# Efficient Broadband Terahertz generation in BNA Organic Crystals at Ytterbium Laser Wavelength

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***Abstract*—We investigate THz generation by optical rectification (OR) in the organic crystal BNA with respect to the crystal thickness and central wavelength of the driving pulse in the near-IR spectral range. We report on high optical- to THz conversion efficiencies around 1 µm and broad spectra exceeding 5 THz.**

## I. INTRODUCTION

Organic crystal technology is presently the most efficient and commonly used platform for intense THz generation, wherein a world record electric field strength of 83 MV/cm has been recently demonstrated [1]. DAST and DSTMS crystals are the commonly used crystals. However, the main limitation of the crystals is related to the fact that phase matching for THz generation can be achieved only at wavelengths larger than 1200 nm, where a choice of conventional lasers is rater limited. Therefore, most of the sources rely on Optical Parametric Amplifiers (OPAs), which convert the fundamental output of Ti:Sapphire (800 nm) or Ytterbium (1030 nm) lasers to longer wavelength. The efficiency of parametric amplification is limited to about 15%, as the spatial beam profile of high energy OPAs generally can be rather inhomogeneous due to Kerr non-linearity in the OPA crystals. This leads to a poor performance and eventually damage of the fragile organic crystals.

BNA is a unique commercially-available organic crystal, in which phase matching between the generated THz and driving pulses at wavelengths below 1200 nm can be achieved, allowing efficient THz generation. Using Ti:Sapphire laser as a driver, THz generation has been demonstrated with the conversion efficiency of around 0.2% and a bandwidth of up to 3 THz [2]. In the long wavelength range (1200 nm- 1550 nm), it was shown that even larger bandwidths (> 6 THz ) and a higher efficiency (0.8%) are achievable [3].

In recent years, Ytterbium lasers have become an emerging technology for the generation of high-energy femtosecond pulses at the central wavelength of 1030 nm. In this work, we study the dependence of THz generation in BNA organic crystal on pump wavelengths around 1-µm as well as on crystal thickness, and demonstrate high potential for an efficient THz generation when BNA crystals are pumped with Ytterbium lasers.

## II. RESULTS

Tunable in the near-IR spectral range, 50-fs driving pulses are generated in a commercial OPA (TOPAS, Light Conversion), operating at a repetition rate of 1 kHz and pumped by a Ti:Sapphire laser system (Fig.1). To separate the generated THz pulse from the pump, several long pass filters (LPF) are used.

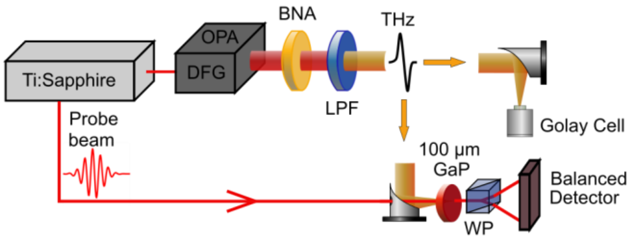

Fig 1. Schematics of the experimental setup for THz generation and detection. The BNA crystal is pumped by a wavelength tunable driving source in the near-IR, which is blocked by several long pass filters (LPF) after THz generation. The THz energy is recorded with a Golay Cell and the THz spectrum is measured with electro-optical sampling. WP – Wollaston Prism.

Generated THz radiation is detected with a Golay Cell (MTI microtech) and the spectra are recorded with an electro-optical sampling setup based on a 100 µm thick GaP crystal.

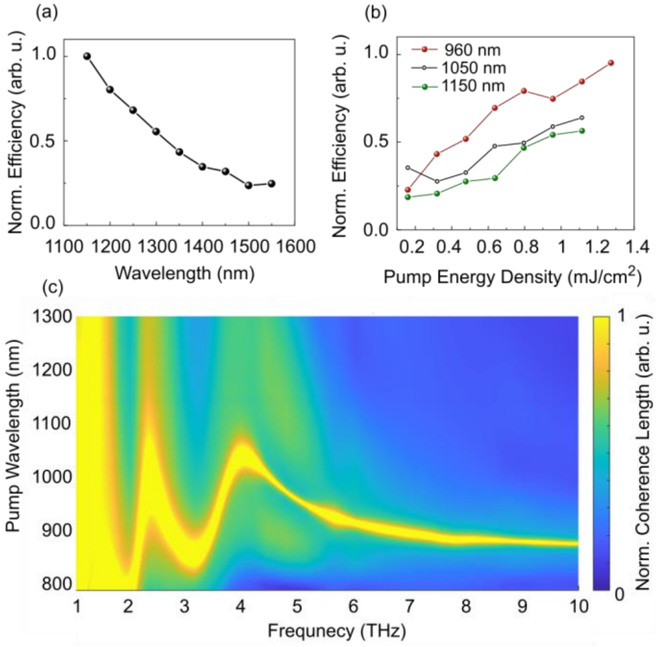

Fig 2. Normalized optical- to THz conversion efficiency in dependence of the pump wavelength (a) and pump fluence (b) , respectively, for a 550 µm thick BNA crystal. (c) Normalized coherence length with respect to the pump wavelength and generated THz frequency.

