Conversion Efficiency and Device Behavior of Edge-coupled Membrane Photonic Transmitters

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Summary:
Terahertz (THz) technology has attracted a lot of attention recently and a compact high-power high-efficiency THz emitter is important to promote its applications. Compared with other methods to generate THz emissions, photonic transmitters have the advantages of room temperature operation, tunable THz wavelength, and integratability with other semiconductor devices to become compact THz sources. Recently, we had demonstrated a novel edge-coupled membrane photonic transmitter that is based on a high bandwidth MSM traveling-wave photodetector (TWPD). A conversion efficiency of 2×10^{-4} at a 1.6THz radiation frequency was achieved [1]. In this paper, we discuss the conversion efficiency and device behavior of the edge-coupled membrane photonic transmitters. With a radiation frequency of 645 GHz, we can improve the conversion efficiency higher than 0.1% while this value is a function of optical illumination power, device bias, and antenna design.

Fig.1 show an example structure of the discussed membrane photonic transmitter, which is composed of a high-speed photodetector, a RF choke filter, and a planar antenna. Please notice that this new structure is different from our previous one [1]. We adopted MSM-TWPD due to its high power-bandwidth product [2] and coplanar-waveguide- (CPW-) fed slot antennas due to its easy connection with planar devices. The RF choke filter behind the slot antenna is for the RF isolation from the dc probe pad. Including this specific example device with an antenna resonating at 645 GHz, all our devices were fabricated on LTG-GaAs layers on top of AlGaAs cladding layers. To study their device physics and saturation behaviors, we excited the photonic transmitters with broad optical pulses with temporal modulations inside, radiating quasi-CW THz waves [1]. The broad optical modulated-pulse was created by passing a femtosecond pulse through a tunable high finesse Fabry-Perot filter and the modulation frequency is determined by its free spectral range. For the example device shown in Fig.1 operating at its antenna's resonant frequency, the measured THz power and conversion efficiency versus optical excitation powers under different bias are shown in Fig. 2. The radiation THz power saturates under high optical excitation due to the defect saturation in the LTG-GaAs [3]. By increasing bias voltage, the tolerable optical saturation power also increases (arrows in Fig. 2b). These nonlinear saturation behaviors will be extensively discussed in the conference and they determine the device's optimized operation condition. The measured maximum THz power and external conversion efficiency (including coupling loss) for this specific 645GHz device are 3.9 W and 0.1 under 15V bias voltage and 3.5mW optical power excitation. According to our knowledge, this is the best-achieved conversion efficiency for photonic transmitters operating above 500GHz. With such a high conversion efficiency with edge-coupled structures, these photonic transmitters can integrate with edge-emitting laser diodes to realize compact THz sources for future applications. This work is sponsored by Institute of Applied Science & Engineering Research, Academia Sinica, TAIWAN, ROC.

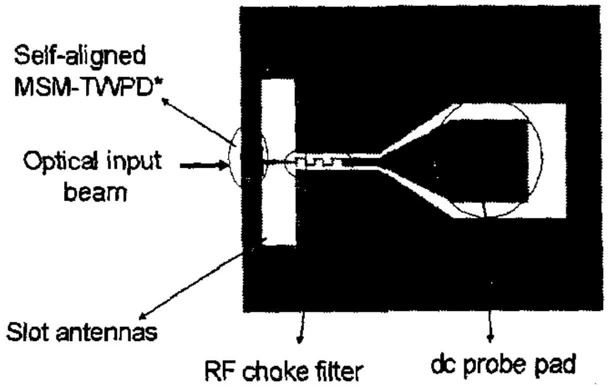

Fig. 1 Schematic structure of an edge-couple membrane photonic transmitter designed to operate at 645GHz.

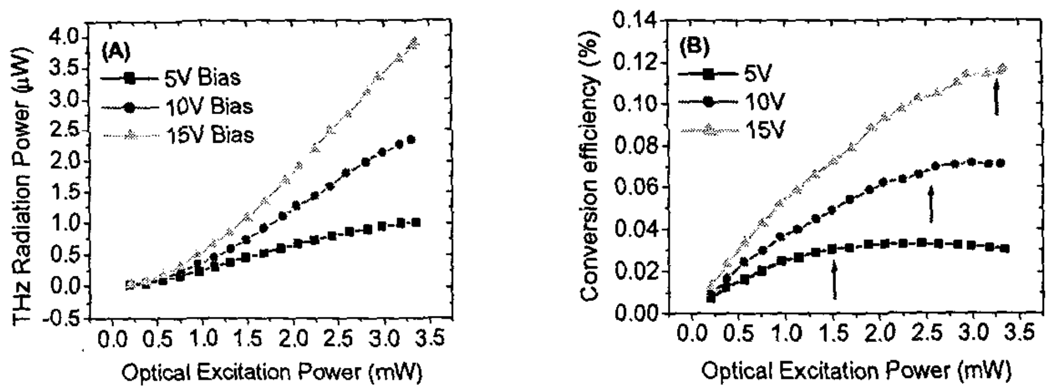

Fig. 2 (a) Optical excitation dependent THz radiation power under different bias voltages of the device shown in Fig. 1. (b) Its corresponding optical excitation dependent conversion efficiency under different bias voltages.

Reference:

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