Enhanced Terahertz Wave Generation via Combination of Cherenkov Phase Matching and Waveguide Crystal

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1. Introduction

Terahertz (THz) waves are an electromagnetic region which lies between microwave and lights. Since the THz waves have features of both electric wave and visible lights, novel observations are possible by using THz technologies. For the further THz application, the improvement of THz source in terms of power and bandwidth is essential. Many methods have been applied to generate THz waves. One typical method to use THz waves is THz time domain spectroscopy (THz-TDS). For the source of THz-TDS, two methods due to femtosecond pulse laser pump are famous to generate THz waves. One is the PCA, and other one is non-linear optical (NLO) crystals employing optical rectification of femtosecond laser pulses. NLO crystals have higher damage threshold compare to the PCA, then we can expect strong THz generation employing NLO crystals.

We have carrying on Cherenkov phase matching method for effective THz wave generation [1,2]. This method makes it possible to suppress the absorption of a NLO crystal and generate coherent THz waves along Cherenkov angle. Furthermore, prism coupled Cherenkov phase matching method (PCC-PM) is an elegant method for the THz generation using NLO crystals. When we use cladding material with a suitable refractive index formed into a prism, it should be able to extract THz waves from NLO crystals without the total internal reflection inside crystal.

However, even PCC-PM method has several disadvantages such as absorption and a phase mismatching caused by the thickness of a crystal. Waveguide structure of NLO crystal is able to suppress these issues due to the thin thickness. Ridge structure further is able to concentrate pump beams on narrower area; hence it is possible to rise up the power density of pump beams. We here report successful THz generation from waveguide NLO crystals.

2. Results

We used $LiNbO_3$, DAST, and OH1 crystals in this study. The crystals were coupled to a spherical Si prism, which satisfied the Prism-coupled Cherenkov phase matching condition. The THz radiation generated as spherical waves from each point of the crystals and was enhanced almost 50° from the pump-beam axis. We focused the pump beam on the $LiNbO_3$ waveguide, the surfaces of bulk crystals and edge face of waveguide OH1 crystal. The THz waveform was radiated from the waveguide illuminated by a 1560-nm pump pulse. The radiated THz pulses were observed by the method of time domain spectroscopy with photoconductive antenna. We observed broadband THz generation from each crystal. The shape of obtained THz pulses was an ideal half-cycle. Fig. 1 shows the corresponding spectrum obtained by Fourier transformation of the time-domain spectrum from waveguide $LiNbO_3$. The bandwidth of the spectrum was up to 7 THz, and the dynamic range of output spectrum was 80 dB. This fact result from advantage of Cherenkov phase matching. We obtained THz-wave generation from NLO crystals with a high dynamic range and wide tuning range.

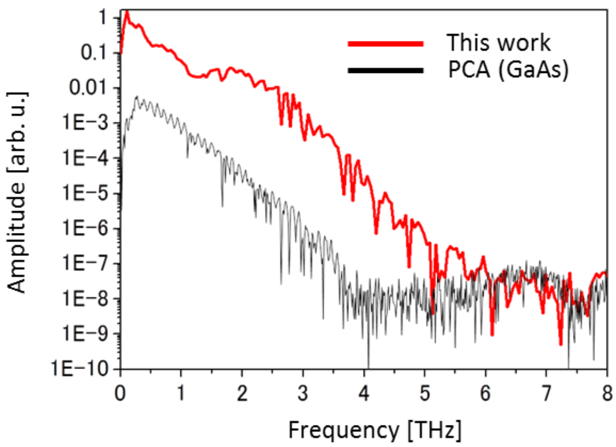

Fig. 1. Frequency spectra of generated THz wave from waveguide $LiNbO_3$ (red line) and conventional photoconductive antenna (black line). The output from waveguide is clearly broadband and high dynamic range.

3. Conclusions

We demonstrated THz wave generation from nonlinear crystals using Cherenkov-phase matching method. Wide frequency and highly effective THz waves generated from $LiNbO_3$ waveguide, DAST and OH1 crystal illuminated by a 1560 nm pump pulses. The generated THz waves in terms of $LiNbO_3$ waveguide were over 80 dB in a dynamic range and over 7 THz in a frequency.

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References

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