

The study of photocurrent and power of THz radiation photoconductive antennas based on GaAs dependence on geometry of focusing and radiation parameters of femtosecond laser

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Abstract The results of experimental study of the effect of the focal spot location and the power density of radiation of femtosecond (FS) laser within the electrode gap of LT-GaAs photoconductive antenna on the photocurrent and average THz emission power are presented.

1. Introduction

The recent advent of high-power pulsed lasers, in particular, those with femtosecond pulse duration, opened the way to develop compact generators and detectors of broadband terahertz (THz) radiation, based on the interaction of laser radiation with matter [1]. Photoconductive antennas[2] or nonlinear optical crystals[3] are commonly used as active conversion elements. From the viewpoint of the efficiency of the optical–terahertz conversion, the former case appears more preferable [4, 5]. Currently, gallium arsenide grown by molecular-beam epitaxy at lower temperatures $T < 300^\circ\text{C}$ is the most actively studied material for photoconductive antennas. The best structures based on “low-temperature” gallium arsenide (LT-GaAs) exhibit subpicosecond lifetimes of nonequilibrium carriers, relatively good mobilities ($\sim 10^3 \text{ cm}^2/\text{V}\cdot\text{s}$), high dark resistivities and breakdown fields ($\sim 10^5 \text{ V/cm}$) [6, 7].

To achieve the best performance characteristics of photoconductive antennas it is important to provide the optimal focusing of the pump FS laser radiation into the area between antenna electrodes. Previously we reported the temporal and spectral characteristics of various types of photoconductive antennas [8,9]. Here we report results of the effect of laser focusing conditions on the THz emission power of several photoconductive antennas.

2. Experimental setup

The scheme of the experimental setup is shown in figure 1. The experimental setup consists of a femtosecond laser (pulse duration 100 fs, pulse repetition rate 80 MHz). The average laser power focused to the antenna did not exceed 100 mW. The setup also included visible and THz focusing optics, pyroelectric detector and oscilloscope. The antennas studied were commercial ones of Zomega company as well as those manufactured by LETI and in microelectronics technology center of MEPhI. All antennas have the same



electrode geometry shown in Figure 2. The gap between electrodes was $200\ \mu\text{m}$. The focusing optics allowed to var the focus spot diameter as well as the spot position within the electrode gap.

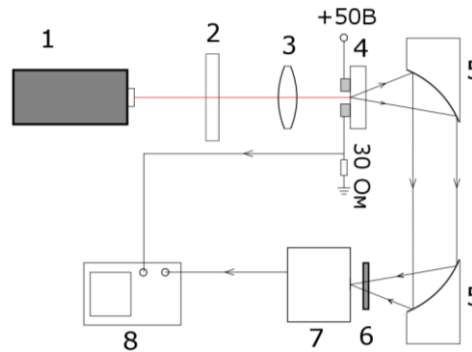


Figure 1. Experimental setup: 1- femtosecond laser, 2 – attenuator, 3 – spherical / cylindrical lens, 4 – photoconductive antenna, 5 – off-axis parabolic mirrors, 6 – THz filter, 7 – THz detector (pyroelectric), 8 – oscilloscope Tektronix TDS 2012B.

3. Experimental results

Firstly, it was studied the effect of the laser focus spot position within the electrode gap. The spot diameter was set to $25\ \mu\text{m}$ and the dependence of the photocurrent and THz output was measured as a function of the spot shift from the center of a gap. The results are shown in Fig. 3 and Fig4. The maximum photocurrent was observed when the focus spot of FS laser radiation was placed exactly in the middle of the inter-electrode gap. On the contrary the maximum average power of THz radiation occurs when the spot is shifted by about $30\ \mu\text{m}$ in the direction of the positive electrode of the photoconductive antenna.

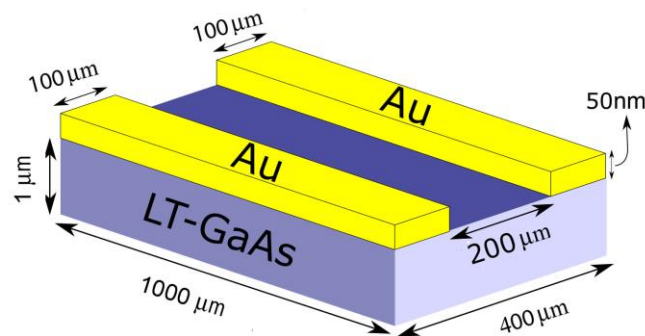


Figure 2. Geometry of the photoconductive antennas.