We first investigate THz generation with respect to the central wavelength of the driving pulse. In Fig.2.(a) the dependence of the normalized optical- to THz conversion efficiency on the pump wavelength is shown for a 550 µm thick BNA crystal. The energy of the driving pulses is kept constant when the central wavelength is tuned from 1160 nm – 1550 nm. A decrease in conversion efficiency with increasing wavelength of the driving pulses can be observed. The same tendency persists for even shorter pump wavelengths, as depicted in Fig.2.(b) where the dependence of THz generation efficiency on pump energy density is shown. The pump beam diameter was set to be 2 mm at FWHM level. Fig.2.(b) reveals that we operate in the linear regime wherein saturation of the conversion efficiency is not observed. The highest efficiencies are achieved for the shortest pump wavelength of 960 nm. The experimental results are affirmed by the simulations presented in Fig.2.(c), which shows the coherence length with respect to the pump wavelength and generated THz spectrum. It confirms a broad spectrum and maximum coherence length for driving pulses in the spectral range around 1 µm. For even shorter pump wavelengths, the coherence length decreases again which results in a reduced THz conversion efficiency and narrower THz spectrum.

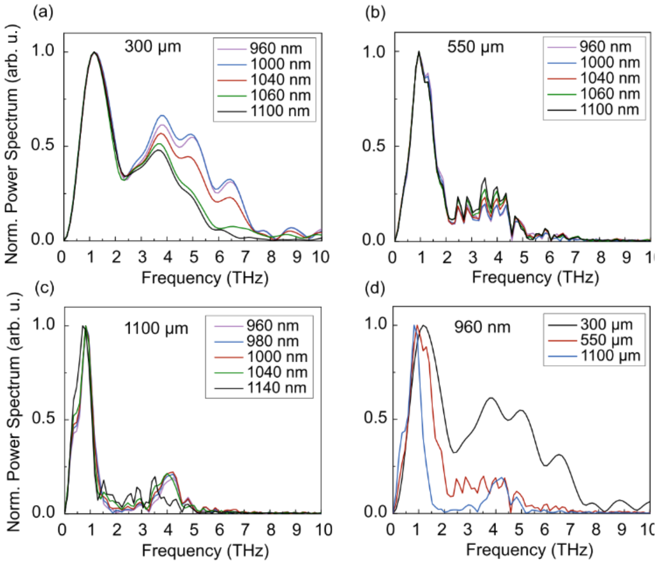

Fig 3. Normalized power spectra for crystals with different thicknesses pumped with driving sources of different wavelengths (see legend). (a) Crystal thickness of 300 µm, (b) 550 µm and (c) 1100 µm. (d) Comparison of the spectral content for a constant pump wavelength of 960 nm for different crystal thicknesses. For a crystal thickness of more than 550 µm , the THz spectrum becomes almost wavelength independent

This statement is further supported when the generated THz spectrum is investigated for different crystal thicknesses and pump wavelengths, as shown in Fig.3. THz spectra generated in a thin BNA crystal of 300 µm exhibit a pump wavelength dependent spectral width and the broadest spectrum reaching 7 THz for short wavelength driving pulses. In contrast, no significant spectral changes of the THz radiation can be detected when the pulse is generated in a BNA crystal of 550 µm or thicker. Nevertheless, spectral components extending above 5 THz can be recorder for all crystals under investigation when they are pumped around 1 µm.

## III. SUMMARY

In conclusion, we investigate THz generation in the organic crystal BNA for different crystal thicknesses and pump wavelengths with respect to the THz conversion efficiency as well as the generated spectral content. Highest optical to THz conversion efficiencies along with a broad THz spectrum (reaching 7 THz) can be found for driving pulses centered at around 1 µm, as demonstrated experimentally and theoretically. This paves the way for applications of the Ytterbium lasers for efficient THz generation in BNA organic crystals.

## REFERENCES

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