Echo-less Photoconductive Switches for High-Resolution Terahertz Time-domain Spectroscopy


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Overview

Interdigitated photoconductive (iPC) switches are powerful and convenient devices for time-resolved spectroscopy, with the ability to operate both as sources and detectors of terahertz (THz) frequency pulses. However, reflection of the emitted or detected radiation within the device substrate itself can lead to echoes that inherently limit the spectrscopic resolution achievable from their use in time-domain spectroscopy (TDS) systems. We demonstrate a design of iPC switches for THz pulse emission and detection that suppresses such unwanted echoes and provides high-resolution in frequency. As a proof-of-principle, the $2_1^1-2_2^1$ and the $1_4^1-2_2^1$ rotational lines of water vapor have been spectrally resolved, demonstrating a spectral resolution below 10 GHz.

1. A buried metal interdigitated photoconductive switch

- a) Schematic of a standard photoconductive switch.
- b) Schematic of a buried metal photoconductive switch.
- c) Cut view of a buried metal interdigitated photoconductive switch. A gold plan is inserted below a 10 µm thick layer of undoped GaAs.
- d) Calculated electrical potential $U$ for an applied voltage of 4V.

2. Experimental characterization as emitter

- Experimental setup for emitters’ characterization. Based on a THz Time-Domain Spectroscopy setup.
- No effect of buried metal on radiation diagram (numerical calculation).

3. LT-GaAs layer for switches as detectors

- Measurement of carrier lifetime in the LT-GaAs active layer (optical pump – THz probe technique).
- Blue line: variation of THz reflectivity of LT-GaAs layer after a 100fs – 800nm excitation optical pulse at t=0fs.
- Red line: Numerical fit $\tau = \frac{1}{\gamma} \exp\left(\frac{t}{\tau} - 1\right) \exp\left(-\frac{t}{\tau}\right)$

4. Time traces and echo suppression

- Resolution limited only by echo in detection crystal (42 ps time window).
- THz power concentrated in a single pulse: higher peak amplitude for a given polarisation bias electrical field.
- $E_{bias}=10$ kV/cm

5. Spectral resolution improvement

- Rotational lines of water are resolved
- $2_1^0-2_2^0$ (1.661007 THz), $1_4^0-2_2^0$ (1.669944 THz)
- Frequency separations of 8.9 GHz and 47 GHz.

Conclusions:
- THz pulse generation and detection with echo suppression.
- High-resolution in the spectral window 500 GHz – 3.5 THz experimentally demonstrated.
- Demonstration of 9 GHz spectral resolution from $2_1^2-2_1^1$ and $3_{41}^1-2_2^1$ water vapour rotational lines measurement.
- Perspectives: better understanding of spectral properties, including influence of the distance between electrodes and the buried metal plane.