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Layered Terahertz Crystal Structures for Improved Terahertz Output

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Abstract: We have improved the THz output and damage threshold of yellow organic THz generation crystals by fusing them to sapphire and using liquid crystals as index matching fluid to reduce reflective losses. © 2022 The Author(s)

1. Introduction

Organic yellow terahertz (THz) generation crystals such as BNA [1,2], MNA and NMBA [3] can be pumped with the output of Ti:sapphire laser systems due to their lower absorption cutoffs (relative to orange-red organic THz generators like DAST, DSTMS, and OH-1). Although these crystals are unique in their ability to be pumped with 800 nm light, they cannot be pumped at high fluences without melting due to small amounts of two-photon absorption and low melting points. Originally demonstrated for BNA [2], we have developed a way of improving their damage threshold by bonding these yellow crystals directly to sapphire plates. The high thermal conductivity of the sapphire guides heat away from the THz generator and enables the crystals to be pumped at higher fluences without melting. Pumping BNA, MNA, and NMBA crystals at higher fluences allows us to achieve greater THz electric fields. To increase THz output even further, we have developed a layered structure (sandwich structure) to reduce reflective losses that occur between the air and the THz generation crystal [4]. We demonstrate that a layer of liquid crystal (N-(4-methoxybenzylidene)-4-butylanilinene) can be used as an efficient THz index matching fluid (with much lower THz absorption than regular liquids) between the sapphire-fused yellow crystal and 1.5 mm of Teflon. These less drastic changes in refractive index from material to material reduces reflective losses as the IR light and THz light move through the materials.

2. Results

In our previous work, we have shown that fusing BNA crystals directly to sapphire plates increased their damage threshold by up to 10 mJ/cm^2 [2]. Bare BNA crystals can damage and melt at fluences as low as 4 mJ/cm^2, whereas some sapphire-fused BNA will increase in THz output up until fluences of 14 mJ/cm^2. We have been able to fuse yellow NLO crystals MNA and NMBA to sapphire, as well, improving their damage threshold and allowing us to make use of the full power of our Ti:sapphire laser system.

In a separate work, we showed that by layering the NLO crystal DAST with THz index matching fluid and materials such as glass and high-density polyethylene, the THz intensity improved by about 50% [4]. This was the direct result of layering materials with more similar refractive indices and THz index matching fluid to decrease the amount of reflective loss.

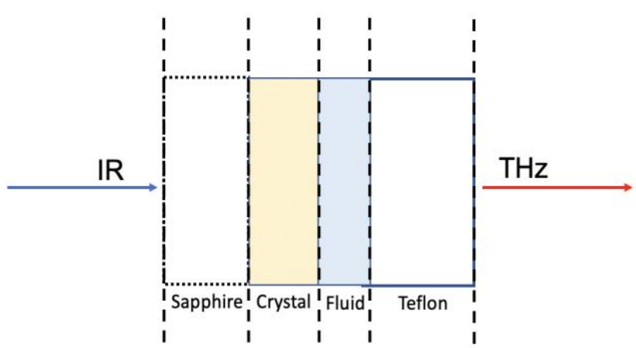

Figure 1. Diagram of new sandwich structure. A layer of liquid crystal (N-(4-methoxybenzylidene)-4-butylanilinene) is sandwiched between the sapphire-fused crystal and Teflon. Reflective losses occur at each of the dashed lines.

In an effort to improve the damage threshold and the THz output of yellow NLO crystals BNA, MNA and NMBA, we have layered each of these sapphire-fused NLO crystals with liquid crystal and Teflon. **Figure 1** shows a simple diagram of our updated damage threshold. Even though the IR and THz light are still lost through reflection, the loss is not as great as when light moves directly from air to the crystal due to the large difference in refractive index between the two mediums.

We measured the THz output of these NLO crystals when fused to sapphire and when in the sandwich structure. **Figure 2a** shows the THz generation spectra for BNA fused to sapphire (Bare Crystal), and BNA in a sandwich structure (Structure) obtained at a wavelength of 1250 nm using the output of an OPA. We see that the Fourier amplitude is higher for the structure than the sapphire-fused BNA over the 0.5 THz to 4.5 THz range. **Figure 2b** shows the THz intensity generated from the sandwich structure compared to the sapphire-fused crystal. We see that there is a 90 % improvement in the THz intensity when the BNA is in a sandwich structure.

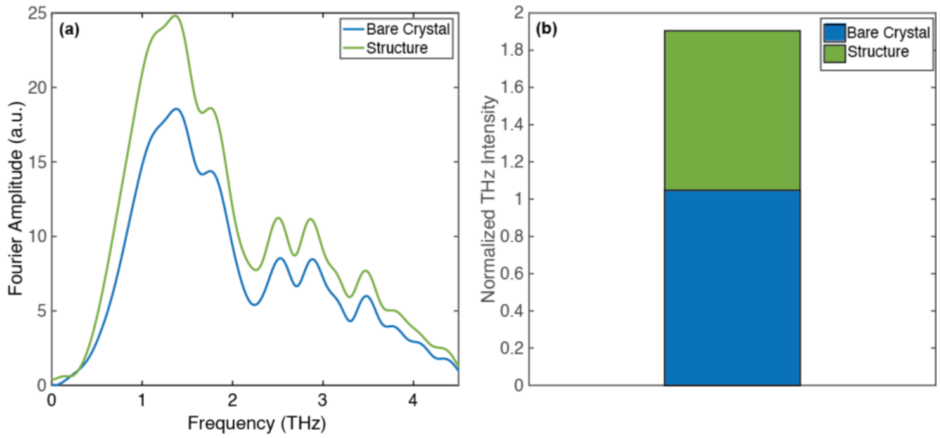

Figure 2. **(a)** The THz spectrum of a BNA crystal fused to sapphire (Bare Crystal), and a BNA crystal in a layered structure (Structure). **(b)** The normalized THz output intensity of the BNA fused to sapphire and the BNA sandwich structure.

3. Summary

We have shown that we can improve the damage threshold and THz output of yellow organic THz crystals by bonding them to sapphire and layering them with THz index matching fluids. This allows us to take advantage of the full power of Ti:sapphire laser systems while generating more THz. We will present on the similar improvements to damage threshold and THz output for the crystals MNA and NMBA.

4. References

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