Study of the properties of $BaGa_4Se_7$ crystal in the terahertz region

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***Abstract*—The far-infrared properties of a newly grown crystal, $BaGa_4Se_7$, were investigated with a THz-TDS system. Refractive indices and absorption coefficients of this material between 0.1THz-1THz were obtained. The measured properties predicts potential application of $BaGa_4Se_7$ in THz-DFG. THz-DFG using $BaGa_4Se_7$ was analyzed theoretically and the phase-matching conditions were calculated. It seems that a promising prospect of THz application can be expected by using $BaGa_4Se_7$ as the NLO crystal.**

I. INTRODUCTION

Recently, $BaGa_4Se_7$ has been reported as a new NLO crystal exhibiting great potential in wide tunable and high-power mid-IR and far-infrared generation, owing to its possession of high NLO coefficients, high laser damage threshold, and wide transparent regions simultaneously compared with other mid-IR NLO materials[1-3] .

In this study, we carried on investigations on the dispersion and absorption properties of $BaGa_4Se_7$ in THz spectral range with a THz-TDS system. Due to some great merits of $BaGa_4Se_7$, we expected efficient emission of THz wave generated from a difference frequency process and analyzed the phase-matching conditions in THz difference frequency generation (THz-DFG).

II. RESULTS

The measurement of THz properties of $BaGa_4Se_7$ was performed using a standard THz-TDS system, as shown in figure 1. THz pulses, presenting good linear polarization, were generated by a low-temperature grown GaAs photoconductive antenna with a 50 μm slit. The excitation source was a Ti:sapphire laser with 75 fs duration and 80MHz repetition rate working at 800 nm wavelength. A ZnTe crystal was used for detection. All the experiments were carried out at 25 degree. The THz spectrum, ranging between 0.1 and 2.5 THz, could be obtained by applying a fast Fourier transform to the THz waveform. The achieved spectral resolution was 12.5GHz.

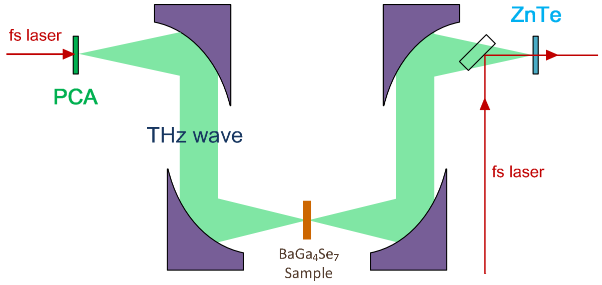

Fig.1. Schematic diagram of THz-TDS system

The transmitted THz pulse is changed by both dispersion and absorption of the samples. Thus, the refractive index and absorption coefficient can be extracted from the transmitted waveform. The refractive index n and absorption coefficient α are given as[4,5]

$$n = \frac{c\varphi}{2\pi d v} + 1 \qquad (1)$$

and

$$\alpha = \frac{2}{d}\ln\left[\frac{4n}{A(1+n)^2}\right] \qquad (2)$$

where A is the THz amplitude transmittance, and φ is the phase difference between the sample and reference pulses. The refractive indices and absorption coefficients of $BaGa_4Se_7$ were extracted from the experimental data of the transmittance waveforms with these two equations.

The measured absorption coefficients of $BaGa_4Se_7$ along three dielectric axes are shown in figure 2. The measured frequency range is cut off at approximately 1THz due to the limit of the THz-TDS system. The measured refractive indices of $BaGa_4Se_7$ along three dielectric axes are shown in figure 3, which exhibits large dispersion between 0.1THz-1THz. The value of the refractive index on x axis ranges from 3.6 to 4 between 0.1THz to 1THz, which is the smallest among the three axes. The refractive index along y axis ranges approximately from 3.9 to 4.35, which is larger than the refractive index along the z axis on the whole spectral range from 0.1THz to 1THz.

