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THz radiation generation from polariton parametric scattering in a LiNbO₃ waveguide

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RESUME

The presentation will focus on polariton parametric scattering in a rectangular waveguide made of Lithium Niobate to generate THz radiation. We highlight an emission of ultra-short THz pulse with a spectrum centered around 3 THz with a large bandwidth of 4 THz.

KEY WORDS : *Lithium Niobate, Terahertz generation, Waveguide,*

1. INTRODUCTION

Polariton parametric scattering in polar crystals such as Lithium Niobate (LN) is a promising method to generate THz radiations from a second and third order nonlinear processes, delivering large or narrow bandwidths. Particularly, polariton scattering have been investigated when a long pulse pumps the material to generate tunable long THz pulses [1,2]. A significant challenge hindering this technique lies in the generation of a THz spectrum centred at frequencies exceeding 2 THz, primarily due to the gain spectrum of LN, and the important absorption coefficient at higher frequencies [3]. In this submission, we highlight the possibility to overcome this limitation by pumping a waveguide made of LN with a high optical intensity in the sub-picosecond regime.

2. PRINCIPLE AND EXPERIMENTAL SET-UP

The generation of THz pulse is the result of light scattering from a polariton, i.e a coupling between optical phonons and photons in the polar-Raman active LN. The scattering involves the second and third order nonlinear processes. The strong interaction of the pump pulse in the material creates an optical idler and a polariton pulse in the THz frequency. From the photon energy conservation, the generated optical idler is spectrally shifted from the pump by the THz spectrum while the momentum conservation law leads to the angle-dispersive properties of the emitted pulses. In this investigation, the THz radiation was generated and guided in a rectangular LN waveguide ($0.5 \times 0.5 \times 16 \text{ mm}^3$) such that the THz radiation propagates in the pump propagation direction. The experimental set-up is shown in Figure 1. The crystal has been pumped by ultra-short pulses at a repetition rate of 85 kHz with a pulse-energy of 7 μJ . The spectrum is centred at 1025 nm and the pulse duration is 400 fs. The pump was focused with a 150 mm lens and polarized along the z axis of the crystal. The temporal waveform of the generated THz electric field was measured with the electro-optic sampling technique using a small fraction of the laser beam. The THz beam is collimated and focused into a GaP crystal to perform the EO sampling using a thin silicon filter and two parabolic mirrors.

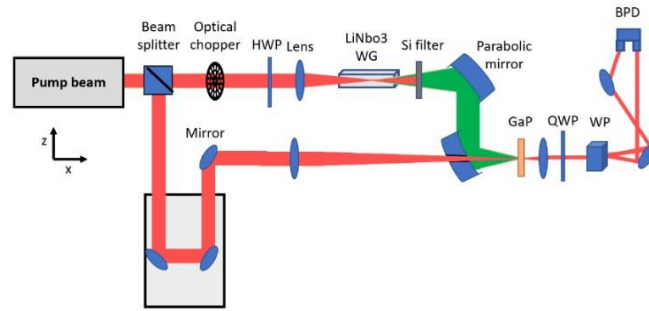


Figure 1 Experimental set-up. QWP/HWP-quarter/half wave plate; WP-Wollaston prism; BPD-balanced photodetector

3. RESULTS AND ANALYSIS

Figure 2.a shows an example of a recorded temporal trace when the pulse energy is set at $7 \mu\text{J}$. The spectrum, obtained from the fast Fourier transform of the temporal trace, is broad with a width of $\sim 4 \text{ THz}$ centred at 3 THz (Figure 2.b). The optical spectrum at the output of the waveguide is also shown in Figure 2.c and corresponds to the idler simultaneously generated with the THz. The spectrum has multiple Stokes peaks emitted from the spontaneous polariton parametric scattering process. The spectral shifts of the peaks relative to the pump are in good agreement with the THz spectrum. As the idler is angularly emitted at the output, the spectrum is not smooth and depends on the spectrometer orientation. We also calculated the expected THz spectrum from the phonon polariton dispersion curve and the diffraction modified Schwarz-Maier plane wave model [4]. By including the mode area mismatch between the optical and the THz fields together with the limited diffraction geometry, we corroborate the emission of a very large spectrum centred at 3 THz .

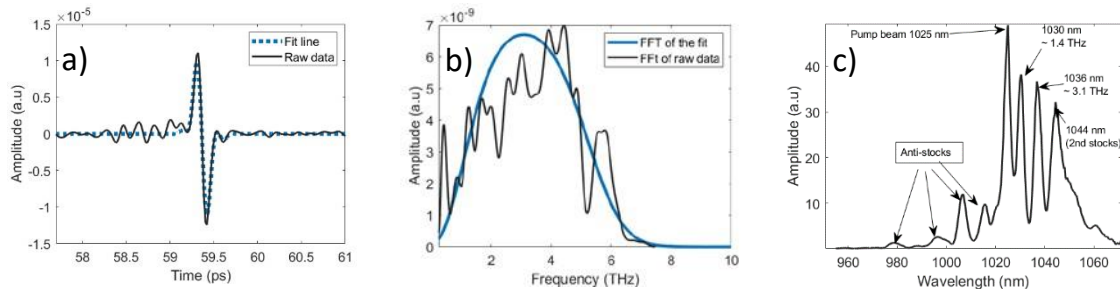


Figure 2 a) Temporal waveform of the detected THz pulse and its fit b) Corresponding spectra obtained by FFT c) Optical spectra at the output of the waveguide.

4. CONCLUSION

Polariton parametric scattering in LN made waveguide has been presented to generate THz radiations with a large band of $\sim 4 \text{ THz}$ centred at 3 THz . The generated optical spectrum of the idler and the predicted spectral THz gain are consistent and confirms our observations. This result is an excellent step toward the development of ultra-fast THz amplifier.

5. REFERENCES

- ¹A. M. Warriar, R. Li, J. Lin, A. J. Lee, H. M. Pask and D. J. Spence, "Tunable THz generation in the picosecond regime from the stimulated polariton scattering in a LiNbO₃ crystal." *Optics Letters* **41**, 4409-4412 (2016).
- ²Y. Takida, J. I. Shikata, K. Nawata, Y. Tokizane, Z. Han, M. Koyama, T. Notake, S. Hayashi, and H. Minamide, "THz-wave parametric gain of stimulated polariton scattering", *Phys. Rev. A* **93**, 043836 (2016).
- ³U. T. Schwarz and M. Maier. "Frequency dependence of phonon-polariton damping in lithium niobate." *Physical Review B* **53** (9), 5074 (1996).
- ⁴T. Wang, Y. Huang, M. Chuang, Y. Lin, C. Lee, Y. Lin, F. Lin and G. K. Kitaeva. "Long-range parametric amplification of THz wave with absorption loss exceeding parametric gain." *Opt. Expr.* **21.2**, 2452-2462 (2013).