600-GHz Wave Generator Consisting of Arrayed Light Sources in Combination with Arrayed Photomixers

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Abstract *We proposed a terahertz wave generator consisting of arrayed light sources and arrayed photomixers. We testified 600-GHz wave beam forming at a prototype of the terahertz wave generator and confirmed a directional gain caused by the array arrangement.*

Introduction

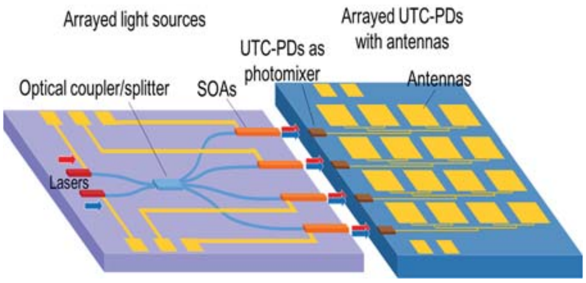
The technologies for higher speed data transmission have been an important issue these days due to the amount of rapidly increasing data to be dealt with. Data transmission using terahertz wave whose frequency band ranges from 0.1 to 10 THz can be a promising technology to fulfil the demand. Photomixing at a photodiode is one of the techniques to generate the terahertz wave. The uni-traveling carrier photodiode (UTC-PD) has commonly used as a photomixer. In spite of its flexible tunability of the frequency and phase by photonics technologies, a higher radiation power has been desired at the UTC-PD. Therefore, the arrayed configuration is essential for enhancement of the power.

We had already demonstrated 600 or 700 GHz terahertz wave generation at the arrayed UTC-PDs[1],[2]. In the experiment, two lightwaves were lased by two lasers, coupled by a fibre coupler and divided into arrayed outputs by fibre splitters. The outputs were optically coupled to the UTC-PDs. In addition, an optical delay line was used at each path to attain terahertz wave phase matching for in-phase combination. Though the fibre-based configuration is useful for such a feasibility demonstration, this configuration would preferably be integrated into a single module for a future practical use.

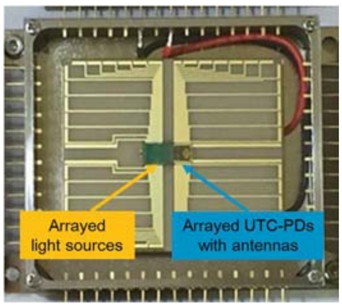
This time, we proposed a terahertz wave generator consisting of arrayed light sources and arrayed UTC-PDs that are designed to be coupled with each other without fibre optics. We fabricated the arrayed light sources based on the lasers and semiconductor optical amplifiers (SOAs). In the experiment, at first, we testified that the arrayed light sources have a high uniformity of their output power. Then, we demonstrated 600-GHz wave beam forming using arrayed channels and confirmed a directional gain caused by the array arrangement.

Concept of terahertz-wave generation module

Fig. 1(a) shows a conceptual schematic of the proposed terahertz-wave generator consisting of arrayed light sources and the arrayed UTC-PDs. At the arrayed light sources, two lightwaves from two lasers are distributed into each output so that they are coupled to the arrayed UTC-PDs. At the arrayed UTC-PDs, each UTC-PD generates terahertz current and antennas integrated with the UTC-PD radiate a terahertz wave. Total path lengths from the lasers to the antennas are designed to be the same so that the radiated terahertz waves are combined in a same phase. Fig. 1(b) shows a sample model of the terahertz generator module that gives an image of a future practical component. The module needs only DC currents injected to the light sources as well as DC voltages applied to the UTC-PDs.



(a)



(b)

Fig. 1: (a) Schematic view of arrayed light sources and arrayed UTC-PDs (b) a sample model of terahertz generator module.

Design and fabrication of arrayed light sources

The arrayed light sources were designed based on InP/InGaAsP waveguide. Fig. 2 shows a design of eight-channel device. The integrated device consists of two distributed feed-back lasers (DFB-LDs) and eight SOAs. The lightwaves from the DFB-LDs, whose frequency difference is about 600 GHz, are coupled by a 2x1 multimode interference (MMI) coupler and then divided into eight through seven cascaded 1x2 MMI splitters. Lightwaves are amplified by the SOAs which are aligned with 0.25-mm pitch. A 0.25-mm pitch micro-lens array (MLA) is attached at the output of the SOAs. The integration chip was sited on an alumina-based wiring board, which was mounted on a metal package via a Peltier cooler.

