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Dielectric properties of BiB_3O_6 crystal in the sub-THz range

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***Abstract*—We present the thorough studies of dielectric properties of BiB_3O_6 (BIBO) crystal in the sub-THz range. We observe a large birefringence $\Delta n = n_Z - n_X = 1.5$ and the values of absorption coefficients of all three axes to be less than 0.5 cm^{-1}. The difference from visible range in angle ϕ between the axes z and X is found to be more than 6°. The simulated phase-matching curves show the optimal value of the angle θ to be around 25.5°±1° for an efficient millimeter-wave generation under the pump of 1064 nm laser radiation.**

I. INTRODUCTION

THE negative biaxial crystal of bismuth triborate belongs to the non-centrosymmetric monoclinic space group $C2$. BIBO is a promising nonlinear optical material and it demonstrated as an ultraviolet radiation source, a second harmonic generator, and a parametric frequency converter of ultrashort pulses [1]. Its dielectric x-axis is parallel to the crystallophysical Y-axis (crystallographic b-axis) and the angle ϕ between the axes z and X is about 47° [2]. It was shown previously that the crystal is sufficiently transparent in the range below 2 THz and exhibits significant birefringence [3]. However, due to the small thickness of the samples, it was not possible to get a reliable measure of the absorption coefficients. In this work, samples with a thickness of 5 mm were studied, which made it possible to refine the absorption coefficient of the crystal and obtain some new data on the properties of the BIBO at terahertz frequencies.

II. RESULTS

The absorption coefficient in the sub-THz range of spectra (below 0.5 THz) was found to be less than 0.5 cm^{-1} for all axes as it shown in Figure 1. It is necessary to pay attention to the fact that linear absorption could strongly limit the nonlinear conversion efficiency [4]. For example for a 5 mm thick sample, with an absorption coefficient of 1 cm^{-1} – conversion efficiency decreases from 1 to 0.78 a.u., for absorption of 10 cm^{-1}, only 0.328 of initial efficiency remains. It is also worth noting that complex dielectric permittivity for different crystal planes is varied. Especially in the THz range, measured spectra strongly depend on the mutual orientation of the crystal plane and the incident beam polarization.

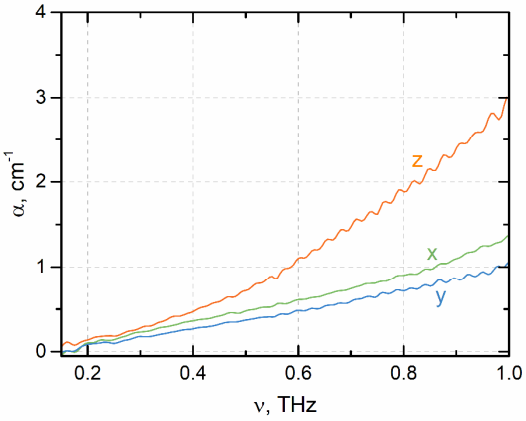

Fig. 1. Absorption coefficients measured from x- and y-cut BIBO slabs.

We have measured ϕ angle using TeraScan frequency-domain spectrometer from Toptica Photonics (linewidth is about 10 MHz). The measurements were carried out with the crossed high-quality polarizers (the contrast > 6 orders of magnitude @ 0.3 THz). It was shown that the dielectric frame xyz in the sub-THz is rotated more than 6 degrees from the visible and its dispersion was about 5 degrees (Figure 2).

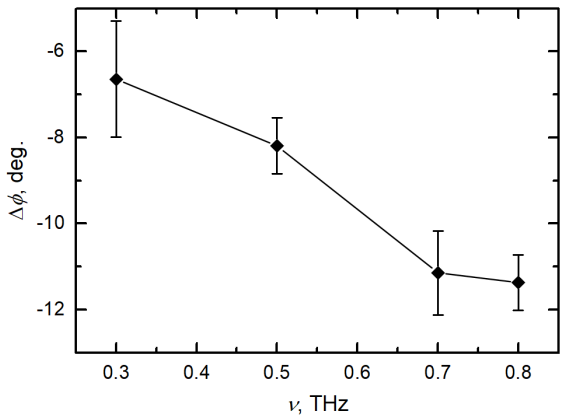

Fig. 2. The difference from visible range in angle ϕ between the axes z and X.

Taking this into account, the refractive index and Sellmeier equations were refined as it shown on a Figure 3. We obtain the same order of refractive indices as earlier [5], but more precisely at the frequencies below 0.2 THz due to increased SNR at this range for mm thick samples.

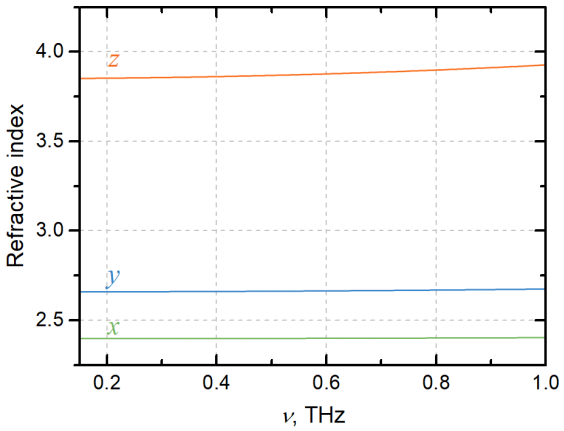

Fig. 3. Refractive index of BIBO crystal in the sub-THz range.

The phase-matching curves were simulated showing the optimal value of the angle θ to be around 25.5°±1° for a millimeter-wave generation under the pump of 1064 nm laser radiation in the *xz* principal plane.

III. SUMMARY

In comparison with well-known β-BBO, or LBO crystals BIBO shows the highest nonlinear coefficients and the lowest absorption in the THz range, which in turn positions it as a promising downconverter of high-power laser radiation. A found large dispersion of the ϕ angle should be considered when generating broadband terahertz waves. The optimal value of the angle θ found to be around 25.5°±1° for the efficient millimeter-wave generation under 1 μm laser pump.

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