THz pulse generation in $ZnGeP_2$ with near-IR pumping

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Abstract— THz wave generation was investigated in nonlinear $ZnGeP_2$ crystals with the fs pumping at 800 nm and 950 nm. Transmission and absorption spectra were analyzed. Refractive indices of the $ZnGeP_2$ in the THz range were measured and approximated in the form of Sellmeier equations. Phase-matching conditions were calculated. Calculated conditions are well correlated with experimental data.

Keywords— nonlinear optical crystals, THz radiation, THz sources, femtosecond lasers

I. INTRODUCTION

A positive nonlinear $ZnGeP_2$ (ZGP) crystal of the point symmetry group $\bar{4}2m$ has a transmission range of 0.74-12 μm at "zero" absorption, high nonlinear, mechanical, thermal properties, and damage threshold [1]. Due to this, ZGP crystal is widely used in mid-IR ns-sources to produce high-power pulses at room temperature under the pump in the 2.5-10.7 μm range [2]. Using most attractive solid-state lasers (0.67-2.5 μm) as pumping sources are hindered by the presence of an intense absorption with a loss factor of 0.6 to 5 cm^{-1} or even more in short wavelength range. However, a number of articles devoted to the study of the possibility of THz generating by fs-lasers pumping ZGP crystals, including the short-wavelength absorption range, have recently appeared [3-5].

II. EXPERIMENT

THz wave generation is investigated in nonlinear ZGP crystals produced in Russia pumping by fs Ti:Sapphire laser complex Start-480M (Avesta, Russia) operating at 800 nm and 950 nm. Crystals under test were sub- or a few mm-length, well-polished, and without anti-reflective coating. Transmission spectra of the crystals were measured in the spectral range of 0.2-3.5 THz at room temperature using THz time-domain spectrometer Zomega Z-3 (Zomega, USA). Transmission spectra depends on a type of crystal growth technology. Absorption coefficient at 1 μm is found between 0.6 cm^{-1} and 5 cm^{-1} or even higher for different crystals. It was established that absorption coefficient in the central part of investigated THz range is not changing after annealing and can be approximated in the form of the following Sellmeier equations:

$$n_o^2 = 10.897 + \frac{0.60675\lambda^2}{\lambda^2 - 2570} \qquad (1)$$

$$n_e^2 = 11.043 + \frac{0.60675\lambda^2}{\lambda^2 - 2230} \qquad (2)$$

Model estimation using obtained equations shown the possibility of $oe \rightarrow e$ and $oe \rightarrow o$ types of three-wave mixing for THz wave generation. In the experiment, single-mode emissions of the pump laser system were carefully focused onto the crystal input surfaces to achieve the power density of up to 1 PW/cm^2. During the experiment, both types of three-wave mixing were realized. HDPE polarizer (Tydex, Russia) controlled polarization of the output wave. Output THz signals were measured using GC-1P Gollay cell hardware-software complex (Tydex, Russia). Within the short-wavelength part of the THz range, generated emission was additionally selected using LPF-14.3-25 filter produced by Tydex. Finally, the long-wavelength boundary of the emission was 0.04 THz. Achieved peak power of the generated THz emission pumped with 800 nm was about 1 kW; it was a little bit larger ~1.12 kW within a 950 nm pumping, that well coincides with pre-estimated results. Damage threshold of the samples is found to be higher than 1.8 TW/cm^2.

It is necessary to emphasized that used crystals are not high optical quality. Therefore, using higher quality crystals will raise THz wave generation efficiency.

Unlike widely used GaSe (low exploitation properties) and $LiNbO_3$ (cryogenic cooling and complex frequency tuning mechanics are necessary) crystals, ZGP based sources are more appropriate for fs THz application. As well as they do in ns mid-IR practice.

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