Theoretical and experimental study of a terahertz time-domain spectrometer based on photoconductive antenna

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We construct a terahertz time-domain spectrometer (THz-TDS) system based on photoconductive antenna (PCA). A 800 nm Ti:sapphire femtosecond laser with 80 MHz repetition rate provides the pump and probe laser pulse, which has a 45 fs pulse width (as short as 15 fs is available) and as much as 400 mW power. Two commercial PCAs with 34 um and 6 um gap size are used as the emitter and receiver, respectively. We characterize this system by measuring its absolute radiated THz power, spectral bandwidth, signal-to-noise ratio (SNR) and dynamic range. Using this system, we study the response of the PCA as the emitter and receiver to the laser power and/or biased DC voltage, as well as their influences on the SNR and dynamic range of the TDS system.

In addition, we present a 3D full-wave finite-difference time-domain (FDTD) analysis of the PCA-based terahertz source. The modeling consists of two parts. For the first part, the 3D drift-diffusion and continuity equations coupled with Poission equation are used to simulate the photoconductive carrier generation and transport process. For the second part, the full-wave interaction and propagation is analyzed by solving 3D Maxwell's equation with FDTD method. The coupling between these two parts is implemented by applying the electric field obtained from the Maxwell's equation to the carrier transport equation. The whole process of THz radiation generated by the laser-pulse-gated PCA can be simulated using this method.

We further explore a set of parameter study (such as semiconductor material's properties, laser power and biased DC voltage) for PCA using the 3D full-wave analysis method, and compare the simulation results with the experiments. It is believed that the analysis method can be used as an optimization tool for PCA design and application.