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Laser-plasma Terahertz-based Electron Density Diagnostics

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1. Introduction

Recently, terahertz(THz) based plasma diagnostics has been studied as one of the newly emerging method for the electron density diagnosis. In THz-based diagnostics, electron density is deduced from the amount of the phase shift of the THz wave that passed through the target plasma. In this sense, this method is more or less similar to the conventional millimeter-based diagnostics. But if laser-plasma THz is used as a THz source, ultra-broadband frequency bandwidth (~up to a few tens of THz) is available, giving a wide measureable electron density range. Therefore, in practical point of view, laser-plasma THz-based diagnostics can possibly be a strong method for diagnostics. Moreover, it is possible to scan the electron density of the target plasma in a very short time if single-shot THz detection technique is applied, allowing fast measurement of plasma electron density.

In this presentation, electron density measurement results using laser-plasma THz source with THz time-domain spectroscopy(THz-TDS) detection method will be presented.

2. Methods and Results

2.1 Laser-plasma THz generation

During the experiment, THz radiation produced from laser-plasma interaction was used as the THz source. The laser system used in this work is Ti:Sapphire regenerative amplifier system, which can produce approximately 40 fs pulse duration with 1~3 mJ of pulse energy. The laser-plasma interaction can be easily done by just focusing a femtosecond (fs) laser pulse train to air using a lens. From the focal point of the lens, a few centimeter-long laser-plasma is created, and from this laser-plasma, THz pulse is produced [1]. To enhance the THz pulse energy by endowing the laser-plasma with strong drift current, an electrode was installed to apply DC bias to the laser-plasma [2, 3].

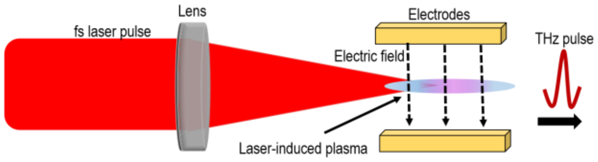

Fig. 1. Laser-plasma THz generation with a DC bias applied.

2.2 THz-TDS

The produced THz pulse was detected by THz-TDS method. THz-TDS is a widely used conventional THz detection method thanks to its robustness. THz-TDS detection is based on electro-optic effect in a nonlinear crystal such as ZnTe, which was adopted in this work. When THz is illuminated onto the nonlinear crystal, the crystal will display birefringence according to the amplitude of the THz electric field. Therefore, detecting the birefringence effect is to detect the THz field amplitude. By shooting the probe laser pulse to the THz-illuminated nonlinear crystal, one can see the polarization rotation of the probe beam due to the birefringence. After passing through the nonlinear crystal, a quarter wave plate, and a Wollaston prism, the probe beam will be spatially divided into two perpendicular (s-pol., p-pol.) components. The divided beam is collected by a balanced photodetector, and the difference of the amount of the two perpendicular components gives the THz amplitude information at a specific point.

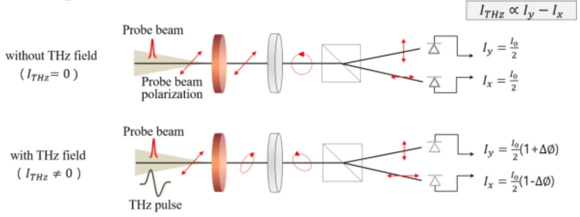

Fig. 2. THz-TDS detection method.

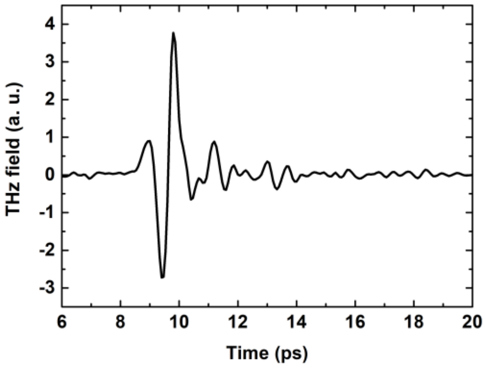

Fig. 3. Detected THz waveform from THz-TDS method.

2.3 Plasma Source

To test the THz-based diagnostics method, an inductively-coupled plasma (ICP) was used as a target plasma. The ICP device discharges argon gas in the chamber using 13.56 MHz RF power source with an impedance matching network.

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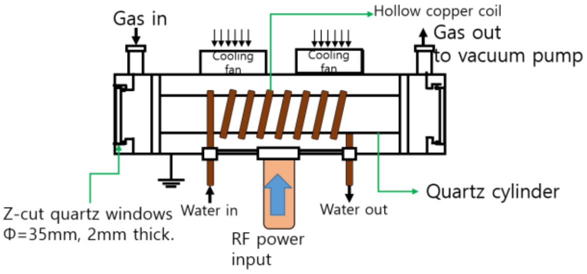

Fig. 3. The inductively-coupled plasma(ICP) device.

The RF power source can deliver RF power to the neutral argon gas in the chamber up to 600 W.

2.4 Results

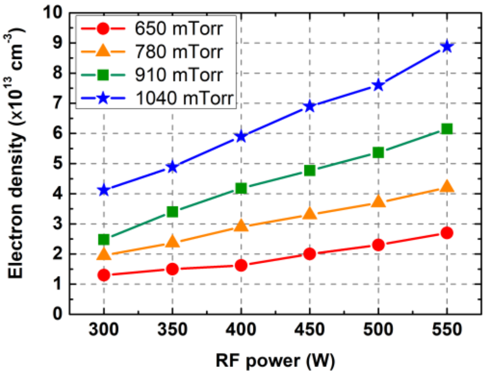

Fig. 4. Electron density vs. RF power.

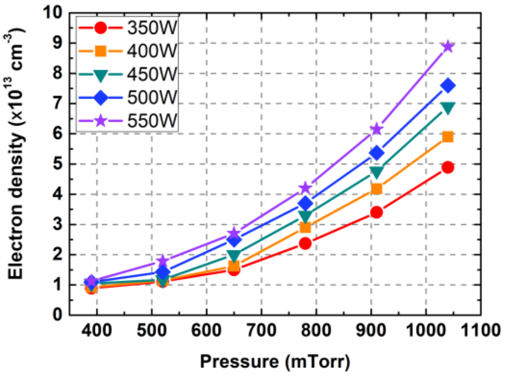

Fig. 5. Electron density vs. argon gas pressure.

Using the laser-plasma THz, electron density measurement was successfully done. The measured electron density shows increasing electron density as input power and initial argon pressure increases. The measured electron density lies within 10^{13} cm^{-3} regime, which is known for the electron density range of tokamak. This implies the possibility of THz radiation can be a promising diagnostics tool for the fusion plasmas.

3. Conclusions

Electron density of the inductively-coupled plasma was measured by the laser-plasma THz. We confirmed that the THz-based plasma diagnostics works well and figured out that the THz radiation can be a good candidate for the electron density diagnostics tool for the fusion plasmas in the future.

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