주기적으로 분극반전된 $LiNbO_3$ 와 $LiTaO_3$에서 펨토초 펄스레이저를 이용한 테라헤르츠파 발생

Terahertz Pulse Generation in Periodically Poled Lithium Niobate and Lithium Tantalate Using fs Pulse Laser

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The development of terahertz(THz) radiation sources has considerable interesting in spectroscopy, imaging, medical diagnostics, gas sensing, and astronomy. A common way to generate coherent THz waves is by the optical rectification of a femtosecond (fs) laser pulse using an electro optic (EO) crystal. For efficient single-cycle THz generation, group velocities of the optical and the THz pulses should be the same in the medium. This is accomplished in only a few crystals such as ZnTe or GaP around wavelength of 800 nm [1]. An alternative approach to the tunable narrow-band THz generation with multicycle or arbitrary waveforms by the optical rectification of fs laser pulses was demonstrated using periodically poled nonlinear crystals [2]. In this work, we present a forward and backward THz generation by DFG, which allows the generation of narrow-band and multicycle THz waveforms. The main idea is to utilize the group velocity mismatch between the optical and THz waves in periodically poled lithium niobate (PPLN) and lithium tantalate (PPLT) crystals. The optical and generated THz pulses will be separated after a walk-off length then the optical pulse will lead the THz pulse by the optical pulse duration. If the periodically poled domain length is comparable to the walk-off length, each domain contributes to the THz radiation independently. Because of the periodic reversed sign of the nonlinearity at each domain, the generated THz waves also have reversed wave forms alternatively. As a result, the form of THz wave is corresponding to the structure of the periodically poled domains (quasi-phase-matched period). This idea was proposed before by Lee and coworkers however, the origin of THz generation was not explained clearly from the optical rectification of the fs laser pulse. In this study, the origin of THz generation can be clearly explained by DFG process. The two different types of THz generation are satisfied by the broadband fs pump laser [2].

Forward and Backward THz generation via difference frequency generation

A broadband fs laser pulse, which consists of several frequencies such as ω_1 and ω_2, can induce nonlinear polarization with a difference frequency, ω_{THz} ($= \omega_1 - \omega_2$), assuming $\omega_1 > \omega_2$ in a periodically poled nonlinear crystal. The difference frequency (THz frequency) can be described as

$$\Delta\vec{K}_{DFG} = \vec{K}_{\omega 1} - \vec{K}_{\omega 2}, \quad \vec{K}_{\omega THz} = \Delta\vec{K}_{DFG} - \vec{K}_{\Lambda}. \tag{1}$$

K is the wave vector at each frequency, and $K_{\omega\ Hz}$ is the grating wave vector. If we select ω_1 as a center frequency of the fs pulse, DFG frequency can be varied by varying ω_2 within the spectral bandwidth of the fs pulse. where, Λ is the QPM period.

As shown in Fig. 1 a pump laser, 1 kHz Ti-Sapper regenerated amplifier system with center wavelength of 800 nm was used. For the THz detection the EO sampling method was applied with a 1.55-mm long ZnTe crystal. Before using the QPM crystals for THz generation we used a LiNbO3 (LN) crystal to understand the difference of THz radiation between dispersive and non-dispersive medium at optical and THz frequency (Fig. 2).

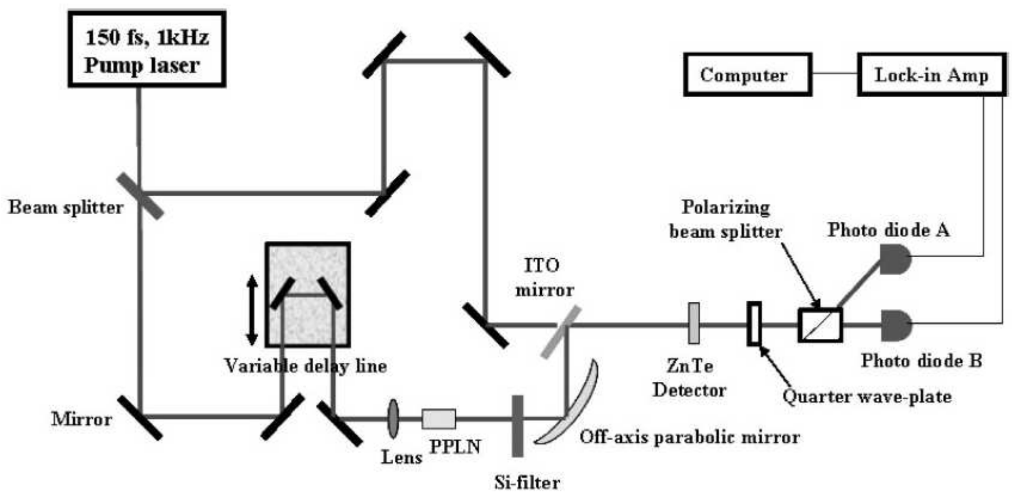

Fig. 1 Experimental set-up for THz generation and detection by EO sampling method.

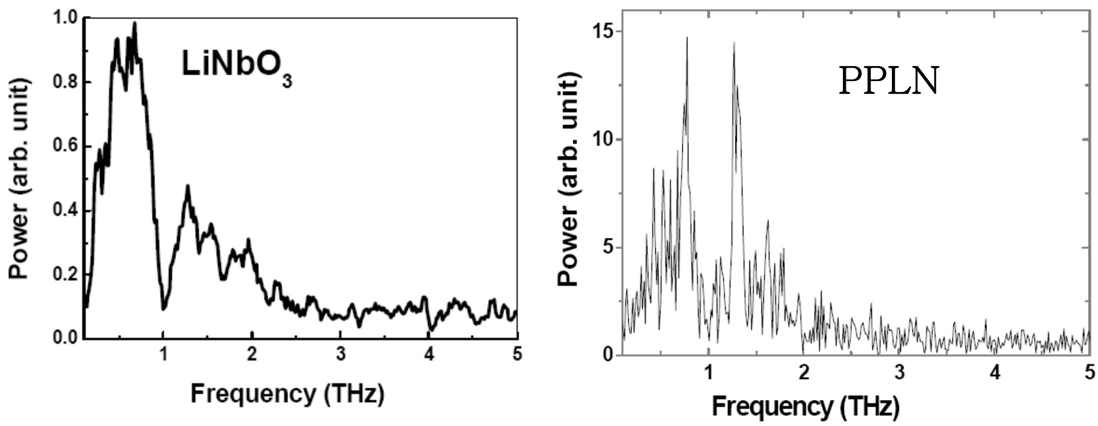

Fig. 2 Generated terahertz pulses in 2 mm-long $LiNbO_3$ crystal and 2 mm-long periodically poled lithium niobate crystal with a QPM period of 30.8 μm

In Summary, we measured the backward THz generation at 1.3 and 1.7 THz from PPLN and PPLT, respectively, at room temperature. In the presentation we will discuss more detail about the backward and forward THz generation depend on QPM condition.

[1] Q. Wu and X.-C. Zhang, Appl. Phys. Lett. 68, 1604 (1996).

[2] N. E. Yu, C. Jung, C.-S. Kee, Y. L. Lee, B.-A. Yu, D.-K. Ko, and J. Lee, Jpn. J. Appl. Phys., 46, 1501 (2007).