Comparative simulation study of ZnTe heating effects in focused THz radiation generation

Hungyen Lin[a], Bernd M. Fischer[a,b] and Derek Abbott[a]
[a] Centre for Biomedical Engineering and School of Electrical and Electronic Engineering, The University of Adelaide, SA 5005, Australia
[b] Institut Franco-Allemand de Recherches de Saint Louis, 68301 Saint Louis Cedex, France

***Abstract*—With prolonged intense exposure of an optical beam on the ZnTe crystal, the problem of crystal photodamage becomes increasingly relevant. In reducing the risk of damage, practically this has meant a decrease in applied optical power density. The heating effects with a reduced power density are investigated.**

I. Introduction And Background

NONLINEAR crystals such as ZnTe are widely used as THz emitters in THz-TDS. The IR pump beam (in our system from a Spectra-Physics Mai Tai) has typically a beam waist of approximately 1 mm, therefore some degree of optical focusing is necessary. There have been studies on THz emission with varying optical spot size [1, 2]. The problem of photodamage becomes increasingly relevant when high optical power density impinges on the crystal. The damage threshold for ZnTe is quoted as 100 GW/cm^2 in [2] but in our experiments, damage is observed with a lower power density especially after prolonged use. Photodamage on the crystal is visible as a black mark on the crystal surface with the naked eye or otherwise as a drop in the generated THz radiation intensity and hence the signal-to-noise ratio. This is important to applications such as THz near-field studies using electro-optical crystals such as ZnTe where the resolution is dependent on the IR spot size [2, 3]. Extensive review on THz near-field imaging techniques can be found in [4]. In reducing the possibility of photodamage, this has meant practical decrease in optical power density, i.e. increase spot size and decrease pump power. The work here therefore attempts to simulate and compare the heating effects over time for a ZnTe crystal using a recently published THz heating model [5].

II. Simulation

The heating model applies Kirchhoff's heat equation to model the influence of a THz beam on a sample. It is a generalized model and can be easily applied to any dielectric material by changing the thermal conductivity and optical constants. Here we apply the model to quantitatively differentiate the temperature difference from high and low optical pump power density on a ZnTe crystal with the physical parameters in [6, 7]. The model estimates the worst case scenario temperature rise, which occurs at long time durations when equilibrium is reached. This therefore is applicable to a typical knife edge measurement or an image acquisition that may typically span from 12 hours to greater. High power density is conducted with 200 mW averaged IR power centered at 800 nm, and focused with a 20 mm focal length lens to give a beam waist of 5 µm. Low power density on the

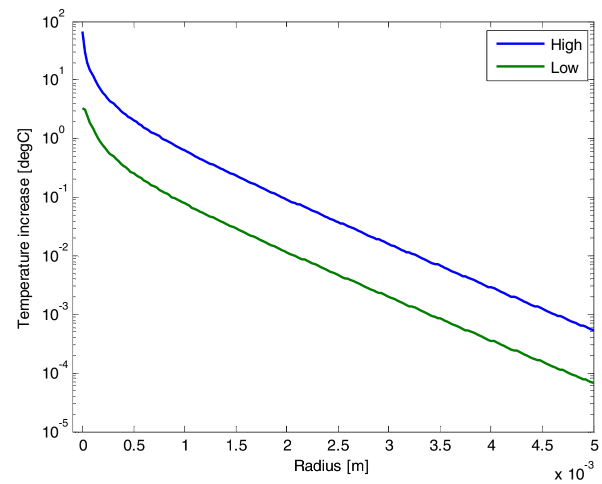

Figure 1 - ZnTe temperature increase on the crystal surface as a function of sample radius for high and low pump power density respectively

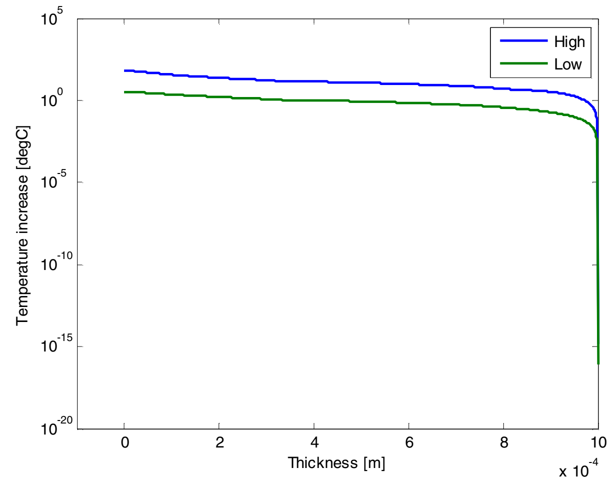

Figure 2 - ZnTe temperature increase on centre of the beam as a function of sample thickness for high and low pump power density respectively

other hand is conducted with 25 mW IR power also centered at 800 nm and focused with a ten times longer focal length to give an approximately 10 times larger beam waist of 50 µm. The resulting power density is thus 800 times smaller than the former. The optical beam is incident on a 1 mm thick 5 mm radius <110> ZnTe crystal from Zomega Terahertz Corporation. On the surface of the crystal, the temperature changes as a function of the radial distance from the centre of the beam as shown in Figure 1. Figure 2 shows that at the centre of the beam, the temperature changes as a function of

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crystal thickness. It can be observed that maximal heating occurs on the crystal surface. The average temperature increase on the crystal surface over time at the center of the beam for the high power density is 67°C as opposed to 3°C for the low power density.

Figures 3 and 4 compare contour plots for high and power densities respectively. The heating is large for small beam waist while the penetration depth is comparatively lower, this is consistent with water heating in [5]. The work also aids in explaining the burning of the crystal surface.

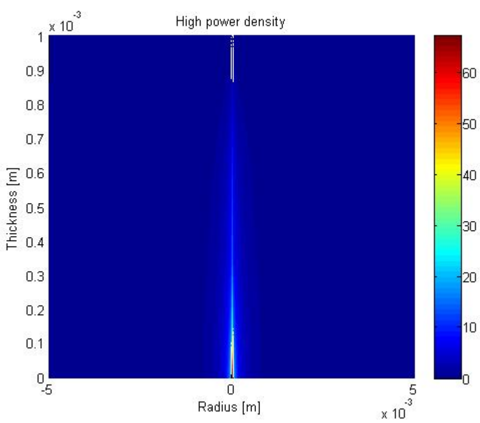

Figure 3 - Contour plot of penetration depth for high power density

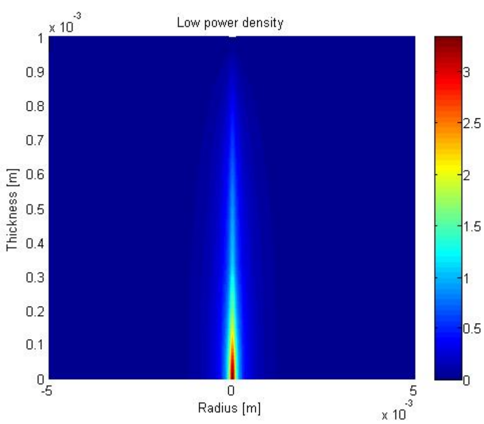

Figure 4 - Contour plot of penetration depth for low power density

III. CONCLUSION

We have applied a recently published water heating model to model the prolonged heating effects of an optical beam on a ZnTe crystal for THz radiation generation. The simulation result quantifies the worst case scenario average temperature rise of 67°C for high pump power density as opposed to 3°C for the low power density. Maximum heating is observed to occur on the crystal surface and the heating is large for a small beam waist with a comparative lower penetration depth than lower power density.

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