§18. Dispersion Effects of Optical Fiber for Utilizing a Terahertz Time-Domain Spectroscopy for Large-Size High-Temperature Plasma Measurements

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In the future burning plasma experiment, the electron density will be quite high and up to the order of 10^{22} m^{-3}. In such high dense plasmas, the conventional diagnostic technique of electromagnetic wave is still expected to measure the electron density profile, its fluctuation, etc. The demanding and utilizing frequency is getting into terahertz regime (0.1 THz-10 THz). However, the generation and detection of terahertz waves are not a well-developed technology at present. In addition, since the transmission of terahertz wave is one of the development issues, the terahertz diagnostic system have to be set adjoined to the plasma apparatus. A terahertz time domain spectroscopy (THz-TDS) configuration is a possible candidate, where the generator and detector mounted in small units are activated by femtosecond optical pulses delivered via optical fibers. [1)]

Because reference 2 showed that the telecom band (~1.5 μm wavelength) pulsed light can be used for the THz-TDS system, the low loss transmission could be expected by using this band. However, the general purpose single-mode fiber (categorized in ITU-T G.652 B) for telecommunication has quite a large level of dispersion around 20 ps/nm/km at a wavelength of 1.5 μm. It leads to a large frequency chirp, and the fiber cannot be used for the transmission of the pumped light. The dispersion-shifted single-mode fiber (ITU-T G.653 category) is one solution because the dispersion value of this fiber at 1.5 μm is almost zero, and transmission losses are less than 0.22 dB/km. Therefore, we test the characteristics of this type fiber.

Several lengths of the dispersion-shifted optical fiber (Fujikura FutureGuide DS), with dispersion of less than 3.5 ps/nm/km and a dispersion slope of less than 0.085 ps/nm2/km, as per the catalog, were tested to observe the dispersion effect. For these tests, the pumped laser pulse width was around 100 fs at a wavelength of 1.5 μm. This corresponds to a wavelength broadening of around 200 nm. The laser light is forced to chirp regardless of the dispersion-shifted fiber. Figure 1 shows the waveform measured by an autocorrelator[3)] before and after passing through the fiber. The shape of the femtosecond laser pulse becomes broader. The pulse width is plotted as a function of the fiber length in Fig. 2. The experimental value almost agrees with the estimate of around 400 fs at 100 m. Here we used the dispersion listed in the catalog. It should be noted that the catalog value was measured by a continuous wave. We can conclude that the dispersion effect can be calculated, and some methods of dispersion compensation, such as using an optical grating, can be designed. We will apply such a method to the LHD plasma experiment in the near future.

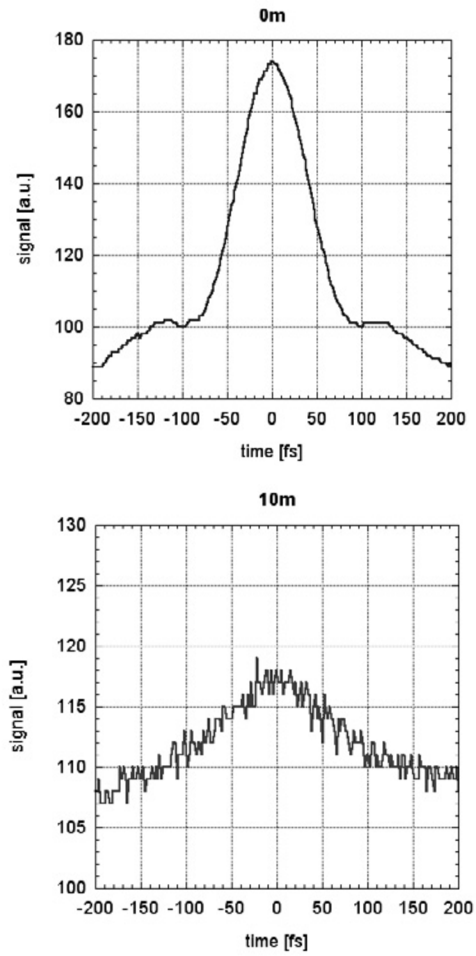

Fig. 1. Waveform of the autocorrelated signal w/o a fiber (top) and with a 10 m fiber (bottom).

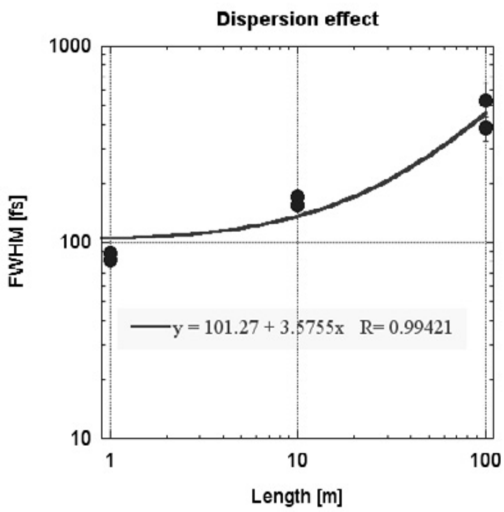

Fig. 2. Pulse width via the optical fiber having lengths of 1, 10, and 100 m.

1) Tokuzawa, T. et al., "Terahertz reflectometer for high-dense plasma measurements", Proc. LAPD2007.
2) Takazato, A.et al., Appl. Phys. Lett. **90** ,101119 (2007)
3) Kadoya, Y. et al. : Ann. Rep. NIFS (2011-2012) 151.