Optica High-brightness Sources and Light-driven Interactions Congress 2022 (EUVXRAY, HILAS, MICS) © Optica 2022

Comparison of Lithium Niobate Based Multicycle Terahertz Sources for Pulse Shape Control

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Abstract: Efficiency and pulse shape quality of lithium niobate-based multicycle THz pulse source conceptions were systematically investigated by high-level numerical calculations.

1. Introduction

High energy single cycle THz pulses can be generated in lithium niobate crystal (LN) with high efficiency by optical rectification of ultrashort laser pulses [1], and they have widespread applications [2, 3]. In some applications, for example driving certain electron accelerator schemes, multicycle THz pulses can be more advantageous than single-cycle ones [4]. Contrary to visible or near-infrared light pulses, in the THz domain generating single- or close to single-cycle pulses is easier than multicycle ones. The reason for this is that in the presence of velocity matching [5]the electric field of the arising THz pulse is proportional to the time derivative of the intensity of the pump pulse creating it [6]. Recently many publications have been appeared on multicycle THz generation [7, 8], however, little emphasis has been placed on the THz waveform, whereas in any physical process where the field strength of the light pulse plays a role, the controllability of the temporal shape of the field strength is crucial.

In this work, with the help of numerical calculations, we show the degree to which the temporal shape of the field of the generated THz pulses can be controlled for the cases of a conventional tilted pulse front excitation source [5] and for periodically polarized lithium niobate (ppLN) source, pumped by a single short (~ few 100 fs), or long (2-20 ps), intensity-modulated laser pulses (see the conceptions in Fig. 1.) This kind of intensity-modulated pulses can be produced by interfering two narrowband or chirped pulses (with the same chirp parameter) and delayed the two to each other.

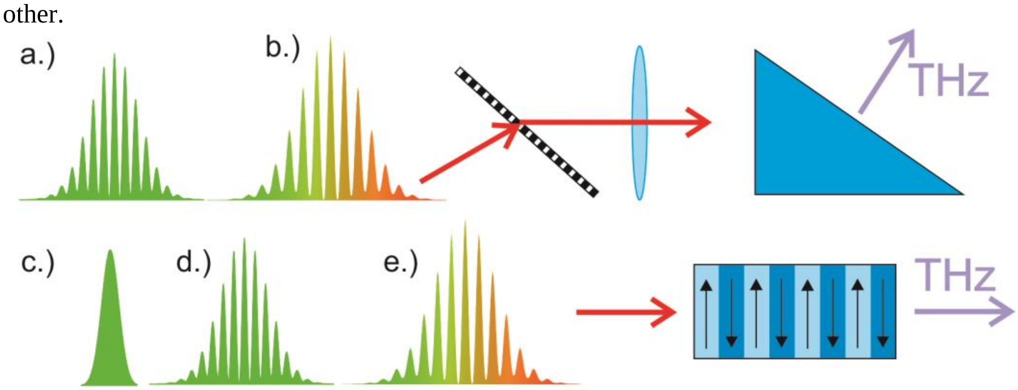

Fig. 1. Conceptions for generation multicycle THz pulses by intensity-modulated narrowband (a, d), or broadband chirped (b, e) and Gaussian-shaped (c) pulse in conventional (a, b) and ppLN crystals (c, d, e).

2. Method

Numerical code was used for the calculation which take into consideration the effect of the material and angular dispersion and the generated THz pulse feedback to the pump pulse. In the present paper, we strived to show generation of THz pulses with 1 THz central frequency and 5 oscillation periods (5 ps pulse duration), however, our calculations were performed over a wide range of parameters. The period of the ppLN, the spectral distance between the two narrowband pump pulses, the chirp parameter and the group delay of the chirped pulses was set according to satisfy conditions needed to generation THz pulses with 1 THz central wavelength. The peak intensities of the individual 5 ps long pulses (see in Fig. 1a, b, d, e) in the intensity-modulated pulses were 7.7 GW/cm^2 (so the peak intensity of the modulated pulse is 15.4 GW/cm^2) The simple Gaussian profile pulse (Fig. 1c) was 500 fs long with 44.7 GW/cm^2 peak intensity.

