Amplitude and phase beam pattern measurements of a waveguide-type HEBM at 1.9 THz

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***Abstract*— We measured beam patterns of a fabricated corrugated horn of a waveguide-type hot electron bolometer mixer (HEBM) in amplitude and phase at 1.9 THz. The HEBM block was set on a 4-K cold stage of a cryostat with an external ellipsoidal mirror. Amplifier/multiplier chain (AMC) source were used as a local oscillator and as a RF source. The beam pattern was measured from a detected beat-note by scanning the RF source horizontally and vertically. The measured data was calibrated using the data at the beam center. A far-field beam pattern was obtained by Fourier transform calculation.**

Keywords—beam pattern measurements, corrugated horn, hot electron bolometer mixer, terahertz.

I. Introduction

Measurement of an antenna beam pattern of a hot electron bolometer mixer (HEBM) is important to evaluate a receiver performance especially for astronomical observations or atmospheric measurements. We have measured beam patterns of a corrugated horn of a waveguide-type HEBM in amplitude and phase at 1.9 THz. The concept of a measurement setup was presented in the 29th ISSTT symposium [1]. The measurement setup was referred the previous work [2, 3]. Although a phase-locked THz-QCL is described in the figure of the proceedings, we are currently using an amplifier/multiplier chain (AMC) source as a local oscillator. In the future, we will try to use a phase-locked THz-QCL for the measurement at the higher frequency of 2~4.75 THz.

II. Measurement and Results

A corrugated horn at 2-THz band was developed for a waveguide-type HEBM [4]. The corrugated horn at 2-THz band was manufactured using a 15-µm blade by KMCO (Kawashima Manufacturing Co. Ltd., Japan). The width of the teeth and the notch are measured to be 18 µm and 15 µm, respectively and the depth is 37.5 µm (75 µm at the deepest point). The number of the teeth is 140. The HEBM and an external ellipsoidal mirror were installed on a 4-K cold stage of a cryostat of a pulse-tube cooler. The HEBM was pumped using an amplifier/multiplier chain (AMC) source using a mylar beam splitter. Another AMC source with a probe (WR-0.65) set on the XY stage was used as an RF source. The beam patterns in amplitude and phase were measured from a beat-note using a lock-in amplifier by scanning RF source horizontally and vertically in a range of 15.2 mm with a spatial resolution of 79 µm which corresponds to a Nyquist sampling rate of λ/2 at 1.9 THz. Figure 1 shows the block diagram of the measurement system. It is noted that the phase beam pattern was measured by subtracting the unwanted component from the oscillators of the AMC sources. The same unwanted component was generated by a microwave circuit shown in the boxed area on the left of the figure. Figure 2 shows the photograph of the measurement system. A radio wave absorber is placed around the horn to avoid the radio wave reflection.