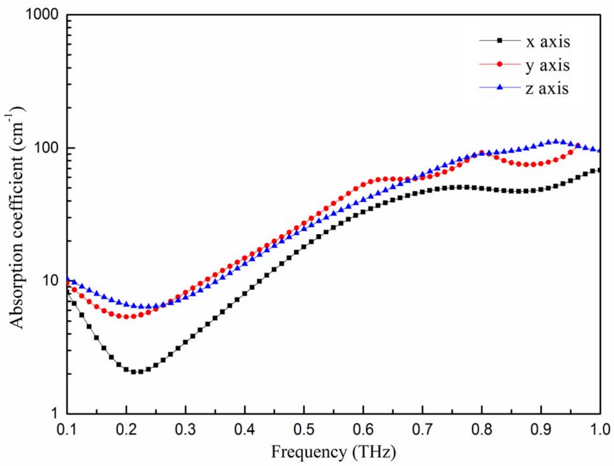

Fig.2. Absorption coefficients of $BaGa_4Se_7$ along different axes

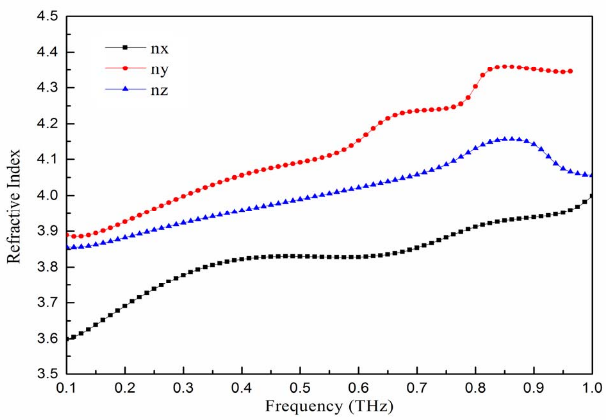

Fig.3. Refractive indices of $BaGa_4Se_7$ along different dielectric axes

According to the current research, $BaGa_4Se_7$ birefringence meet the difference frequency phase matching conditions. In addition, the measured transmittance of $BaGa_4Se_7$ during the range of 500nm to 18um is so large that the wavelengths of pump source for THz-DFG could be chosen flexibly.

We also calculated the collinear phase matching conditions of THz-DFG using $BaGa_4Se_7$ crystal. The pump source is an OPO pumped by the second harmonic of a Nd:YAG laser, working as a dual-wavelength source near 1.064μm. The refractive indices of the near-infrared pump beam were calculated with the Sellmeier coefficients provided by Zhai *et.al*[6]. The calculated relationship between the phase matching angle θ and the wavelength of generated THz wave is shown in figure 4.Two sets of phase-matching (PM) curves are calculated at both side of $\Omega = 28.8°$, which represents the optic axis with zero birefringence at 1064nm. The phase-matching conditions can be easily satisfied at both side of the optic axis for wide-tuning THz difference frequency generation.

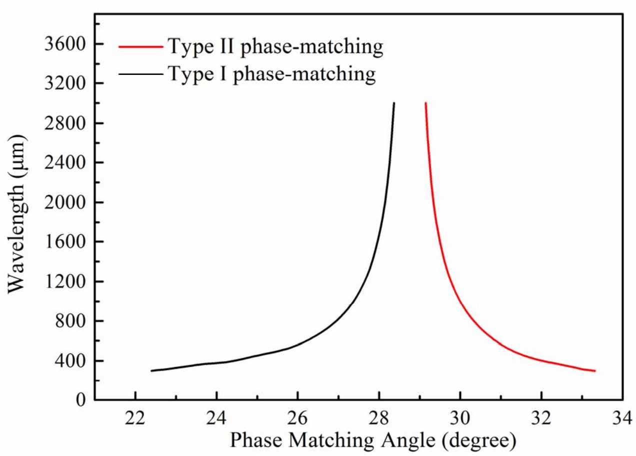

Fig.4. Calculated phase-matching curves of THz-DFG with $BaGa_4Se_7$, pumped by dual-wavelength source near 1064nm

III. SUMMARY

In general, the refractive indices and absorption coefficients of $BaGa_4Se_7$ are measured in the THz spectral range with a THz-TDS system. The measured properties predict potential applications of $BaGa_4Se_7$ in the frequency range of 0.1THz -1THz. THz-DFG with $BaGa_4Se_7$ is analyzed theoretically and the phase-matching conditions are calculated with the refractive indices given in this work. Experimental verifications of the theoretical analysis and calculations will be carried out in our future work.

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