Proceedings Paper:

Kidd, C., Rosamond, M.C., Gill, T.B. et al. (4 more authors) (2023) Improved Large Area Photoconductive Antenna Design for High Field THz Generation. In: 2023 48th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz). 48th International Conference on Infrared, Millimeter and Terahertz Waves (IRMMW-THz), 17-22 Sep 2023, Montreal, Canada. IEEE . ISBN 979-8-3503-3661-0

https://doi.org/10.1109/IRMMW-THz57677.2023.10299215

Improved Large Area Photoconductive Antenna Design for High Field THz Generation

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***Abstract*—An improved large area design has been developed for LT-GaAs photoconductive antenna arrays fabricated on optically transparent sapphire substrates to generate high field terahertz (THz) radiation. By optimising a design to support larger biasing fields, a 1.5 times improvement in signal strength resulting in fields of up to ~200 kV/cm is reported.**

I. Introduction

Owing to the low energy of THz frequency photons, they are desirable for a variety of applications, including stimulating elementary excitation in many materials [1]. The push towards high THz electric field strengths is one that has been driven by the potential applications they provide. High field strengths are essential for investigating non-linear characteristics of materials, providing information on non-linear transport mechanisms [2]; and interactions and control of condensed matter systems [3-5].

Large area photoconductive arrays (LAPCAs) are capable of producing high THz electric fields [6,7], but are yet to reach the ~MV/cm fields that can be generated by optical rectification in nonlinear crystals such as lithium niobate. However, advantages over optical rectification such as high conversion efficiency and electrical field control motivates further improvements to LAPCAs. Bacon et.al [8] have demonstrated the benefits of fabricating Low-Temperature grown Gallium Arsenide (LT-GaAs) PCAs on sapphire substrates. By replacing the semi-insulating-GaAs substrate with sapphire, the parasitic current channel present in the SI-GaAs substrate is removed, leading to a reduction in joule heating and higher breakdown fields, showing up to 8 times the signal that was previously achievable for the same designs on SI-GaAs. Further benefits include through-substrate illumination and the removal of the requirement to mask alternate gaps in the array. Work presented in [9] has shown that using smaller gap sizes on smaller area devices supports larger biasing fields, consequently producing larger THz signals achieved from similar active areas. Here, we show how this and further fabrication improvements can be translated to LAPCA designs that produce field strengths of up to ~200 kV/cm.

II. Experiment

An 18 x 18 mm LT-GaAs on sapphire LAPCA was fabricated with 50 µm wide gaps. To optically pump the device, a 40 fs amplified Titanium:Sapphire system with an 800 nm central wavelength and 1 kHz repetition rate was used. The emitter was placed in a focus-through geometry and the signal detected by electro-optic sampling, using a 150-µm-thick Gallium Phosphide crystal. To characterise the device, the optical saturation point was first found and then the biasing field increased. The optical pump power used was 220 µJ.

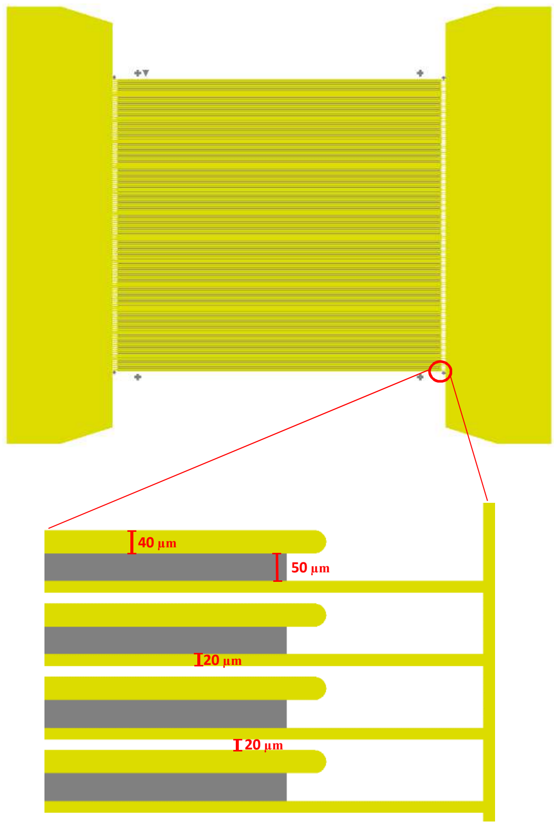

Figure 1. The diagram shows the LAPCA design, taken from the CAD. The close up shows the device dimensions.

III. Results

The results in figure 2 shows that the 50 µm gap device has a near linear increase with applied bias. The improved design allows for the applied bias to be increased to 3.5 V/µm across the gap, resulting in THz field strengths increasing to ~200 kV/cm which is a ~1.5 times improvement on the maximum field strength reported in [6] of a similar size large 200 µm device.

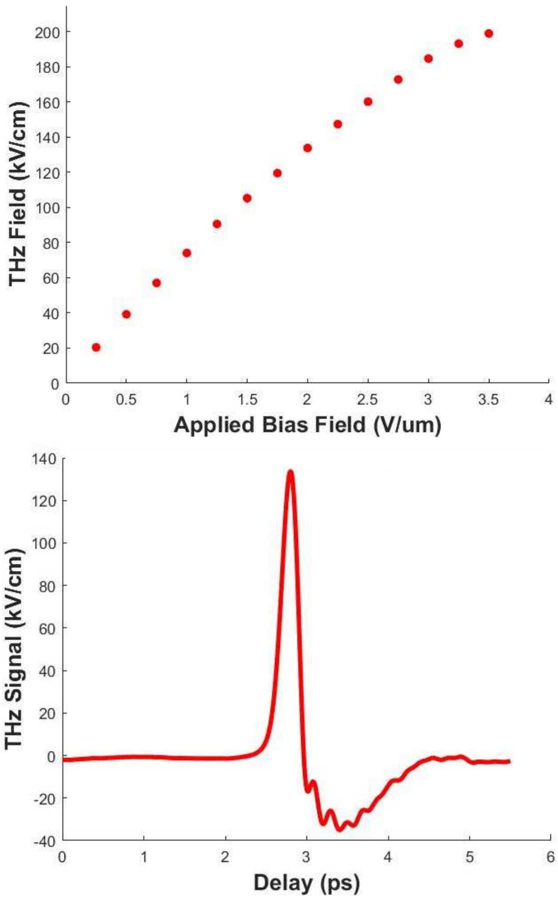

Figure 2. Response of the LAPCA when optically excited with 220 uJ pulses. (Upper) Variation in peak THz field with applied bias, and (lower) THz electric field with time at a bias of 2 V/µm.

Acknowledgements

This work was supported by funding from EPRSC U.K (grants EP/P021859/1 and EP/W028921/1)

Data Availability

The data presented with this paper is openly available from:
https://doi.org/10.5281/zenodo.8096668

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