Generating THz Pulses with Longitudinal Electromagnetic Field

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Ultrafast control of materials by terahertz (THz) waves has attracted great interest in the area fundamental physics and in technological applications. Response of THz to two dimensional materials, and the ability to suggest unique response when strong THz fields are applied vertically to their plane, makes it the candidate of choice for future high frequency electronics. Studies of such responses at ultrafast timescales expand our understanding of these materials, and allow for ultrafast control over their properties. For the application of vertical electromagnetic fields, cylindrical vector (CV) beams, which have a polarization state with axial symmetry in the beam cross section, are suitable because of the production of longitudinal electric or magnetic field components in the vicinity of the focal point (Fig. 1(a)) [1].

For the generation of the CV beam in the optical region, a segmented waveplate is commonly used, and as such not suitable to convert THz pulse with broadband spectral components to the CV beam. Therefore, a method to directly generate a broadband THz vector beam has been developed using a GaP (111) crystal with threefold symmetry for terahertz generation. Results from this study demonstrated that it is possible to directly generate a broadband THz CV beam by exciting the segmented GaP (111) crystal with linearly polarized femtosecond pulses [2] or by exciting a normal GaP (111) crystal with polarization-controlled femtosecond pulses [3]. It revealed that THz longitudinal electric field was generated by focusing them, and that these broadband THz CV beams can be easily converted to THz vortex beam [4].

These methods limit the intensity of the THz longitudinal electric field due to the generation efficiency of the nonlinear crystals. In recent years, higher-intensity THz light sources such as THz free electron lasers have also been developed [5]. If a CV beam can be generated from any linearly polarized light regardless of the type of light source, higher intensity of longitudinal electric THz filed can be realized. Thus, this study demonstrates a new method for converting linear polarized THz Gaussian beams into Hermite–Gaussian 01 (HG_{01}) beams, and by generating strong longitudinal electric fields by focusing them. A specially designed silicon prism is used for the polarization-conversion (Fig. 1(b)), which has a total internal reflection plane, half of which is coated by gold. Since gold has a larger refractive index than silicon, half of the incident beam is phase shifted when reflected. When the THz beams were incident at a specific angle, the relative phase shift between the two halves was equal to π, resulting in relative polarization reversal. Using this technique, we successfully converted the THz pulse generated from a lithium niobate crystal into a HG_{01} mode and generated a 36 kV/cm THz longitudinal electric field by focusing them [6].

In this talk, I will introduce these our study for THz longitudinal electromagnetic field generation so far and discusses the future developments.

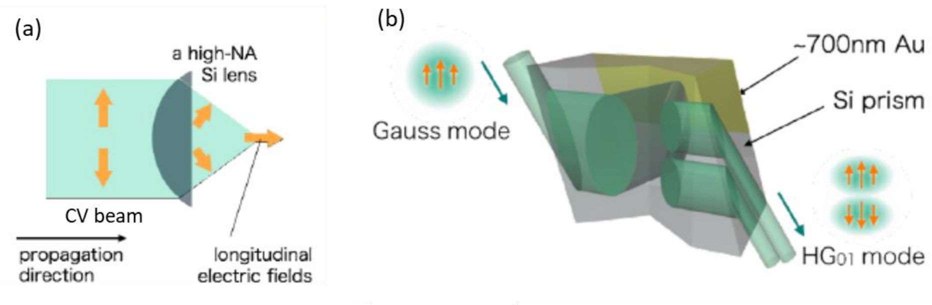

Fig. 1. (a) scheme of longitudinal electric fields from CV beam (b) Schematic of the silicon polarization-conversion prism

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