§5. Terahertz Wave Emission Using Fiber Laser Excitation for Large Plasma Experimental Device

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In the microwave-based measurement of high density plasmas, the frequency to be used is getting into terahertz regime. However, the generation and detection of terahertz waves are not a well-developed technology at present. In addition, since the waveguiding of terahertz wave is not easy, the terahertz system must be set adjoined to the plasma apparatus. A terahertz time domain spectroscopy (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. To keep the pulse width in 100 fs order after a propagation of more than several meters distance, one need to use the optical pulses in telecom band (~1.5 μm wavelength). The aim of this research is to develop the terahertz generators and detectors excitable at 1.5 μm. As the first step, we investigated the signal-to-noise (S/N) ratio of the terahertz signals of the present system obtained in a sub-second acquisition time needed for the plasma measurements.

The experiments were performed using a TDS system, which we had already developed, with some modifications. The emitter and detector were photoconductive antennas made on low-temperature-grown (LTG) InGaAs[1,2], which is the candidate for the 1.5 μm excitation, in comparison with those made on LTG GaAs, which is widely used for the excitation at ~800 nm. To make the comparison possible, we used the optical pulses at 780 nm a second harmonics of a mode-lock fiber laser (1560 nm, pulse width ~ 60 fs, rep. rate ~ 50 MHz). The antennas are the dipole type with a length of 50 μm, which is the one appropriate for the frequency range of 1 ~ 10 THz. A fast time delay unit was introduced to the TDS system so as to acquire the time domain trace within millisecond spans.

Shown in Fig. 1 is the amplitude spectrum (thick curve) detected by the LTG GaAs antenna with the acquisition time of 0.5 s. The emitter was the LTG InGaAs antenna with a bias of 30 V and excitation of 1.2 mW. It was found that a S/N ratio more than 26 dB can be obtained in the range of 300 GHz ~ 1 THz. The amplitude spectra of the terahertz pulses obtained in the acquisition time of 4.5 s and 0.5 s are shown by the thick curves in Fig. 2. In this case, both the emitter and the detector were LTG InGaAs photoconductive antennas. In comparison with the GaAs antenna, the signal is weak and the noise is higher. As a result, a useful spectrum could not be obtained in the 0.5 s acquisition time. However, since the excitation laser power can be easily increased by more than an order when we use the primary output (1560 nm) of fiber lasers. There are also several ways of improving the S/N ratio, such as the antenna design. Hence, we expect that it is not difficult to realize a 10 dB improvement, which may be acceptable at least for the cut-off frequency (plasma density) measurements. We will perform the development in the next year.

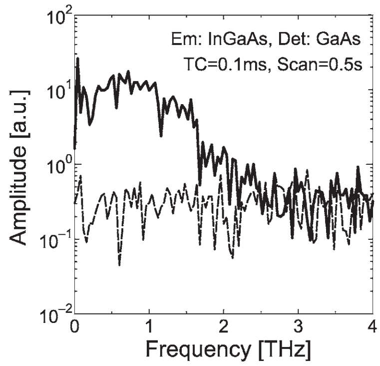

Fig. 1. Amplitude spectra of the terahertz wave detected by the LTG GaAs photoconductive antenna with the acquisition time of 0.5 s. The dashed trace shows the detector noise.

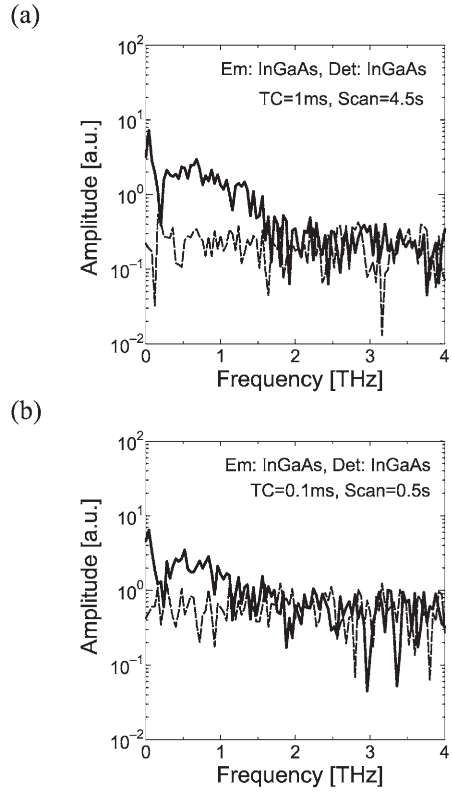

Fig. 2. Amplitude spectra of the terahertz waves emitted and detected by the LTG InGaAs photoconductive antennas with the acquisition time of (a) 4.5 s and (b) 0.5 s. The dashed traces depict the detector noise.

1) Takazato, A. et al. : Appl. Phys. Lett. **90** (2007) 101119.
2) Takazato, A. et al. : Appl. Phys. Lett. **91** (2007) 011102.