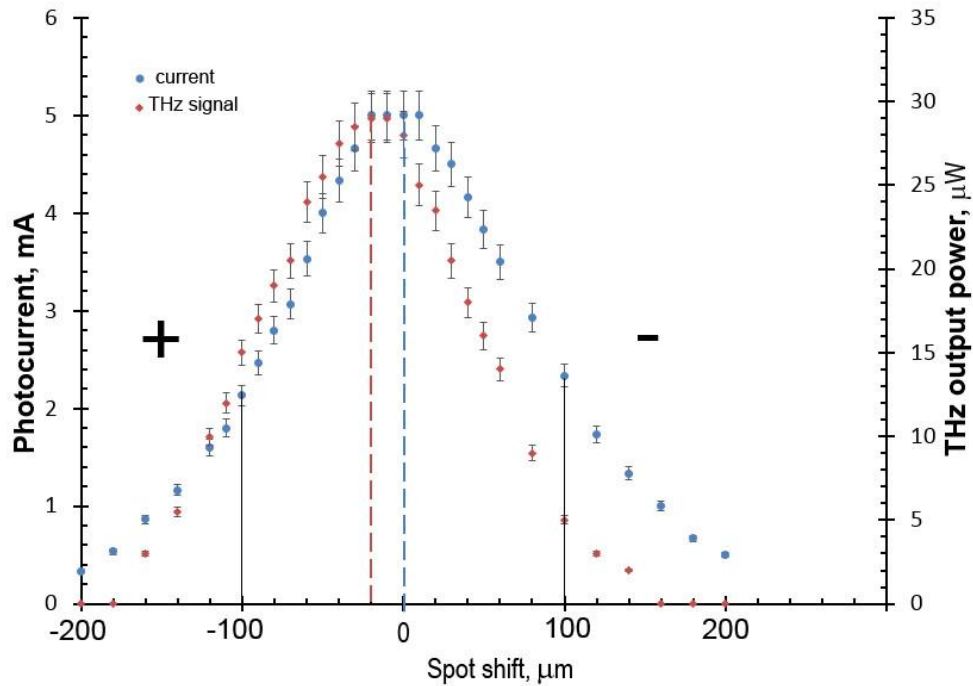


Figure 3. The dependencies of photocurrent and output THz power on the spot shift from the center of inter-electrode gap. Antenna Zomega, spot diameter 25 μm , average FS laser power 10 mW

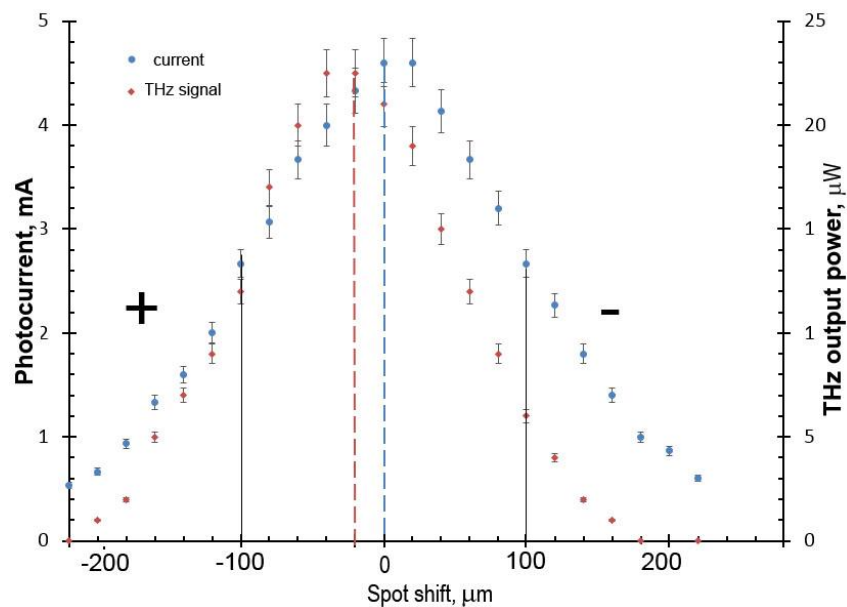


Figure 4. The dependencies of photocurrent and output THz power on the spot shift from the center of inter-electrode gap. F=Antenna Zomega, spot diameter 25 μm , average FS laser power 7 mW

The output THz average power for different focus spot diameters was measured while total excitation FS laser power was kept constant. The results are shown in Fig.5. The tendency is clearly seen of increasing THz power with more sharp focusing.

