# Edge-coupled membrane terahertz photonic transmitters with high conversion efficiency

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**Abstract:** We demonstrate a novel terahertz photonic transmitter: edge-coupled membrane photonic transmitters without silicon lenses. This device has record high optical-to-terahertz power conversion efficiency. All these factors make an integrated compact all-solid-state terahertz source possible.

**OCIS codes:** (260.5150) Photoconductivity; (320.7080) Ultrafast devices

Terahertz technology has attracted a lot of attention recently and has been applied in THz image systems and THz spectrometers [1,2]. There are several methods to generate terahertz waves. By photomixing in low-temperature-grown GaAs (LTG-GaAs) photoconductors with printed dipole antennas, the generation of continuous-wave (CW) terahertz radiation can be achieved [3]. Besides, one can also use high repetition-rate mode-locked laser to excite photonic transmitters for THz waves generation [4]. In this paper, we demonstrate a novel terahertz photonic transmitter that is composed of an edge-coupled metal-semiconductor-metal traveling-wave photodetector (MSM TWPD) and a co-planar-waveguide (CPW) fed slot antenna as shown in Fig.1. Because of the large bandwidth-efficiency product of the MSM TWPD [5], a membrane photonic transmitter with high conversion efficiency at 1.6THz can be achieved. In addition, the edge-coupled structure makes an integrated compact all-solid-state terahertz source possible.

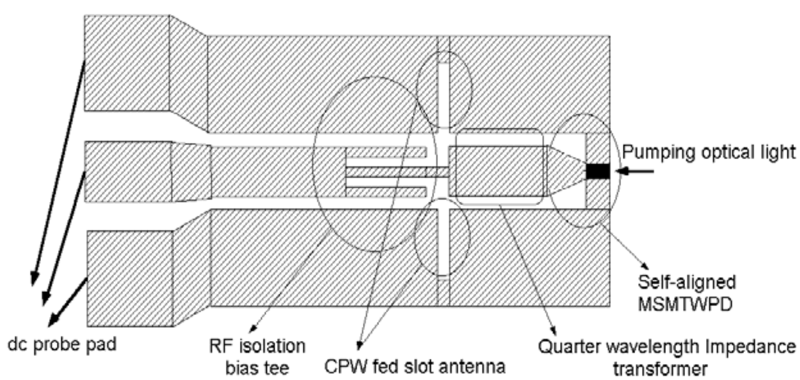


Fig. 1 The top view of photonic transmitter.

In most traditional photonic transmitters, Si lenses are needed to improve the radiation efficiency from the substrate. However, for our devices, we removed the GaAs substrate and mounted the membrane of fabricated device on a glass substrate. Because of the lower dielectric constant of glass compared with that of GaAs substrate, the terahertz power could be radiated to free space from the glass substrate more easily without the aid of Si lenses. Fig. 2 shows the experiment setup. We utilize the Febry-Perot resonator with the resonant frequency of 1.6THz to increase the repetition rate of optical pulses and the bolometer to detect THz power. In order to obtain the correct THz power, we also have to correct the THz beam propagation loss in air. Fig. 3 shows the measured bias dependent output power (solid squares) at 1.6THz after considering propagation loss under the fixed optical power excitation (0.66mW). High conversion efficiency of $\sim 2\times10^{-4}$ can be achieved at a 15V dc bias voltage. The obtained 135nW average THz power corresponds to the peak THz power of 1.6 mW. We squared the measured bias dependent photocurrents (open circles) and fitted them to the bias dependent THz output power. The two curves overlap very well as the bias is below 7V. When the bias exceeds 7V, the two curves begin to separate. We attribute this phenomenon to the increased carrier lifetime of LTG-GaAs under high bias voltages.

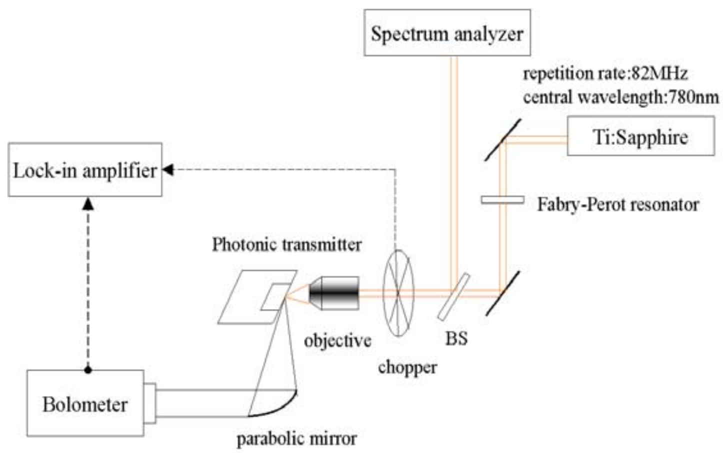


Fig. 2 Schematic diagram of the experiment setup

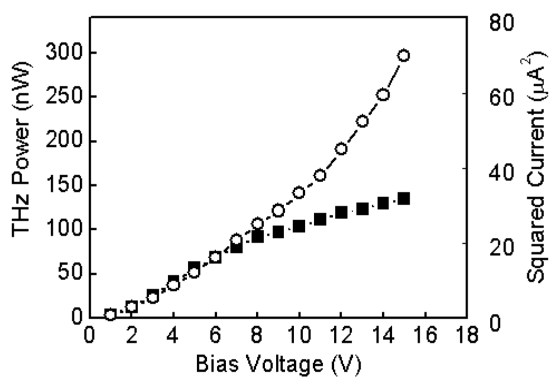


Fig. 3 THz power (solid squares) and squared photocurrent (open circles) vs. bias voltage for input power of 0.66mW.

The conversion efficiency of this demonstrated device should be able to be improved since the output power is proportional to quadratic input power [3]. However, our current Fabry-Perot resonator can't sustain the power over 0.7mW. The demonstrated maximum available conversion efficiency is thus limited by the optical excitation power from the Fabry-Perot resonator instead of the bandwidth degradation or thermal heating problems of this device. Moreover, we only collected the THz power from the glass substrate side in our experiment. Therefore, even higher conversion efficiency can be expected if we can also collect the THz power from the free space side.


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