Integrated Horn Antenna for THz Photomixing in LTG-GaAs

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***Abstract*—The investigation of THz generation using low-temperature-grown GaAs (LTG-GaAs) photoconductors integrated with horn antennas is reported. Results obtained using a photomixing experiment are presented. A maximum generated power of 1 µW at 780 GHz was achieved for an optical power of 2×80 mW and a photocurrent of 1 mA.**

I. Introduction And Background

SINCE the first photomixing experiment using LTG-GaAs at THz frequencies by Brown and co-workers [1], many authors have studied the photoconductor but few studies have been devoted to the antenna. Three kinds of antennas are generally used for this application: spiral, log-periodic and dipole antenna. They are all planar antennas fabricated at the semiconductor/air interface. The THz waves are principally radiated in the semiconductor substrate and it is necessary to use a high permittivity silicon lens placed at the backside of the substrate to extract and collimate the radiation. This lens presents several drawbacks: the adjustment is very critical, it is difficult to bond it without parasitic reflections and there is no broadband anti-reflection coating. We have designed a new antenna for THz: the transverse electromagnetic horn antenna (TEM-HA) [2]. In a first step this 3D structure was integrated with a coplanar transmission line and measured with a time-domain pulsed experiment [3]. The results showed that it is a non-dispersive and large bandwidth antenna with high efficiency. Here we present the first results obtained with a TEM-HA integrated with an interdigitated LTG-GaAs photoconductor in a frequency-domain photomixing experiment.

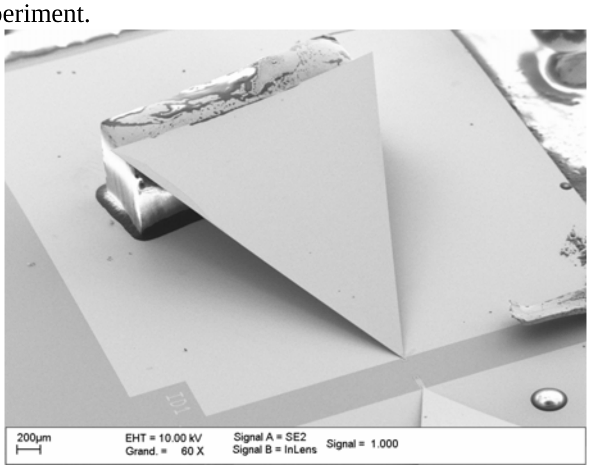

Figure 1: LTG-GaAs photoconductor integrated with a TEM-HA.

II. Device Fabrication

The photoconductor is constituted by five 15 µm-long, 0.5 µm-width Ti/Au fingers separated from each other by 1.8 µm-width gaps. The fingers were patterned by e-beam lithography on a 2 µm-thick LTG-GaAs layer grown by gas-source molecular beam epitaxy at about 200°C. A 100 nm-thick silicon nitride layer was also deposited on the photoconductor as an antireflection and surface passivation coating. The photoconductor is monolithically integrated with the TEM-HA which is constituted by two electrodes: a ground plane and a metallic triangle. The latter is fabricated by patterning on a sacrificial layer a 4 µm-thick gold film with a triangular shape using sputtering, optical lithography and chemical etching. The antenna is then released by etching the sacrificial layer. It is lifted by means of a micromanipulator to an angle of 15° and brazed on a copper cladded PTFE cuboid (figure 1). The photoconductor is biased thanks to a 20 µm-diameter gold wire brazed on the cuboid. The dimensions of the isosceles triangular sheet (length = 3 mm, base = 2.6 mm) have been chosen in order to radiate efficiently from about 100 GHz to at least 1 THz [2].

III. Experimental Set-up

The experimental set-up of the photomixing experiment is shown figure 2. The two optical beams were generated by two 780 nm tunable extended-cavity laser diodes (ECLD), spatially overlapped and amplified by a tapered semiconductor optical amplifier. The output is focused on the 10×15 µm^2 LTG-GaAs photoconductor. The THz waves were radiated directly in the air by the TEM-HA and collected by an off-axis parabolic mirror and detected by a liquid-helium cooled composite silicon bolometer.