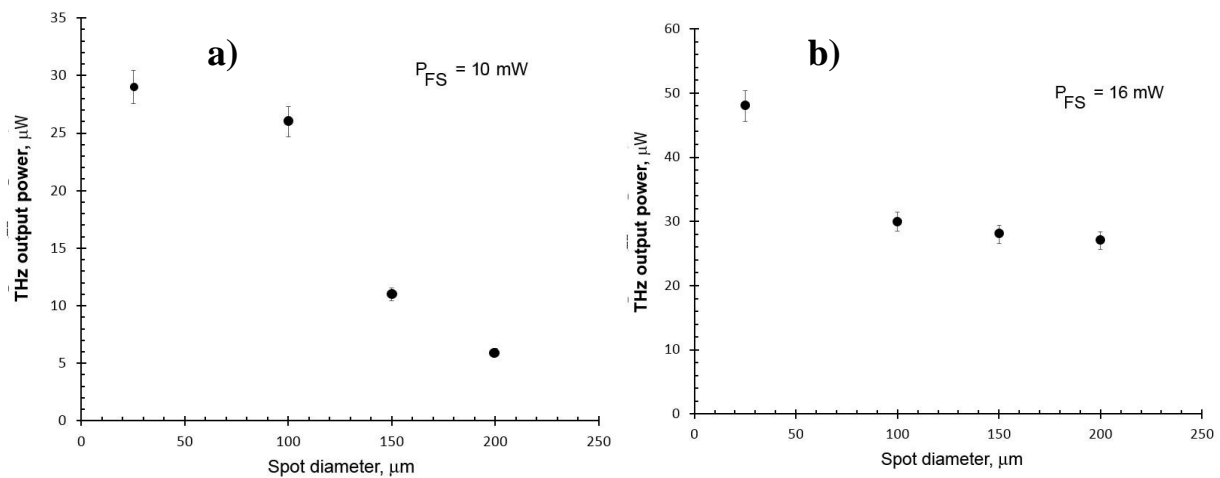


Figure 5. Output THz average power as a function of the focus spot diameter at excitation FS power of 10 mW (a) and 16 mW (b)..

So the increase of the excitation power density resulting in increasing density of excited photocarriers (at the same total FS laser power) allows to enhance the effectiveness of the antenna (Fig.6). For efficient THz generation is necessary to create a sufficient density of photocarrier, which provides power density of FS radiation on the surface of the photoconductive antenna $\sim 10^9 \text{ W/cm}^2$

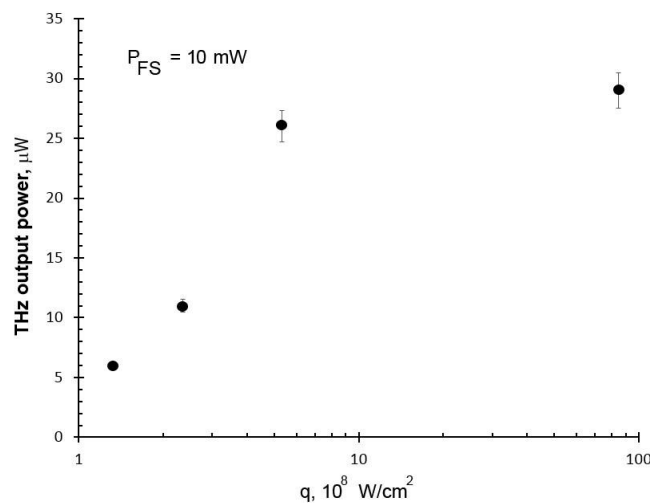


Figure 6. Output THz average power as a function of the excitation FS power density (excitation FS power = 10 mW).

It was found also that the average power of THz radiation are about three times higher in the case when the plane of polarization of the FS radiation is parallel to the electrodes, relative to the case when FS radiation is polarized normally to the electrodes.

4. Conclusions

It is shown that the maximum THz power of the photoconductive antenna is achieved when the focus spot of the exciting FS laser is shifted toward the anode electrode. The sharp focusing of the FS laser beam allows to improve the antenna output without increasing total FS power. Polarization of the exciting FS laser radiation with respect to electrodes is also of importance, and correct its selection can increase the THz output of the antenna.

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