Ultrabroadband THz emission with controlled wave-front from LTG GaAs large area interdigitated photoconductive antenna

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***Abstract*—We demonstrate THz pulses emitted by LTG GaAs large area interdigitated photoconductive antennas with frequency components from 0.3 to 20 THz. The THz radiation is characterized with a 20-µm thick ZnTe crystal and the dynamic range reaches 60 dB. Under an original optical excitation scheme, the emitted THz pulses show frequency-independent spherical wave front, which provides focusing of the THz beam close to the diffraction limit.**

I. INTRODUCTION

Photoconductive antennas driven by femtosecond optical pulses are powerful coherent sources of THz pulses operating at room temperature and widely used for THz spectroscopy and imaging. Among different designs of photoconductive antennas (PA), large-area interdigitated PAs are very attractive since they combine large area and low bias providing high-intensity THz emission with high signal-to-noise ratio [1-2]. Large-area interdigitated PAs are usually illuminated by plane wave-front optical beam or low divergent optical beam. In this excitation configuration, the THz emitted radiation pattern strongly depends on the frequency with high frequencies more directive than low ones. This frequency-dependent spatial emission profile can be problematic in broadband regime since diffraction-limit focusing of the emitted THz pulses becomes hardily achievable.

II. RESULTS

Here, we investigate ultra-broadband emission from low-temperature grown (LTG) GaAs interdigitated PAs excited by 15 fs optical pulses. The subpicosecond carrier lifetime in LTG-GaAs materials [3] is well known to improve the spectral bandwidth of the emitted THz electric field. The photoconductive devices consist of interdigitated electrode metal-semiconductor-metal structures of 500 µmx500 µm surface, with masked every second period of the metal-semiconductor-metal finger structure, ensuring the generation of only in-phase radiation. The THz radiation emitted by the antenna is collected by a first parabolic mirror and focused using a second parabolic mirror on sample under test or on electro-optic crystal for detection. The THz radiation emitted by the antenna is coherently detected using conventional electro-optic detection techniques.

Figure 1a) shows the temporal waveform emitted by the LTG GaAs interdigitated PA illuminated with 15 fs optical pulses with pulse energy of 4 nJ. The temporal waveform shows a main subpicosecond transient of 118 fs FWHM, followed by negative peak with relative amplitude of 40 % attributed to the sub-picosecond carrier lifetime in the LTG GaAs layer. The amplitude spectra, calculated by Fast-Fourier transform and shown in Fig.1b), is centered at 3 THz and extends up to 20 THz with a dynamic range of 60 dB.

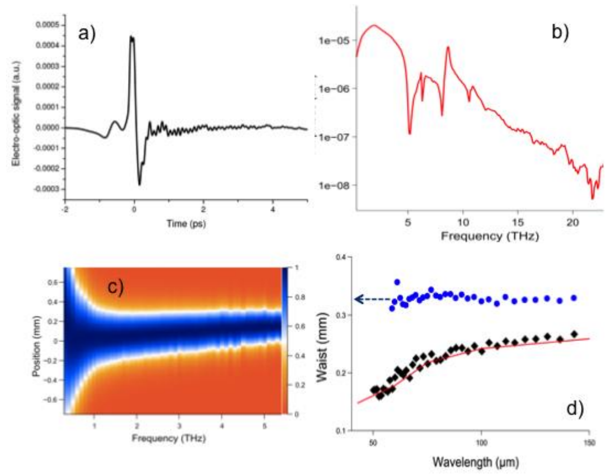

Fig. 1. a) Temporal waveform emitted by the LTG GaAs interdigitated PA and the corresponding amplitude spectra b). c) Contour plot of the spatial profile of the THz focused beam. d) Waist of the focused beam, measured by knife-edge techniques, as a function of the THz wavelength, under plane wave–front (blue dots) and spherical wave-front (black dots) optical excitation.

Under plane wave-front illumination, the emission diagram of THz radiation emitted by interdigitated PAs follows the diffraction law: the divergence angle of the main lobe scales with λ/L, (where L is one dimension of the antenna). As a result, focusing the THz radiation using lens or parabolic mirrors forms the geometrical image of the antenna and its spatial extension is much higher than the diffraction-limit at high frequencies (Fig. 1d blue dots). This limitation can be overcome by illuminating interdigitated PAs with spherical wave-front optical pulses to construct THz emission with a frequency-independent radiation pattern. We have developed the experimental configuration based on spherical wave-front excitation and obtained the spatial extension of the THz beam at the focusing point shown in Fig. 1c. The spatial profil of the focused THz pulses is more confined as the frequency is increased and closely follows the diffraction-limit (Fig. 1d black dots). Such diffraction-limit broadband THz time domain spectroscopy system is promising for investigation of small objects such as quantum dots or cells.

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