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Integrated terahertz emitter-detector chip on thin-film lithium niobate platform

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Abstract: We present a dual-functional integrated chip realized on a thin-film lithium niobate platform, serving as both terahertz emitter and detector, enabling broadband emission and detection from 0.1 to 2.5 THz. © 2024 The Author(s).

1. Introduction

The terahertz (THz) frequency region, ranging from 0.1 to 10 THz between microwaves and infrared, was once called the "terahertz gap" due to the limited availability of THz sources and detectors. However, this gap is now rapidly closing with the advancements in THz technologies. THz technology holds significant potential across various fields, such as astronomy, non-invasive imaging, communication, sensing, and spectroscopy. In particular, broadband THz sources are highly relevant for applications requiring advanced sensing and spectroscopic capabilities [1-3]. Conventional THz systems for broadband emission and detection remain bulky and complex, making the development of a fully integrated, miniaturized THz system on a chip a significant challenge. Lithium niobate is an excellent material for THz emission via optical rectification and THz detection via electro-optic sampling with Mach-Zehnder interferometer (MZI), thanks to its high second order nonlinearity low optical losses in the near-infrared range [4-5]. Recently, thin-film lithium niobate (TFLN) platform has shown great potential for integrated THz systems, with reports on both THz emission or THz detection [2,6-7]. In this work, we develop a single device with dual functionalities based on the TFLN platform, capable of both THz emission and detection. Operating at the zero-dispersion wavelength (~1310 nm) for conventional single mode fiber (SMF), the system maintains short pulse duration without the requirement for complicated dispersion compensation methods, enabling broadband THz emission and detection from 0.1 to 2.5 THz.

2. Results

The schematics of the single-chip THz emission and detection system are shown in Fig. 1(a) and Fig. 1(b). A rib lithium niobate waveguide is split into two arms in order to construct a Mach-Zehnder Interferometer (MZI). One arm of the MZI incorporates a 1 mm transmission line that is terminated by a dipole antenna, while the other includes a gold line with a heating pad for thermo-optic tuning of the operation point of the interferometer. Along the transmission line, both optical and THz modes are matched in velocity [6].

The device is characterized using a THz-Time Domain Spectroscopy (THz-TDS) system with lock-in detection and a commercial photoconductive antenna (PCA) (Fig. 1(c)). To characterize the emission process by our device, the PCA serves as the THz detector and reads out the generated signal. For THz detection, the PCA is biased to function as the THz source, and the TFLN chip captures and confines the THz radiation within its antenna. The chip output is connected to a photodiode to read the detected signal. The TFLN chip operates at 1310 nm, maintaining a narrow pulse duration without requiring dispersion compensation. The PCA operates at 1550 nm, where dispersion-compensating fiber (DCF) ensures pulse durations below 200 fs.

Fig. 1(d) and Fig. 1(e) display the measured time trace and spectrum of the THz signal generated by the TFLN chip, with the PCA as the detector, using a 550 Hz chopper frequency. Fig. 1(f) and Fig. 1(g) show the time trace and power spectrum of the THz signal detected by the TFLN chip, with the PCA as the emitter, modulated by an RF voltage source at 100 kHz. The noise spectrum in Fig. 1(g) demonstrates a dynamic range of ~69.3 dB.