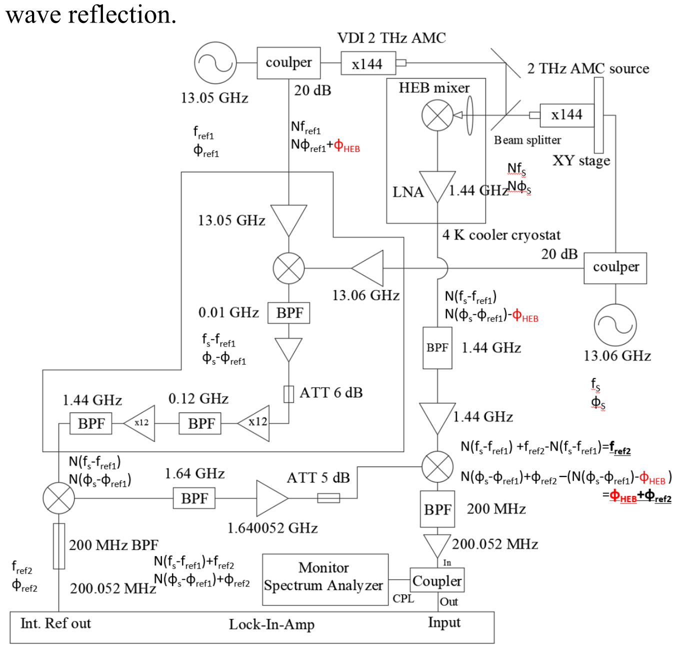

Fig. 1. The measurement setup of the beam pattern in amplitude and phase at 1.9 THz. The beat note from a 2 THz AMC source with a WR-0.65 RF probe was detected by the HEBM. The amplitude and phase of the beat note was measured by scanning the XY stage using the lock-in amplifier. It is noted that the phase beam pattern was measured by subtracting the unwanted

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components from the oscillators, which was generated by the microwave circuit shown in the boxed area in the left of the measurement system diagram.

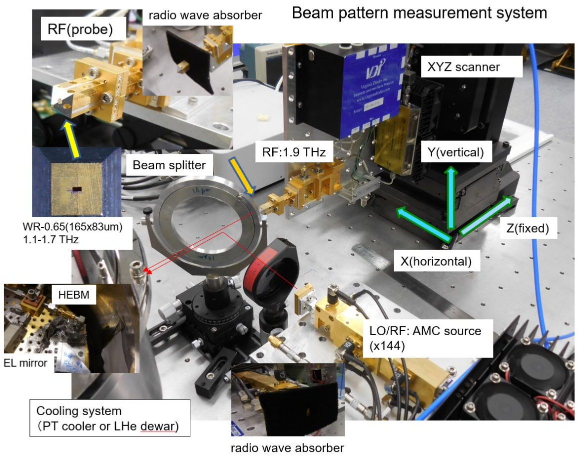

Fig. 2. A photograph of the measurement setup. The HEBM and an elliptical mirror are put on the 4 K stage of the cryostat. A LO signal was fed to the HEBM using a mylar beam splitter. The RF source which has a probe with a WR-0.65 waveguide output is set on the XY stage. A radio wave absorber is placed around the horn to avoid the radio wave reflection.

Figure 3 shows the block diagram of the data acquisition system. The XY stage is controlled by a controller for continuous motion, while data were measured by the lock-in amplifier and acquired using an AD converter by a trigger from the stage. It takes 2 hours for the full resolution mapping. This system is ~7 times faster than the method of controlling the stage and data acquisition using one by one GPIB command.

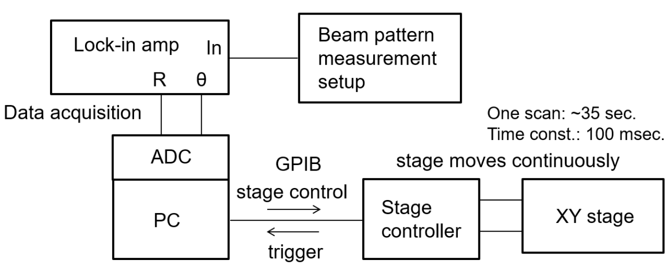

Fig. 3. The data acquisition system. The XY stage is controlled by a controller for continuous motion, while data were measured by the lock-in amplifier and acquired using an AD converter by a trigger from the stage. It takes 2 hours for the full resolution mapping.

Figure 5 (a, b) shows the measured near-field beam pattern of the corrugated horn in amplitude and phase. The phase beam pattern is slightly distorted by the instability of the receiver. In order to calibrated the data, the data at the beam center position was acquired after each horizontal scan as shown in Figure 4 (a). Figure 4 (b, c) show the acquired data at the beam center for the calibration in amplitude and the phase. It slightly changes with time due to the instability of the receiver system.

