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Nonlinear Photonics for Sub-Terahertz Sources

Shima Rajabali[1,2,*], *Xinrui* Zhu[2], *Hana K.* Warner[2], *Yunxiang* Song[2], *Leticia* Magalhaes[2], *Amirhassan* Shams Ansari[2,3], and *Marko* Lončar[2]

[1]Department of Quantum and Computer Engineering, Delft University of Technology, Netherlands
[2]Harvard John A. Paulson School of Engineering and Applied Sciences, Harvard University, Cambridge, MA, USA
[3]DRS Daylight Solutions, 16465 Via Esprillo, CA, USA

Abstract. Terahertz technologies offer unique advantages for communication, sensing, and imaging, yet integrated platforms struggle to perform efficiently in this range. Thin-film lithium niobate, a nonlinear photonic platform, enables compact, broadband, and high-speed terahertz sources through efficient frequency conversion. In this talk, I present our progress on developing sub-terahertz continuous-wave sources on lithium niobate chips, aiming to bridge the gap between electronic and photonic systems for next-generation terahertz integration.

1 Introduction

Terahertz technology has a broad deployment in strategic areas. For example, compared to microwaves, terahertz communication systems can transmit information at much higher rates. In sensing, in contrast to X-rays, terahertz systems can image through optically opaque media without inducing ionization. In manufacturing, terahertz imaging can complement visible imaging and reveal both the compositional and morphological properties of products. In environmental monitoring and medical applications, terahertz waves can detect water in vivo, e.g., in plants or human tissue, since the water has strong resonances in the terahertz. Although integrated circuits (ICs) and photonic integrated circuits (PICs) are mature technologies, their performance remains limited in the terahertz range. Creating a platform seamlessly integrating high-speed terahertz components with current microwave ICs and transducing/converting optical photons to terahertz ones can bridge the gap between electronics and photonics. Despite the evident advantages of terahertz technologies, most research efforts have been implemented in bulk, necessitating a focused shift toward realizing compact, highly sensitive, high-speed, and broadband systems. In this talk, I discuss our effort [1] toward developing (sub)terahertz sources on thin-film lithium niobate, a nonlinear integrated photonic platform [2, 3].

2 Results

A dual-tone source is a key element in photonic-based terahertz transmitters, generating two optical tones separated by a frequency difference f_c, which produce a terahertz carrier through the photomixing process [4]. One of our efforts is to demonstrate an on-chip dual-tone source on the thin-film lithium niobate (TFLN) platform using a single laser. This approach enhances system stability and reduces cost compared to traditional dual-laser setups (Figure 1).

A continuous-wave laser at 1550 nm is edge-coupled to a commercial X-cut TFLN on an insulator chip using lensed fibers. To generate the two tones on-chip, a phase modulator driven at half the free spectral range of a ring filter (FSR: 68 GHz) is used (more detail in

*e-mail: S.Rajabali@tudelft.nl

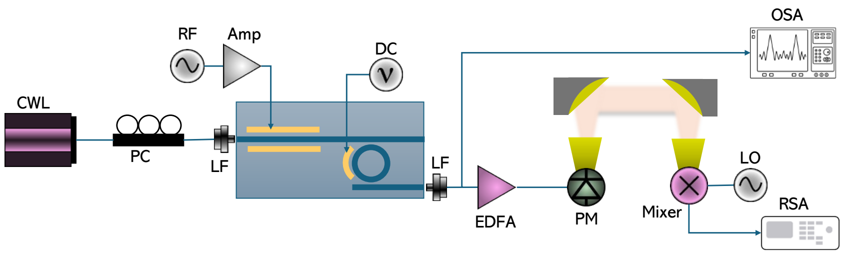

Figure 1. Measurement Setup. CWL: Continuous Wave Laser, PC: Polarization Controller, LF: Lensed Fiber, EDFA: Erbium Doped Fiber Amplifier, Amp: Amplifier, PM: Photomixer, LO: Local Oscillator, OSA: Optical Spectrum Analyzer, RSA: Real-time Spectrum Analyzer.

[5]). The modulated signal is then filtered at the drop port (extinction ratio: 20 dB) and amplified before photomixing (Figure 2a). The amplified signal is sent to a commercial photomixer to generate a sub-terahertz carrier signal. We collect the carrier using a horn antenna, downconvert it, and analyze it with a real-time spectrum analyzer.
Our dual-tone source generates a stable carrier at f_c = 136 GHz with sub-kHz linewidth, while the dual-laser signal drifts by ~20 MHz. After 10(20) dB pre-amplification, the detected signal shows a dynamic range of 32(44) dB, as shown in Figure 2b. The carrier frequency is tunable over more than 5 GHz (4% of carrier frequency).

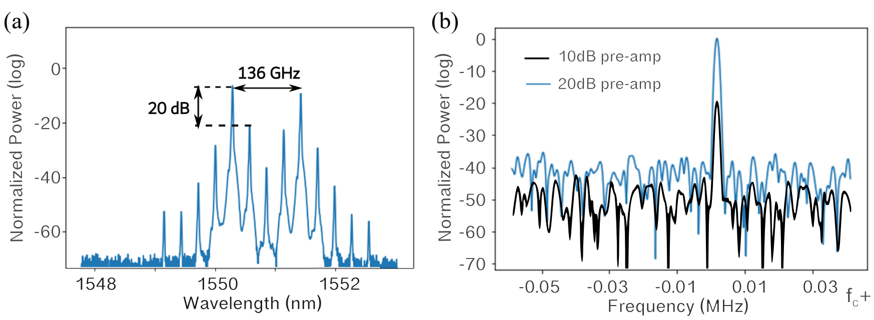

Figure 2. (a) The signal collected with the lensed fiber before EDFA on optical spectrum analyzer, (b) Generated carrier frequency (f_c = 136 GHz) on real-time spectrum analyzer.

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