Efficient Optical-to-Terahertz Conversion of Femtosecond Laser Pulses Propagating Along a Sandwich Structure with Thin $LiNbO_3$ Core

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***Abstract* —A new scheme for efficient optical-to-terahertz conversion of femtosecond laser pulses is experimentally demonstrated. In this scheme the laser pulse is cylindrically focused into thin $LiNbO_3$ layer placed between the BK7 glass substrate and silicon prism. The pulse excites a moving nonlinear polarization in $LiNbO_3$ that emits the Cherenkov cone of terahertz waves in the silicon prism. We measured the terahertz waveform and terahertz energy as a function of the optical pump energy. Up to 10^{-3} conversion efficiency has been observed for 50 μm thick $LiNbO_3$ layer pumped with 100 μJ, 200 fs Ti:sapphire laser pulse.**

I. Introduction And Background

Seaching the ways for efficient optical-to-terahertz conversion is an urgent problem of the terahertz science.

The commonly used scheme of the phase-matched optical rectification of Ti:sapphire laser pulses in ZnTe provides the conversion efficiency typically not higher[1] than 10^{-5}. Newly come tilted pulse front excitation technique increased the efficiency for Ti:sapphire laser pulses in $LiNbO_3$ up to a record value[2] of 6×10^{-4}. The observed red shift of the central wavelength of the optical pump spectrum up to 0.3% corroborated the cascading optical rectification[2].

Recently a new scheme for efficient Cherenkov emission of broadband terahertz (THz) radiation from ultrashort laser pulses propagating in a sandwich-like structure was proposed[3]. The structure consists of a thin nonlinear core cladded with a material with low terahertz absorption. The laser pulse propagates in the core and emits Cherenkov cone of terahertz waves in the cladding. High efficiency of such a scheme was predicted theoretically[3]. In this work, we explore this scheme experimentally.

II. Results

The generation scheme is shown in Fig. 1. The beam of Ti:sapphire laser (with pulse duration of 50 or 200 fs) is focused by a cylindrical lens to the $LiNbO_3$ layer (of thickness 50 or 30 μm) clamped between the BK7 glass substrate and silicon prism. The propagating in the $LiNbO_3$ laser pulse produces a nonlinear polarization which follows the intensity envelope of the pulse. The nonlinear polarization moves with the group velocity of the pulse, which exceeds the phase velocity of terahertz waves in silicon, and emits the Cherenkov cone (wedge) of THz radiation in the silicon prism. The prism is properly cut to output the Cherenkov cone to free space.

The generated terahertz waveform was registered using electro-optic sampling. The terahertz energy was measured by bolometer (QMC Instruments) calibrated by pulsed microwave (100 GHz) signal with duration (30 ns) less that the bolometer time response (~300 ns). We also monitored the optical pump spectrum after propagation through the sandwich structure.

Figure 2(a) shows the terahertz waveform generated by 200 fs optical pulse in the structure with 50 μm thick $LiNbO_3$ core. The conversion efficiency is shown in Fig. 2(b) as a function of the optical pump energy. Visible in Fig. 2(b) saturation of the efficiency can be explained by three-photon absorption of the pump. The maximal efficiency is $\sim10^{-3}$. We observed also a red shift of the optical pump spectrum with the same dependence on the pump energy as for the efficiency. The maximal value of the shift is ~0.4% that corroborates the cascading optical rectification.

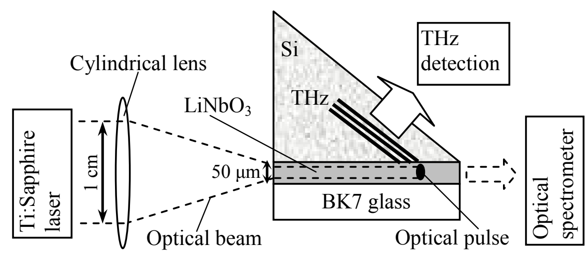

Fig. 1. Generation scheme.

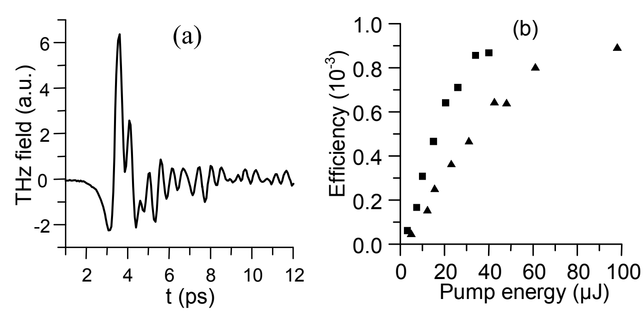

Fig. 2. (a) The terahertz waveform and (b) dependence of the conversion efficiency on the laser pulse energy for the structure with 50 μm thick $LiNbO_3$ core excited with 50 fs (squares) and 200 fs (triangles) laser pulses.

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