Development of a bright polychoromator for Thomson scattering measurements

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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. The electron temperature and the density measurements are critical for studying the equilibrium during ST formation phase [1] and for studying the coupling of RF waves and the plasma. A new bright polychromator was designed and prototypical tests have been carried out.

A Thomson scattering system has been installed on the TST-2 tokamak, and the temperature and density in Ohmic heated and RF heated plasmas are measured [2]. While the densities in these plasmas are in the order of $10^{19}m^{-3}$, the densities in the non-inductive start-up plasmas are less than $10^{17}m^{-3}$. One of the unique features of the system is the utilization of a thick (2 mm diameter), and large NA (0.37) optical fiber. Thanks to the fiber the system becomes compact. The present polychromator is on loan from National Institute for Fusion Science, and it is the same as those used to measure the LHD plasmas [3]. However, the polychromator is designed for an optical fiber with NA=0.22. In order to upgrade the system, the polychromator has been re-designed for NA=0.37 using ray tracing method. We found that utilization of a spherical collimator lens and a spherical focusing lens made of high refractive index glass (SF11), with mono-layer anti-reflection coating enables efficient optics. As a test, the original collimator lens was replaced by a new spherical lens, and the efficiency was improved by a factor 1.5.

In order to enhance the signal quality, we are planning to use a multiple pass scattering scenario (based on a confocal mirror cavity), from which a train of scattering pulses is expected. By resolving each pulse, we can improve the S/N ratio, and we can also distinguish the forward and the backward scattering signals. The latter will provide the information on asymmetric temperature.

For the detector we use an avalanche photo diode with a large diameter (3 mm) and with a small terminal capacity (8 pF) (Hamamatsu photonics, S8890-30). Prototypical circuits were made and tested. The input resistance was chosen to be 470 Ω to ensure a short signal pulse, and the resultant FWHM of the output signal was 13 ns. The noise was estimated from the statistical scatter of the measured signals using Nd:YAG laser pulses. The noise becomes about 10 %, when the detected photon number is estimated to be 1000. The dominant noise source for this photon number is the thermal noise of the input resistance.

[1] A. Ejiri, et al, Nucl. Fusion **49** (2009) 065010 .
[2] S. Kainaga, et al. Plasma Fusion Res. **3** (2008) 027.
[3] K. Narihara, I. Yamada, H. Hayashi and K. Yamauchi, Rev. Sci. Instrum. **72** (2001) 1122.