Contact grating with Fabry-Perot resonator for effective THz light generation

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1. Introduction

Intense THz light is an indispensable tool for nonlinear THz spectroscopy. Presently, the optical rectification in a Mg-doped $LiNbO_3$ (LN) prism with pulse-front control of the pump pulse is widely used as the most effective method for obtaining intense THz light [1]. This conventional method in which the pump pulse front is tilted by a diffraction grating and imaged onto the LN prism, however, has potential problems in scalability. When we employ large-area excitation with a high power pump light, the THz output energy and spectrum become inhomogeneous in space which limits the efficiency of THz light generation.

Recently, we have demonstrated a novel THz generation device to overcome the above problems [2]. Our device based on the concept of "contact grating setup [3]", realizes both the pulse front tilting and the THz light generation in the single device which brings the scalable and extremely compact (~1 cm) THz source as compared with the conventional prism setup (~1 m). Furthermore, to enhance both the diffraction and the THz generation efficiencies, we employed the Fabry-Perot resonator in the device as shown in Fig. 1(a), and obtained the THz output of >1 μJ. In this presentation, we demonstrate the scalability of our device, and optimize the device to realize the maximum performance of the THz light generation.

2. Results

Fig. 1(b) shows the THz output energies from the devices as a function of the pulse energy of the pump laser which was a high-power Yb:YAG laser with 1030 nm wavelength, 1.3 ps pulse duration, and 4 mm in diameter. Using our system, the THz light with the center frequency of 0.23 THz and the frequency range of 0.1–1.0 THz was generated. The THz output was proportional to the square of the input energy, which is a result of the second order nonlinear optical rectification process.

The 2.2 mm thick device could generate the THz pulse with higher energy as compared with the 1.0 mm thick device. When the device thickness is increased more than 2.2 mm, the THz generation is expected to be suppressed by the absorption of the THz light, depletion and angular dispersion of the pump light, and so on. To design the devise with the optimized thickness, we simulated the THz light generation in the contact grating device by solving two-dimensional coupled wave equations. Fig. 2(a) shows the spatial evolution of the intensity profiles of the pump and THz light. As the pump light propagates into the device, the THz light is amplified by it. At z = 2.8 mm, the intensity of the THz light becomes maximum, and starts to decrease, which indicates that the optimized device thickness is 2.8 mm. The spatial mapping of the THz spectra at z = 2.8 mm is shown in Fig. 2(b). The THz beam profile is close to the Gaussian shape with the uniform spectra in space, which suggests that the contact grating setup is scalable, and available to the large-area excitation with a high power pump light.

It should be noted that the optimized thickness depends on the pulse energy and spectral width of the pump light, because the THz generation process is strongly affected by the depletion and angular dispersion of the pump light. Therefore, we have to design the device for each pump light setup.

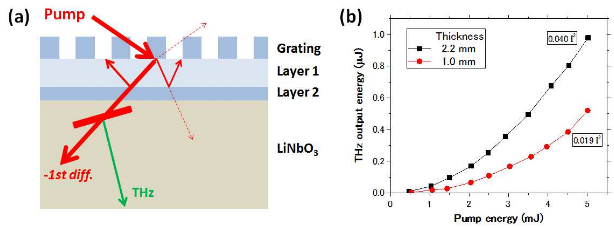

Fig. 1. (a) Details of the contact grating with the Fabry–Perot resonator. A dielectric multilayer is deposited on the LN substrate, and a diffraction grating is fabricated on its outermost layer. The pump light irradiates the grating layer. The −1st-order diffraction light is trapped at the one of the layers which acts as the Fabry–Perot resonator for the diffracted light. (b) THz output energies as a function of the pump energy. The black and red dots represent the results with 2.2 and 1.0 mm thick devices, respectively.

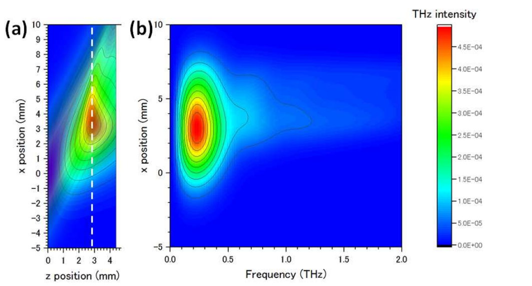

Fig. 2. (a) Spatial evolution of the THz light in the device. The pump light with a pump energy of 4 mJ and a beam diameter of 6 mm irradiates the device from the left at z = 0, and propagates to the upper-right as shown by the background dark profile. The vertical dashed line at z = 2.8 mm shows the optimized thickness with largest THz output. (b) THz spectra as a function of the output position x at z = 2.8 mm.

References

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