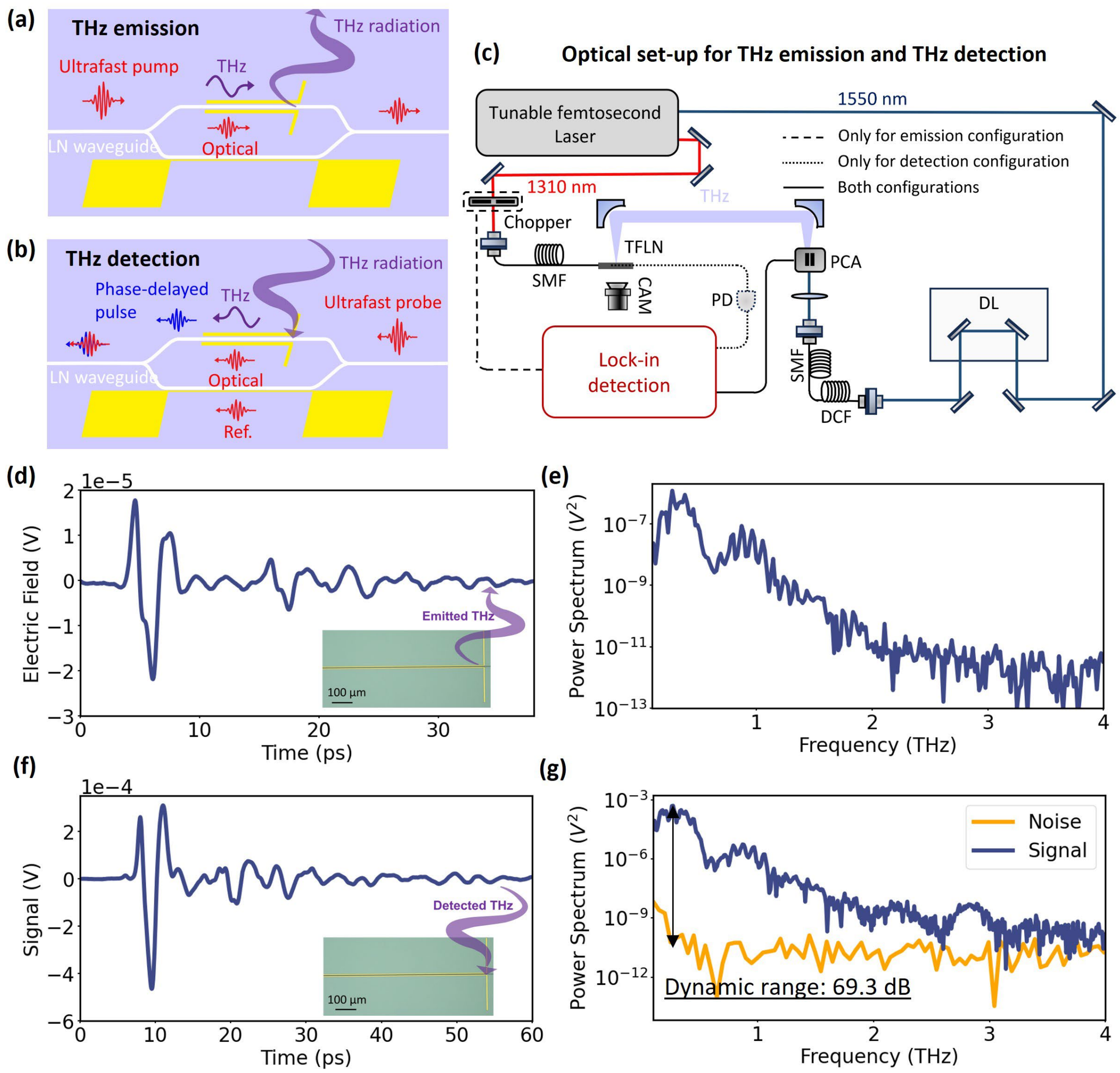

Fig. 1. Schematic of (a) THz emission and (b) THz detection on TFLN chip. (c) Characterization setup for THz emission and THz detection. (d) Time trace and (e) spectrum of generated THz signal from TFLN chip. (f) Time trace and (g) spectrum of detected THz signal on TFLN chip (with noise spectrum and dynamic range).

3. Conclusion

We realize a dual-function integrated THz emitter-detector chip on TFLN platform capable of broadband THz emission and detection (0.1-2.5 THz) from the same device. Our device is fully compatible with commercial fiber technologies thanks to operating at 1310 nm wavelength, thereby eliminating the complexities associated with dispersion compensation.

4. References

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