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To cite this version:
Kenneth Maussang, José Palomo, Jean-Michel Manceau, Raffaele Colombelli, Isabelle Sagnes, et al.. Echo-less Photoconductive Switches for High-Resolution Terahertz Time-domain Spectroscopy. Conférence CNano 2017, Dec 2017, Lyon, France. 110, pp.20 - 25, 2017. hal-02127994

HAL Id: hal-02127994
https://hal.umontpellier.fr/hal-02127994
Submitted on 13 May 2019

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


1Laboratoire Pierre Aigrain, Département de physique de l’ENS, École normale supérieure, PSL Research University, Université Paris Diderot (Paris 7), Sorbonne Paris Cité, Sorbonne Universités, Université Pierre et Marie Curie (Paris 6), CNRS, 24 rue Lhomond, 75005 Paris, France
2Centre de Nanosciences et de Nanotécnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, CN2 – Orsay, 91405 Orsay cedex, France
3School of Electronic and Electrical Engineering, University of Leeds, Leeds LS9 2JT, United Kingdom
4Institut d’Electronique et des Systèmes, CNRS (UMR 5214), Université de Montpellier, 860 rue de Saint-Priest, 34 095 Montpellier Cedex 5, France

Overview
Intergated 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 limits the spectroscopic 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 2J22J1 and the 3J23J1 rotational lines of water vapor have been spectrally resolved, demonstrating a spectral resolution below 10 GHz.

1. A buried metal interdigitated photoconductive switch

![Image of 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.

3. LT-GaAs layer for switches as detectors

![Image of LT-GaAs layer for switches as detectors]

Pre-photolithography sample. The MBE grown sample is waffer bonded to a gold-coated host Si GaAs substrate. The substrate and the AIGaAs (5%) layer of the MBE grown wafer are removed, exposing the LT-GaAs active region with the echo-blocking metal plane 6 µm below the surface.

4. Time traces and echo suppression

![Image of 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 polarization bias electrical field.

Ebias=10 kV/cm

Resolution limited only by delay line length and probe beam alignment stability during scan.

With standard delay lines, few as time windows might be achieved, resulting in sub-GHz resolution.

5. Spectral resolution improvement

![Image of spectral resolution improvement]

Rotational lines of water are resolved
2J2−2J1 (1.661007 THz), 2J3−2J2 (1.669944 THz), 2J2−3J1 (1.716769 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 2J2−2J1 and 3J2−3J1 water vapour rotational lines measurement.
- Perspectives:
  - better understanding of spectral properties, including influence of the distance between electrodes and the buried metal plane.

-kenneth.maussang@umontpellier.fr / sukhdeep.dhillon@lpa.ens.fr