Sub-terahertz wave radiating array consisting of nine photomixers for illuminating smoky environment

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***Abstract*— A sub-terahertz (THz) wave radiating array consisting of nine antenna-integrated uni-traveling carrier photodiode modules was developed. When the radiated sub-THz waves were incoherent, all modules illuminated uniformly in the same area, and the illumination power increased linearly by increasing the number of modules in operation. These illumination characteristics indicate that the range of active imaging in a smoky environment can be extended up to 1 meter or more by using the array.**

I. INTRODUCTION

WE previously proposed a sub-terahertz (THz) illuminator suitable for use with a THz camera when exploring objects in and behind smoke at the scene of a fire [1]. The illuminator contains multiple photomixers, and each photomixer generates incoherent sub-THz waves. The incoherency of the generated sub-THz waves is expected to enable us to increase their intensity by increasing the number of photomixers in operation, which makes it possible to achieve very bright sub-THz illumination. Consequently, objects being searched for in or behind smoke can be illuminated clearly with the illuminator and visualized with the THz camera even though they are surrounded by thick and/or high-temperature smoke. Our preliminary imaging experiment with two photomixers indicated that the use of incoherent sub-THz radiation [2] eliminates the interference pattern on the radiation profile and enables us to acquire clear images. We also confirmed that sub-THz active imaging ensures a clear view in a simulated smoky environment. However, we used only one or two photomixers as the radiation source in that preliminary study, so the radiation power for active imaging was not sufficient. Therefore, we carried out our imaging experiment at a distance of 70 cm or less.

In this paper, we report on the illumination characteristics of a sub-THz wave radiating array consisting of nine photomixers we developed for extending the imaging range in a smoky environment.

II. RESULTS AND DISCUSSION

Figure 1 shows the front view of our sub-THz wave radiating array. Nine plano-convex lenses are attached to a 16-cm-diameter white polyethylene disk. One antenna-integrated uni-traveling carrier photodiode (UTCPD) module [3] is positioned behind each lens. The optical signal for generating incoherent sub-THz waves is supplied to each module through optical fiber. A DC bias is applied in parallel. The axes of the sub-THz beam emitted from the surrounding eight modules incline two degrees to the central beam axis. Therefore, nine beam axes cross at approximately 1 meter in front of the disk.

Fig. 1. Front view of sub-THz wave radiating array.

Incoherent sub-THz waves were generated using amplified spontaneous emission (ASE) noise from an erbium-doped fiber amplifier (EDFA) coupled with a continuous-wave (cw) laser light. Before mixing the ASE noise with the cw laser light, its center frequency and bandwidth were tuned with an optical band-pass filter. Another EDFA amplified the mixed optical signal once. A variable optical attenuator, which was attached to a post-stage of the EDFA, performed on-off modulation processing on the EDFA output. The signal was then split into nine channels and fed into each UTCPD module.

The spatial distribution of the electromagnetic waves emitted from the sub-THz wave radiating array was measured as a function of the number of UTCPD modules in operation with a schottky barrier diode detector and a two-dimensional scanning stage with a lock-in scheme. The results are shown in Fig. 2. Each UTCPD module emitted incoherent sub-THz waves with center frequency and bandwidths of 600 and 40 GHz. Insets (a), (b), and (c) show the emission patterns measured from the 90-cm front. Only the center module operated for pattern (a), center and surrounding thee modules for pattern (b), and all nine modules for pattern (c). Nine modules lit up the center area uniformly, and the illumination power increased linearly by increasing the number of modules in operation.

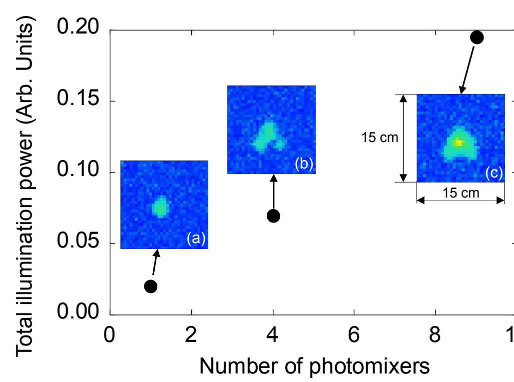

Fig. 2. Total illumination power of sub-THz wave radiating array. Insets show emission patterns measured from 90-cm front.

Figure 3 shows the emission patterns of the sub-THz wave radiating array measured from the 90-cm front when each UTCPD module emitted the sub-THz waves with a frequency of 600 GHz by using two cw laser lights with a controlled wavelength difference. In this case, the coherency of the sub-THz waves was high. Then, interference occurred between the sub-THz waves emitted from every UTCPD module. As a result, a complicated pattern appeared. This is not suitable for illumination.

These results indicate that the use of incoherent THz waves and an array of photomixers should enable the use of a THz illuminator with high brightness for active THz imaging. The imaging range will increase up to 1 meter or more by using a sub-terahertz wave radiating array consisting of nine UTCPD modules.

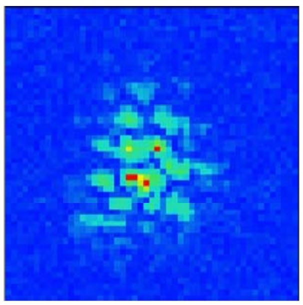

Fig. 3. Emission profile of sub-THz wave radiating array measured from 90-cm front. Sub-THz waves with frequency of 600 GHz was generated using two cw laser lights with controlled wavelength difference.

ACKNOWLEDGMENTS

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