Experimental Visualization of Beam-collimating Effect by Metal Hole Array in THz Region

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Introduction: A study of metal hole array (MHA), a metal plate with a periodic subwavelength hole array, has been attracted a significant research interest due to its extraordinary phenomena within the surface resonance states' (SRSs) bandgap when electromagnetic waves passing through it [1]. A thin MHA, which exhibits a beam-collimating effect, is a promising novel device which can be used in ultra-fast terahertz (THz, 0.1-10 THz) wireless communication in the future. Recently, we have proposed an electro-optic (EO) sensing system, which is based on non-polarimetric self-heterodyne EO detection technique, in order to visualize the THz waves in the near-field region to characterize THz devices [2]. Our system is able to measure the amplitude and phase of THz waves simultaneously with the high accuracy, high repeatability and broad frequency tunability. In this study, we visualize and characterize the beam-collimating effect of the MHA at 125 GHz.

Experiment results and discussions: The MHA, which has triangular patterns with hole's diameter of 1.5 mm and period of 2.5 mm, was placed at the distance 2 cm from the horn antenna surface in our experiment. Fig.1a and 1b shows the visualized THz waves (125 GHz) emitted from the horn antenna and collimated beam by the MHA, respectively. The phase distribution without MHA (Fig. 1a) is spherical, while the phase distribution is converted to planar by the MHA (Fig. 1b). It indicates the collimating effect of the MHA. Fig.2 shows the frequency characteristic of beam divergence ratio, which is defined as the ratio between beam divergence of collimated beam by the MHA and that of beam emitted from the horn antenna at a specific frequency. When the beam is collimated, the beam divergence ratio will be closer to 0. In this experiment, we define that the beam is collimated when this ratio below 0.5. As shown in the graph, the beam was well collimated at 125 GHz with the beam divergence ratio of about 0.15 and worse when the frequency is out of SRSs bandwidth. At 129 GHz, the beam divergence ratio increases dramatically because of that. It can be said that the collimating effect of this MHA has the bandwidth of about 13 GHz. The SRSs can be adjusted and optimized by changing the diameter and period of the hole array. Therefore, the bandwidth can be improved in the future by optimizing the design. In the future, the transmittance property of the MHA will be estimated to realize the demonstration of 10 Gbps wireless communication, which requires the bandwidth of 14 GHz at most.

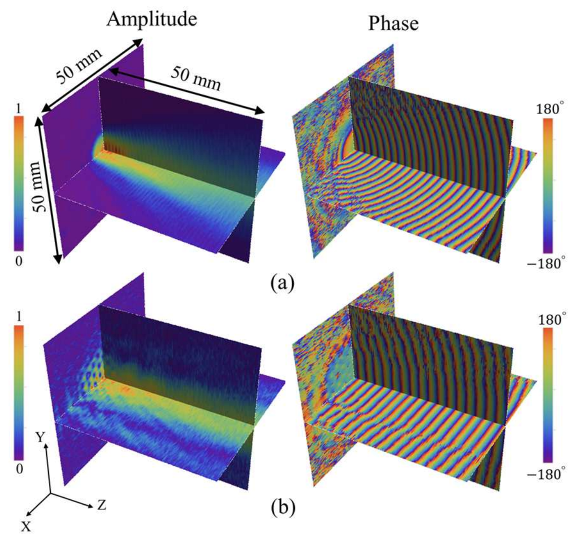

Fig.1 Experimental visualization of THz wave emitted from (a) horn antenna and (b) horn antenna and MHA at 125 GHz

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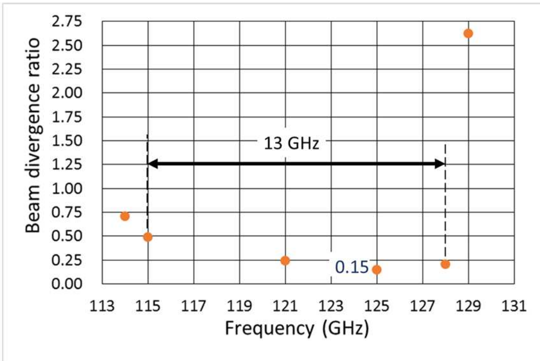

Fig.2 Frequency characteristic of the beam divergence ratio

[1] Y. Cao et al., Opt. Express., vol. 20, pp. 25520-25529, 2012.
[2] S. Hisatake et al., Optica, vol. 1, pp. 365-371, 2014.