Low Optical Power-Driven THz Modulator

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The THz domain is an intense field of research. Nowadays, we notice that many sources (frequency multiplication, QCLs, UTC-PD) and detectors [1] (bolometers, HEMTs, photoconductive antennas) exist. However, only a few modulators are available with low energy consumption and a weak footprint. In this perspective previous works [2] demonstrated the possibility to optically modulate a THz beam running through an InAs slab by photogenerating free carriers. In the continuity of this work, we seek to reduce the required optical power by now operating at 1550 nm in order to benefit from the fiber telecom technology, to have a better control on the beam size and to reach high power densities to obtain very significant effects.

We present here the results of a numerical model implemented on MATLAB in order to try to predict the experiment and to anticipate the different key parameters. Indeed, we show that by reducing the size of the THz beam compared to the initial config. [2] we can then use smaller IR beams to cover the THz beam. These small IR beams allow us to benefit from very high optical densities and we can thus generate much more free carriers in the semiconductor by optical absorption effect. The presence of these carriers allows to reach a quasi-metallic effect of the slab in the desired THz range. We can then modulate the transmission of the THz wave passing through the modulator by switching it between a non-optically-pumped state (dielectric which transmit the THz wave) and an optically-pumped state (metal which reflects the THz).

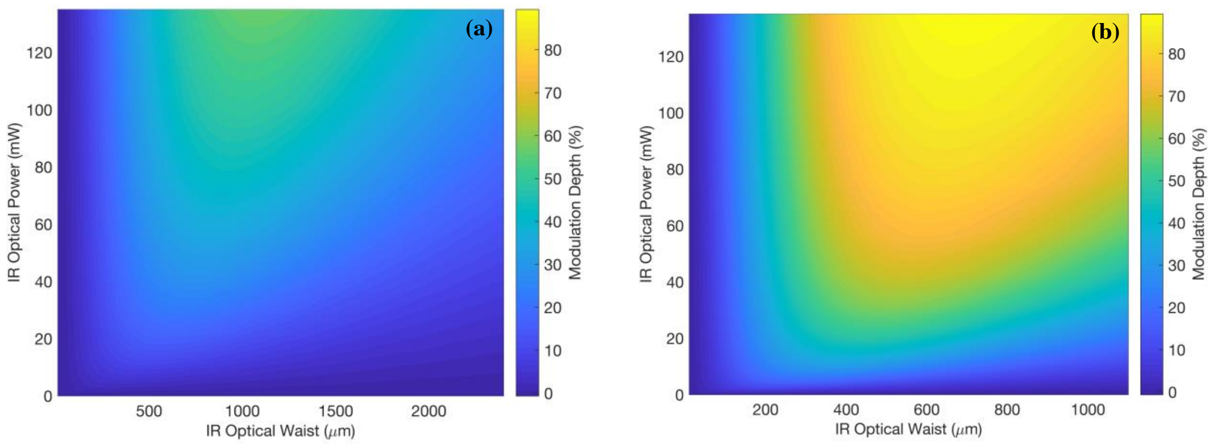

Fig. 1: 2D map of the THz transmission modulation of a 5.5 µm-thick InAs slab for different IR optical waists and IR optical powers for two configurations; (a) THz waist = 1.2 mm and (b) THz waist = 550 µm

As shown in Fig. 1, for a small IR waist, the overlap between the THz and the IR beams is low and therefore the modulation efficiency degrades regardless of IR optical power. At larger IR waist, a higher IR power is required to maintain some modulation efficiency as it depends directly on optical intensity (evolving quadratically with waist). We can see that according to Fig. 1, the initial config. (a) only allows a modulation of the order of 50% (when $w_{opt} \approx w_{THz}$ and this in the desired IR power range). We can see that when we decrease the THz waist in config. (b), we can reach up to 90% of the modulation depth of the transmission.

References:

[1] E. Herrmann et *al.* J. Appl. Phys. 128, 140903 (2020).

[2] E. Alvear et *al.* Appl. Phys. Lett. 117, 111101 (2020).

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