We present a non-invasive broadband air photonic method of terahertz field imaging inside a tapered parallel plate waveguide. The method is based on the terahertz-enhanced second harmonic generation of the fundamental laser beam in an external electric field. We also demonstrate the direct measurements of the frequency-dependent reflection coefficient at the end of the waveguide.

**Introduction**

Guiding of terahertz (THz) waves by various structures is a topic of an ongoing extensive investigation [1]. Due to its unique properties (i.e., dispersionless propagation of the TEM mode with no frequency cut-off), the parallel plate waveguide (PPWG) has attracted considerable attention [2,3,4,5]. Recently a tapered PPWG (TPPWG) have been proposed and investigated [6,7,8,9]. It has been shown that THz waves can be confined inside a PPWG on subwavelength scale in both transverse dimensions what can be used for the THz nearfield microscopy with subwavelength resolution. TPPWG also offer field enhancement and thus have a big potential for studying nonlinear THz phenomena, which in recent years is intensively investigated. For experimental characterization of TPPWG reliable method is on demand. So far only scattering probe detection has been used[10]. The drawback is that the probes perturb the measured field.

We present a non-invasive method that does not change guiding properties of the waveguide. We adapt the air bias coherent detection (ABCD) method of THz radiation [11] and apply it to a TPPWG in order to image the THz electric field distribution inside the waveguide along the propagation direction. The method is non-invasive and does not change guiding properties of the waveguide.

**Expermental Setup**

ABCD Detection

Coherent detection of THz radiation is based on an interaction between the probing laser pulse $I_p$ and THz electric field $E_{THz}$ in the presence of the external oscillating electric field $E_{bias}$. The intensity $I_2$ of the second harmonic (SH) generated as a result of such an interaction can be expressed by:

$$I_{2\omega}(r,t) \propto \chi^{(2)}(r,t) E_{bias}^2(r,t) E_{THz}^2(r,t).$$

In a standard ABCD configuration the probing pulse and the THz transient propagate collinearly through the area of a bias field. For a given THz-probe delay time, each point of the NIR probe interacts with a moving THz waveform and the intensity of the generated SH is expressed as:

$$I_{2\omega}(\tau) \propto E_{bias}^2 \int E_{THz}(\tau) L_s^2(\tau + \tau, r) d\tau dr.$$

The response function $R(f)$ describes the ability of the system for detecting different frequency components can be introduced as follows:

$$R(f) = \frac{I_{2\omega}(f)}{E_{THz}(f)}.$$

Cross-directional THz detection

In our configuration the THz transient and the probe pulse propagate in perpendicular directions. In such a case for a given THz-probe delay time, each point of the NIR probe interacts with a moving THz waveform and the intensity of the generated SH is expressed as:

$$I_{2\omega}(\tau) \propto E_{bias}^2 \int E_{THz}(\tau, r) L_s^2(\tau, r) d\tau dr.$$

The response function $R(f)$ describes the ability of the system for detecting different frequency components can be introduced as follows:

$$R(f) = \frac{I_{2\omega}(f)}{E_{THz}(f)}.$$

For large $L_s$ the interaction length is limited by geometrical dimensions of the focus of the probe beam.

**References**


**Terahertz field imaging inside tapered parallel plate waveguides**

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