Terahertz Emission from Titanium-diffused Magnesium Oxide-doped Lithium Niobate Optical Waveguides

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Titanium-diffused lithium niobate optical waveguides are well known for their use in integrated optical circuits but find little usage in terahertz applications. In this work, we demonstrate that Ti-diffused magnesium oxide-doped lithium niobate (Ti:MgLN) strip waveguides can also act as terahertz emitters and amend this oversight. Titanium-diffusion was performed on an X-cut magnesium oxide-doped lithium niobate plate with dimensions of 10 mm x 10 mm and a thickness of 0.5 mm. Titanium was initially deposited along the Y-direction by electron beam deposition using a 40-µm wide opening in a lithographic mask to create a stripe pattern with a length of 10 mm and a thickness of 100 nm. This was then annealed in a vacuum furnace at a temperature of 1050°C for 10 h in Ar gas to diffuse the Ti. To generate the terahertz pulses, the strip waveguide was excited with a 1.55-µm wavelength ultrafast pulsed laser source with an average power of 21 mW. A lens of focal length *f* = 30 mm was used to focus the beam onto the waveguide facet. The prism-coupled Cherenkov-phase matching [1, 2] configuration in a terahertz time-domain spectroscopy system was utilized to extract the generated terahertz waves, with a triangular silicon prism as the outcoupling medium and a photoconductive antenna as the detector. A near-single cycle terahertz time-domain pulse was observed from the waveguide, Figure 1(a). To assess for the waveguiding, the contrast between emissions from the waveguide and the bulk parts of the sample while moving the sample vertically along its facet was measured in Figure 1(b), and though modest, an enhancement of ~18% in the time-domain signal was seen. This observed difference is due to the excitation beam being confined in a smaller space and resulting in a relatively more efficient conversion from optical to terahertz frequencies [1, 2]. Checking for the insertion loss of the waveguide using the output power from the transmitted central maxima with respect to the pump power, the value was known to be 10.6 dB. This is indicative of the small difference in the THz signals as a function of position, which is attributed to Fresnel reflection losses from the facet, leakage of the pump beam out of the waveguide, and the pump not being wholly collected by the waveguide. Even so, the result is proof of the feasibility of titanium-in-diffusion to output strong terahertz waves from Ti:MgLN strip waveguides, and that it can be a possible option for other terahertz emitters available in the market.

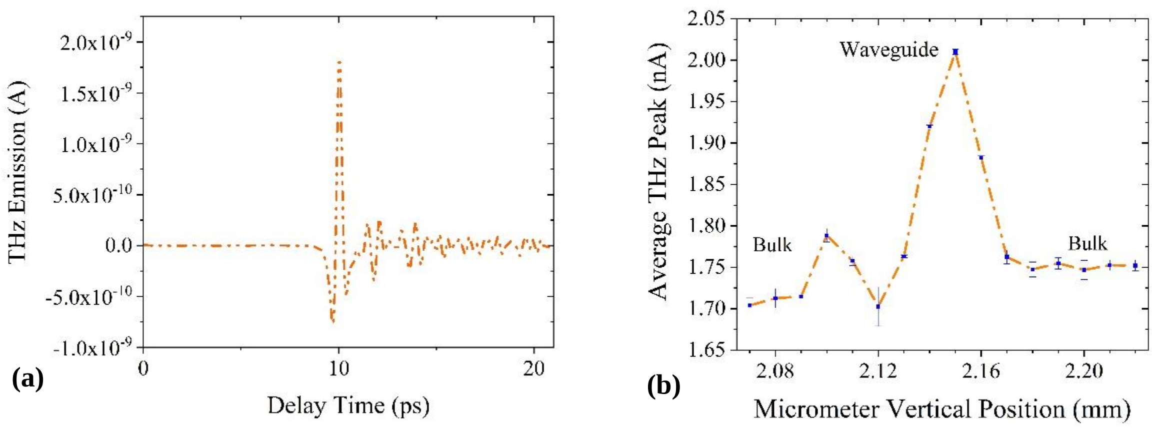

Figure 1. (a) Terahertz time-domain pulse from the Ti:MgLN waveguide. **(b)** Facet scan showing the contrast between the peak terahertz signal from the waveguide and the bulk crystal

References:
[1] K. Takeya et al., APL Photon., vol. 2, no. 1, pp. 016102-1-8, Nov. 2016
[2] S. Fan et al., Optics Letters, vol. 38, no. 10, pp. 1654-1656, May 2013