Radially-polarized Few-Cycle Terahertz Pulse Emission, In-Coupling and Propagation in Coaxial Waveguides

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The hollow coaxial waveguide is an attractive transmission line for Terahertz (THz) pulses (i.e., signals with frequency content over a decade) because its fundamental transverse electromagnetic (TEM) mode is dispersionless. However, generating THz pulses with radial polarization to match the TEM mode has been proven challenging. The standard solution is to use THz antennas with special radial electrodes (T.-I. Jeon and D. Grischkowsky, Appl. Phys. Lett., 85, 6092-6094, 2004; J.A. Deibel *et al.*, Proc. IEEE, 95, 1624-1640, 2007). This solution require however complex fabrication processes.

Here, we propose the use a bias-free THz emission scheme based on radial transient photo-current arising from non-uniform optical excitation of narrow-bandgap semiconductors (InAs) by short optical pulses. Upon photoexcitation of the InAs layer, the photo-generated non-equilibrium clouds of electrons and holes undergo different dynamics leading to unbalanced transient spatial distribution of charge with corresponding dipole moments oriented in the surface plane (R. Mueckstein *et al.*, IEEE Trans. THz Sci. Tech., 5, 260-267, 2015; S.C. Corzo-Garcia *et al.*, Phys. Rev. B, 94, 045301-1-5, 2016). The transient dipoles radiate pulses of THz waves with a spatial profile determined by the optical beam profile and a spectral content ~0.2 to 1.5 THz.

To test the hypothesis, we illuminate an InAs layer with a Gaussian-like beam of varying diameter under normal incidence. The InAs layer is placed at the input of two different 100 mm long cylindrical coaxial waveguides whose estimated TEM mode attenuation is below 40 dB/m in the spectral window of interest. The waveguide output is monitored with an integrated sub-wavelength aperture THz near-field probe. The amplitude peak-to-peak as a function of the optical beam waist reaches a maximum for beam waist slightly larger than the inner conductor diameter for both waveguides. For such optimum beam waist, the spectrogram (Fig. 1(a)) reveals almost flat dispersion, suggesting TEM mode propagation. Indeed, the spatial E-field map of the pulse confirms the TEM mode. No signs of higher-order modes are observed. When off-axis oblique photo-excitation is used to generate linearly polarized THz pulses, the spectrogram reveals the excitation of the first higher-order TE_{11} mode (Fig. 1(b)). The numerical results obtained with the transient solver of CST Microwave Studio^{TM} agree well with measurements and provide insight on the in-coupling mechanism for different optical beam waists. This work suggests that the spatial profile and the polarization state of THz pulses can be tailored by the spatial profile of the optical excitation which opens avenues for THz communications with space-division multiplexing.

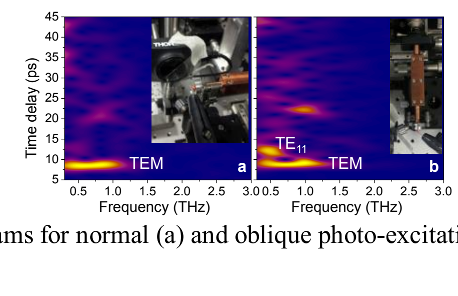

Figure 1. Spectrograms for normal (a) and oblique photo-excitation (b). Insets: setups.