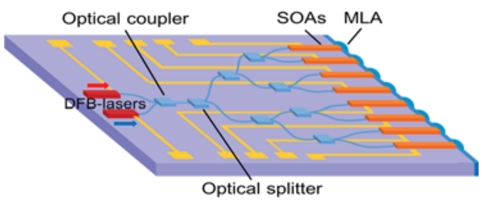


Fig. 2: Structure of arrayed light sources.

Experimental configuration for beam forming

We used UTC-PDs each of which has a bowtie antenna[1],[2]. As shown in Fig. 3 the input lightwaves are refracted at the edge of the chip and introduced into the 0.5-mm-spacing arrayed UTC-PDs.

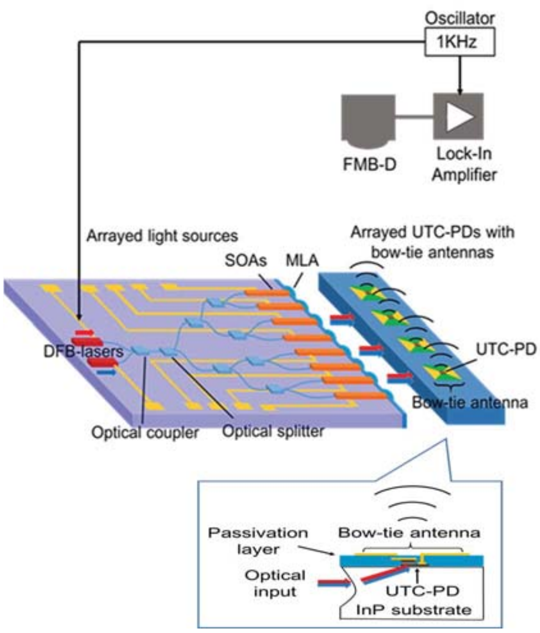


Fig. 3: Experimental configuration.

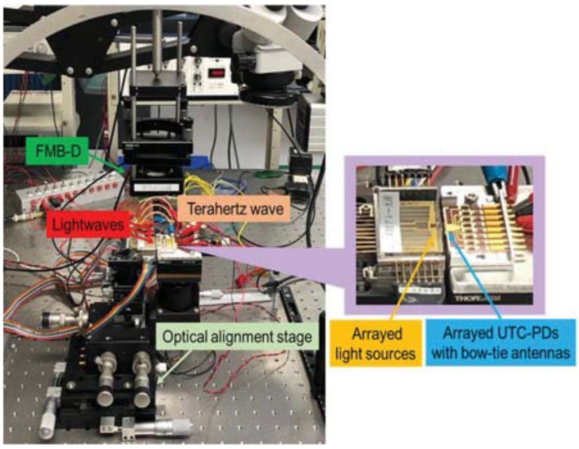


Fig. 4: Photograph of experimental setup.

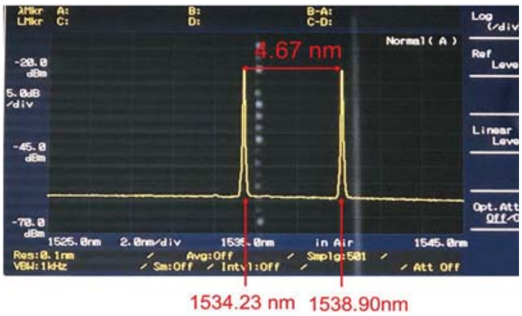
Every two outputs of the light sources are optically coupled to the UTC-PD. The arrayed light sources and the arrayed UTC-PDs were aligned on an optical alignment stage as shown in Fig. 4. A current injected into one of the DFB-LDs was modulated at 1kHz for a lock-in detection. The fermi-level managed barrier diode (FMB-D)[3] is used as terahertz wave detector, which was located at a distance of 30 mm from the bow-tie antennas. The output voltage of the FMB-D was measured at the lock-in amplifier (LIA).