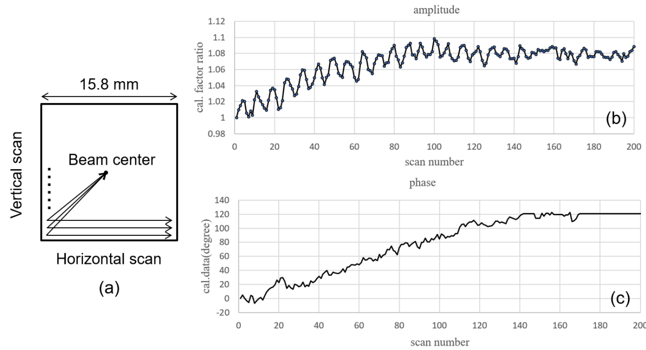

Fig. 4. (a) The calibration data was acquird by measuring the center position of the beam pattern after each horizontal scan. (b, c) The measured data at the beam center for amplitude and phase. It slightly changes with time due to the instability of the receiver system.

Figure 5 (c, d) show the beam pattern after the calibration. Especially for the phase pattern, the data has been improved to be smoothed. The data are plotted in a liner scale. The amplitude data was converted to a logarithmic scale and analyzed by fitting to a Gaussian profile which results the Gaussicity of 98 %.

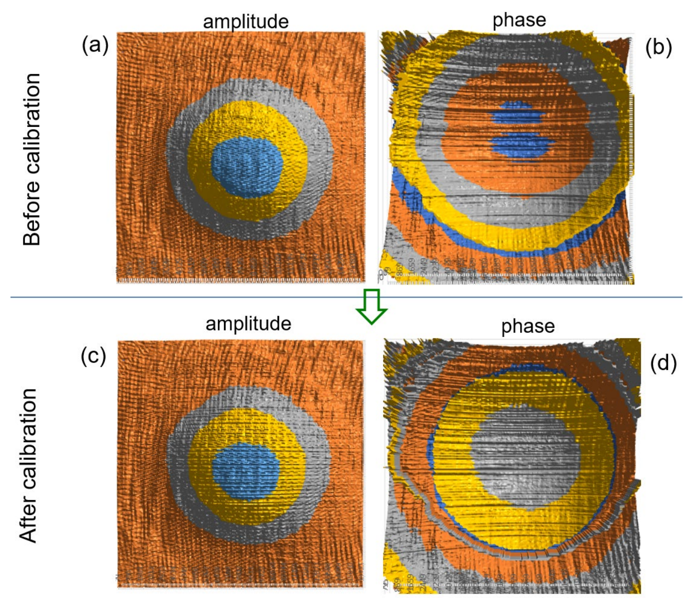

Fig. 5. The measured near-field beam pattern of a corrugated horn with an ellipsoidal mirror in amplitude (a, c) and phase (b, d) in spatial resolution of 79 µm at 1.9 THz. The data were calibrated using the data at the beam center position. The upper images (a, b) show the beam pattern before the calibration and the lower (c, d) shows that after the calibration. Especially for the phase pattern, the data has been improved to be smoothed. The data are plotted in a linear scale.

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Figure 6 shows a far-field beam pattern obtained by Fourier transform calculation.

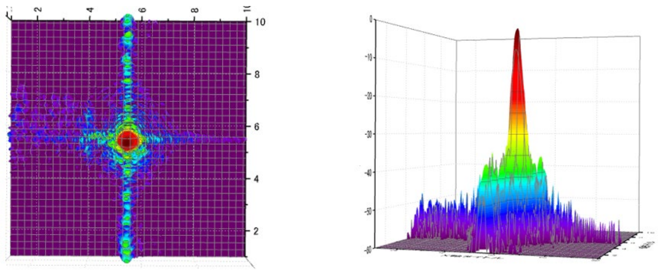

Fig. 6. The calculated far-field beam pattern of a corrugated horn in amplitude at 1.9 THz.

III. Summary

We measured beam patterns of a corrugated horn at 1.9 THz in amplitude and phase. We will also measure the beam patten in cross-polarization. In the future, we plan to measure a beam pattern at higher frequencies of 3 to 4.75 THz using a phase-locked THz-QCL as a local oscillator. At 4.75 THz, a RF source is an important issue.

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