3. Results

The conversion efficiencies of the THz generation are shown in Fig. 2. In the case of a conventional setup, there is no principle limitation of the usable crystal length, however in the case of ppLN setup, beyond the modulation frequency of the intensity-modulated pulse, the number of the period of the ppLN will determine the number of the cycle of the THz pulse. Therefor in the case of using ppLN crystal, the maximal crystal length is only 0.5 mm.

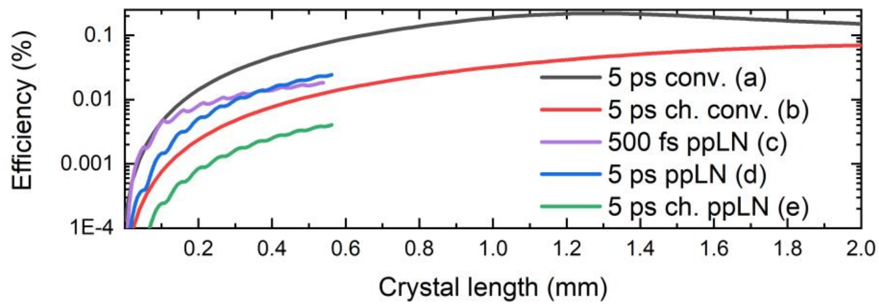

Fig. 2. THz generation efficiency of the above mentioned cases (see Fig.1).

The electric field shape of the generated THz pulses and the corresponding spectra are shown in Fig. 3. In the case of conventional setup, the peak electric field and the efficiency is higher than in the case of using ppLN, however, the spectral distribution and thus the shape of the electric field quality is better for ppLNs.

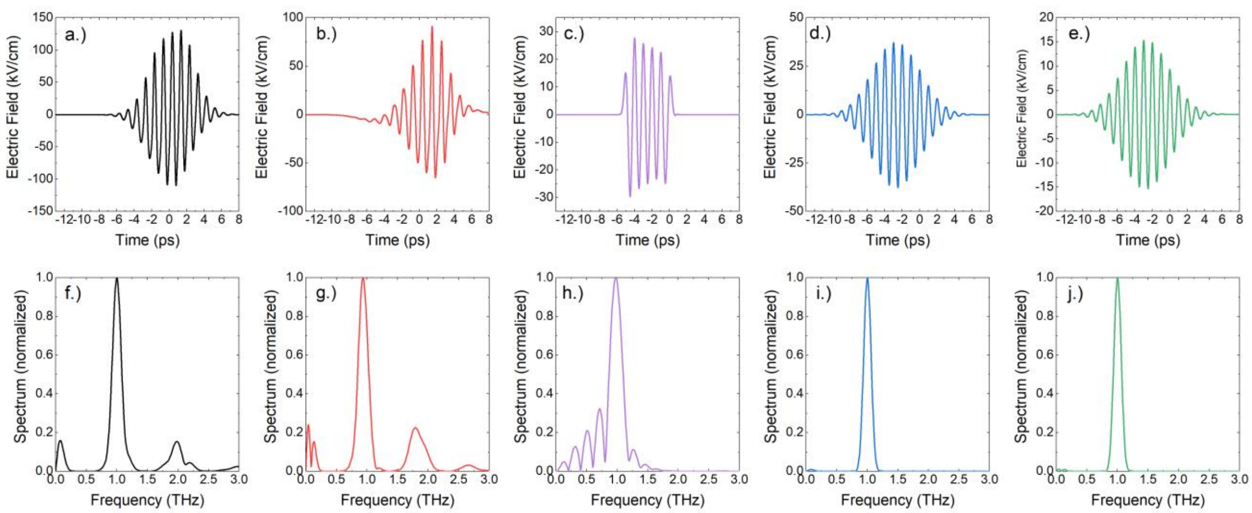

Fig. 3. The generated THz pulse shapes (a-e) and the corresponding spectra (f-j). The color code is the same as in Fig. 2.

Acknowledgement

This work is supported by the ÚNKP-21-5-PTE-965 and ÚNKP-21-1-I-PTE-1045 New National Excellence Program of the Ministry for Innovation and Technology from the source of the national research, development and innovation fund.

4. References

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