375-GHz-Band Antenna-Coupled Optical Modulators Using Electro-Optic Polymer Waveguides and Metamaterial Antenna Arrays

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In wireless communication systems such as 6G and beyond, the radio-over-fiber (RoF) technology that transmits signal waveforms of terahertz waves (0.1-10 THz) using optical fibers will be important. To realize the receivers in the radio section of the mobile fronthaul/backhaul in the RoF systems, it is required to develop devices that convert THz signals into optical signals. Organic electro-optic (EO) polymers can have a large figure of merit (n^3r_{33}) for optical modulation compared with lithium niobate ($LiNbO_3$) and realize ultra-high-speed optical modulation of several hundred GHz or more. In the conventional device manufacturing processes using the EO polymers, a device structure including an EO polymer layer, conductive clad layers, and poling electrodes is first manufactured, and then a voltage is applied to pole the EO polymer layer through the clad layers. However, because the conductive clads strongly absorb THz waves, highly efficient THz devices are difficult to fabricate. In addition, the existence of the poling electrode has imposed restrictions on the device structures. Against this background, we have developed a method of transferring and bonding an EO polymer film that has been poled in advance onto a substrate and fabricated devices that combine the EO polymer film with the terahertz wave low absorption loss materials made of cyclo-olefin polymers (COPs) [1]. By using this method, we fabricated W-band (75–110 GHz) [2] and D-band (110–170 GHz) [3] antenna-coupled optical modulators with EO polymer waveguides and coplanar gap-embedded patch antennas [2] and nonplanar patch antennas [3]. In this study, we fabricated and evaluated 375-GHz-band antenna-coupled optical modulators using the EO polymer waveguides and Au metamaterial patch antennas with the aim of further improving the operating frequency (Fig. 1(a).). Figure 1(b) shows the optical spectrum of output light from the device under irradiation of 375 GHz electromagnetic waves. We observed optical sidebands with a carrier-to-sideband ratio (CSR) of 61.1 dB corresponding to an optical phase shift of 1.8 mrad and demonstrated direct optical modulation by 375 GHz electromagnetic wave irradiation.

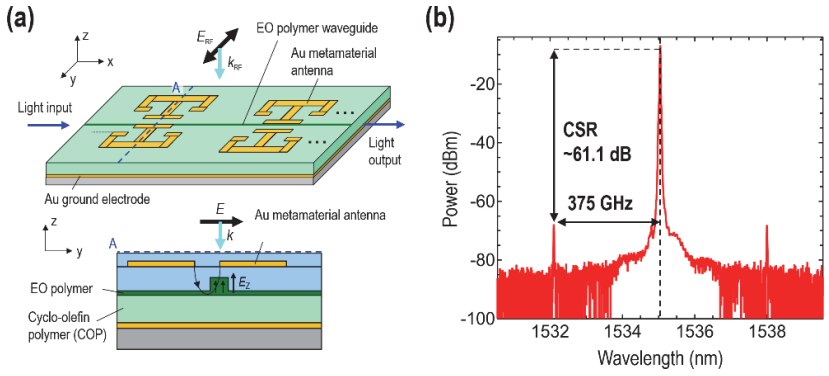

Figure 1. (a) Optical modulator using an electro-optic (EO) polymer waveguide and Au metamaterial antenna array. (b) Optical spectrum of output light from the device under irradiation of 375 GHz electromagnetic waves.

Acknowledgments: This research has been partly conducted under the contract "R&D of high-speed THz communication based on radio and optical direct conversion" (JPJ000254) made with the Ministry of Internal Affairs and Communications of Japan.

References

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