Result and discussion

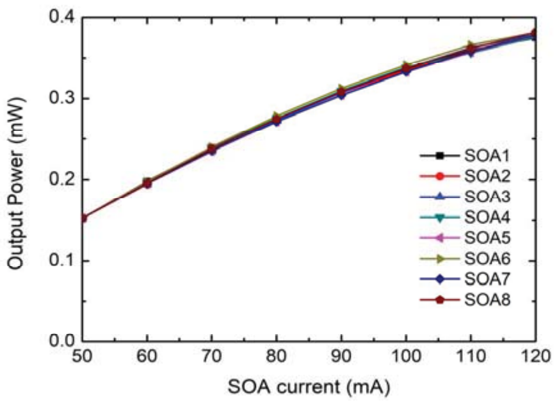
At first, we observed optical spectrum of the light source. Fig. 5(a) shows the spectrum of the output with an SOA current of 50 mA and lasers current of 50 mA. We confirmed that the lasers have wavelength difference of 4.67 nm which would enable 600-GHz wave generation by photomixing. Next, we investigated uniformity of optical output power. Fig. 5(b) shows detected optical power with a fibre as a function of the SOA current with a DFB-LD current of 50 mA. They have a high uniformity within a difference of about 2%. Here, the measured value includes a low optical coupling efficiency with the fibre.

Then, for measuring an angular distribution of the terahertz wave, we rotated the FMB-D around the arrayed UTC-PDs in a plane parallel to the array direction in a range between -20 and +20 degrees from the vertical direction. We measured the combined terahertz power from two UTC-PDs and three UTC-PDs in the array as well as that from single UTC-PD as a reference. Fig. 6 shows measured angular distribution of the terahertz power. We found that the combined power from the three UTC-PDs indicates sharp peak due to directional gain by arrayed configuration. The directivity of the two arrays shows similar distribution to that of the three arrays unlike single

UTC-PD that has flat angular distribution. Fig. 7 shows the relation between the peak combined power and the number of channels. The measured peak power is superlinear to the number of the channels. This suggests the similar trend to the theoretical expectation that it is proportional to the square of the number of channels. The result also shows that the phase of the terahertz wave can be controllable in the module.



(a)



(b)

Fig. 5: (a) Optical spectrum and (b) measured output power at arrayed light sources.

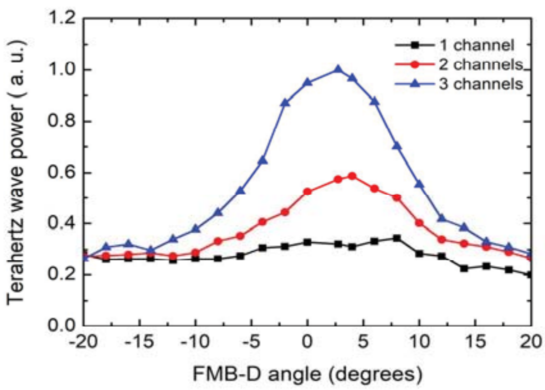


Fig. 6: Angular distribution of terahertz wave.

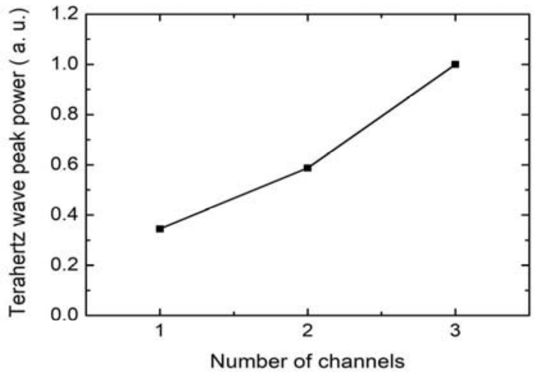


Fig. 7: Relation between peak combined power and number of channels.

Conclusions

We proposed terahertz wave generator consisting of arrayed light sources and arrayed photomixers without fibre-optics components. We designed and fabricated the arrayed light sources and demonstrated 600-GHz wave beam forming using the light sources in combination with the arrayed photomixers, from which we confirmed the effectiveness of the proposed terahertz wave generator in a future practical use.

Acknowledgements

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