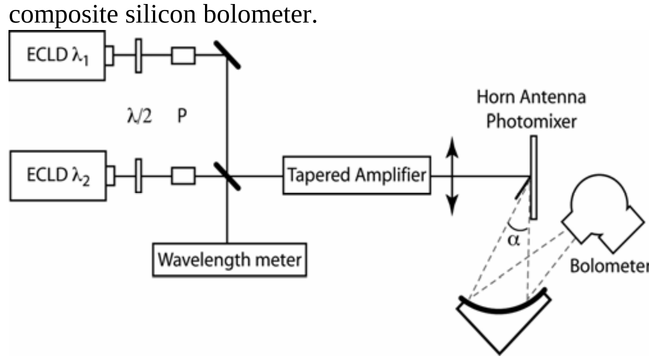

Figure 2: Experimental configuration of the photomixing set-up.

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IV. Results

Figure 2 indicates the detected power (assuming a responsivity of 12 kV/W given by the manufacturer) for an optical power of 2×80 mW and a bias voltage of 15 V. Two series of data are presented which correspond to two values of the collection angle α. In the first configuration, the parabolic mirror was placed to collect the radiation with a maximum angle above the ground plane of α = 38°. In the second configuration, a wider angle was collected (57°) and a 100 mm-focal length PTFE lens was placed in front of the bolometer. As expected, in the second configuration it was possible to collect more power, in particular at frequencies lower than 400 GHz.

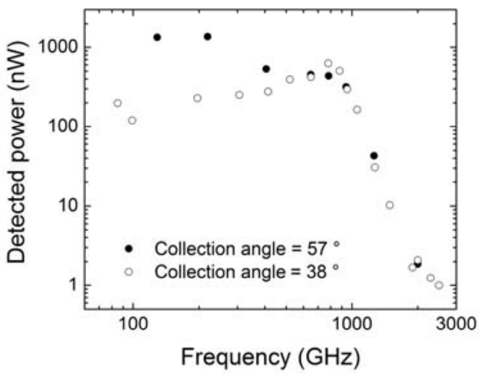

Figure 2: Detected power versus frequency (15 V, 0.7 mA).

Figure 3 shows the detected power versus the photocurrent. This curve was obtained at 780 GHz by scanning the bias voltage between 0 and 19 V. It shows that below 0.6 mA, the THz power increase almost quadratically with the photocurrent. Then a saturation phenomenon occurs progressively. The maximum measured power at 19 V was about 1 µW at a photocurrent of 1 mA. This value is comparable to the best values reported for photomixers integrated with spiral antennas and a silicon substrate lens. We can conclude that the TEM-HA has almost the same efficiency.

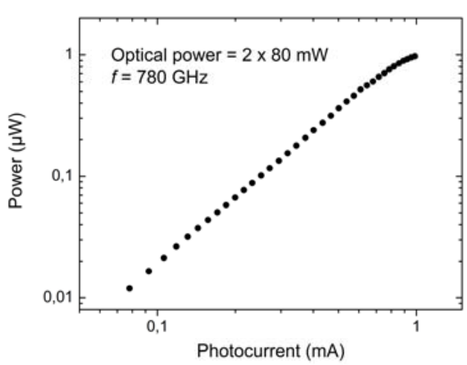

Figure 3: Detected power versus photocurrent.

In order to characterize the polarization of the radiated beam, a grid polarizer was placed between the parabolic mirror and the bolometer. Figure 4 shows the result of a complete rotation of the grid on the detected THz power. The curve is very close to the Malus law. We can deduce that the beam is linearly polarized perpendicular to the ground plane with an extinction ratio of 1.5:100. It is an advantage compared to the spiral or log-periodic antenna for which the polarization is circular, elliptic or linear but not with the same direction at any frequency.

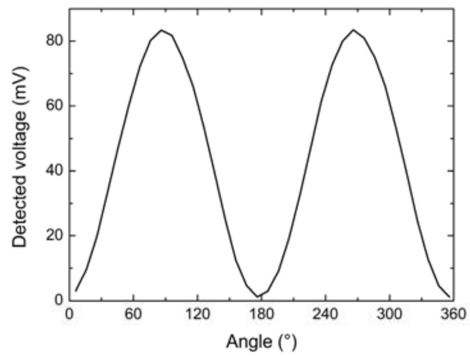

Figure 4: Detected voltage versus the angle of the polarizing grid at 870 GHz.

V. Conclusion

We have demonstrated the fabrication and the characterization of a new large bandwidth THz antenna: the TEM horn antenna. It is an integrated 3D structure that has several advantages compared to the standard THz antennas: high efficiency, compactness (no silicon lens), lightness and linear polarization. It is integrated here with a standard interdigitated LTG-GaAs photoconductor. We have demonstrated photomixing up to 2 THz with a maximum output power of 1 µW at 780 GHz.

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