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Development of calibration method of electron cyclotron emission radiometer for optically-thin magnetized plasma

Yuan-Yao Chang*, Eiichirou Kawamori
Institute of Space and Plasma Sciences, National Cheng Kung University, Tainan, Taiwan
e-mail: gundanoovs@gmail.com

Electron cyclotron emission (ECE) is a well-established technique for measuring electron temperature in optically thick plasmas. However, the conventional ECE-based method is primarily applicable to optically thick plasmas, and a reliable approach for determining electron temperature in optically thin plasmas has yet to be established or widely accepted by the plasma physics community.

In this study, we propose a new calibration method to determine electron temperature in optically thin plasmas using the intensity ratio of ECE harmonics.

This method is based on the Schott–Trubnikov formula [1] for the ECE spectrum, through which we aim to establish a relationship between temperature and emission intensity under optically thin conditions.

Figure 1 shows the relationship between the intensity ratio of the second and third harmonics calculated from the Schott–Trubnikov formula for the electron density n_e of 10^{16}~10^{17} m^{-3}, magnetic field 0.05~0.1 T, which are our typical parameters in our experiment device. Figure 1 illustrates two key points: First, the intensity ratio and temperature have a one-to-one relationship. Second, changes in background parameters have minimal impact on the curve derived from the equation.

To verify this idea, we conduct a laboratory experiment using the Magnetized Plasma eXperiment (MPX) device at National Cheng Kung University, Taiwan, as shown in Fig. 2(a). The MPX is a mirror machine that can generate linear magnetized plasma by exciting the LaB_6 coating on the hot cathode, and five pancake-shaped coils are used to generate magnetic field to confine the plasma. A Langmuir probe (LP) is used to measure the reference electron temperature, while ECE measurement is simultaneously performed using a radiometer. Figure 2(b) shows the circuit diagram of our band-pass filter type radiometer and spectrum analyzer. The signal passes through a 2-way power divider and is subsequently amplified with gains of 20 dB and 45 dB in separate channels. The intensities of the second and third harmonic emissions are analyzed to determine the correlation between temperature and intensity ratio.

In the presentation, we will compare the theoretical calculations with the experimental data and discuss the applicable parameter ranges and related considerations.

This calibration technique is expected to be applied to electron temperature measurements in Taiwan's first spherical tokamak, as part of the ongoing ST (FIRST) project led by the Taiwanese plasma research community.

Reference
[1] I.H. Hutchinson and K. Kato, Nucl. Fusion, **26**, p. 179, (1986).

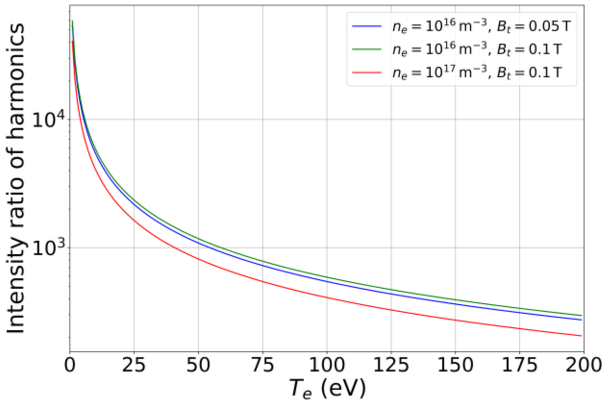

Fig. 1. The relationship between the intensity ratio of the second and third harmonics calculated from the Schott–Trubnikov formula.

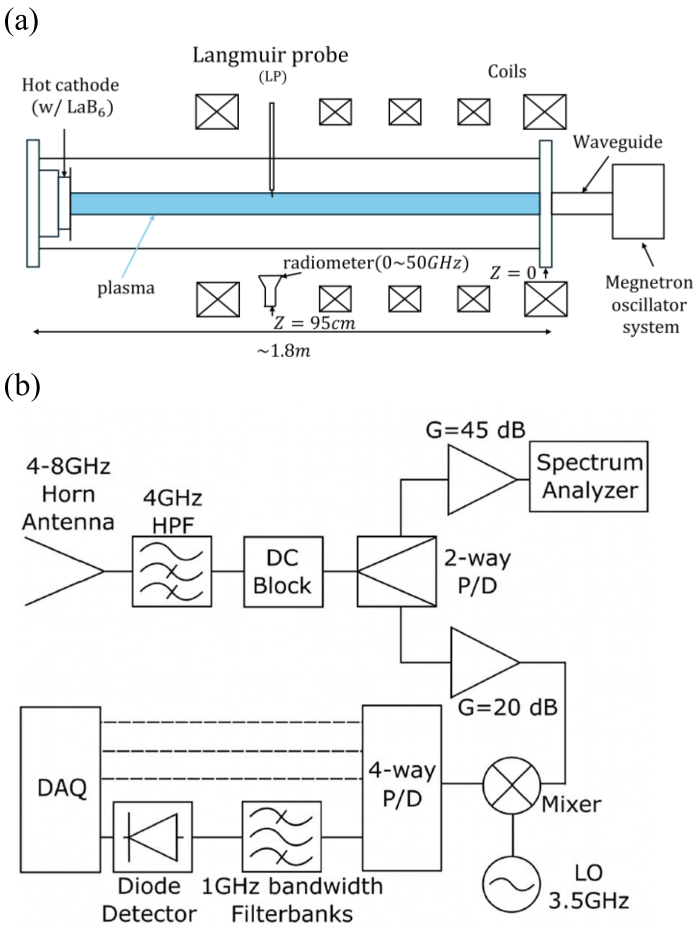

Fig. 2. (a) the experimental setup including the MPX device, the receiver of ECE radiometer and Langmuir probe (LP). (b) microwave circuit of the radiometer.