements, which agree with the theoretical thermal noise or the shot noise.

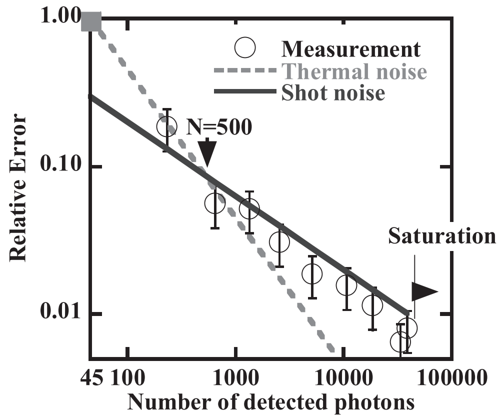

Fig. 3 Relative error of the time integrated signal (open circles). Theoretical thermal noise (dashed line) and theoretical shot noise (solid line) are also plotted.