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

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Abstract— **Interdigitated photoconductive (iPC) switches are convenient sources and detectors for terahertz (THz) time domain spectroscopy. However, reflection of the emitted or detected radiation within the device substrate can lead to echoes that inherently limits the spectroscopic resolution achievable. In this work, we design and realize low-temperature-grown-GaAs (LT-GaAs) iPC switches for THz pulse generation and detection that suppresses such unwanted echoes. This is realized through a monolithic geometry of an iPC switch with a metal plane buried at a subwavelength depth below the LT-GaAs surface. Using this device as a detector, and coupling it to an echo-less iPC source, enables echo-free THz-TDS and high-resolution spectroscopy, with a resolution limited only by the temporal length of the measurement governed by the mechanical delay line used.**

I. INTRODUCTION

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 limits the spectroscopic resolution achievable from their use in time-domain spectroscopy (TDS) systems. For example, with a photoconductive switch made from a 500 µm thick GaAs wafer and with n = 3.6 in the THz range, the first THz echo arises after only 12 ps, limiting the resolution to ~ 90 GHz (3 cm^{-1}). This can restrict applications such as high resolution THz spectroscopy of many polar molecules, where pure rotational spectra typically have linewidths ranging from 0.1 cm^{-1} to 10 cm^{-1}.

A novel iPC switch that suppresses unwanted echoes from the substrate, without power losses, is proposed and demonstrated in emission [1] and in detection [2]. It provides a monolithic "on-chip" solution without any mechanical positioning of external elements post processing. For the emitter, this is realized through a buried metal geometry where a metal plane is placed at a subwavelength thickness below the surface switch structure and semi-insulating GaAs active layer. For detector, this is realized through a buried multilayer low-temperature-grown GaAs (LT-GaAs) structure that retains its ultrafast properties, which after wafer bonding to a metal-coated host substrate, results in an iPC switch with a metal plane buried at a subwavelength depth below the LT-GaAs surface (see Fig.1a). This results in essentially a THz cavity, preventing the propagation of THz pulses into the substrate. Using these devices as emitter and detector together enables echo-free THz-TDS and high-resolution spectroscopy, with a resolution limited only by the temporal length of the measurement governed by the mechanical delay line used (fig. b). As a proof-of-principle, the 2_{12}-2_{21} and the 1_{01}-2_{12} rotational lines of water vapor have been spectrally resolved, demonstrating a spectral resolution below 10 GHz.

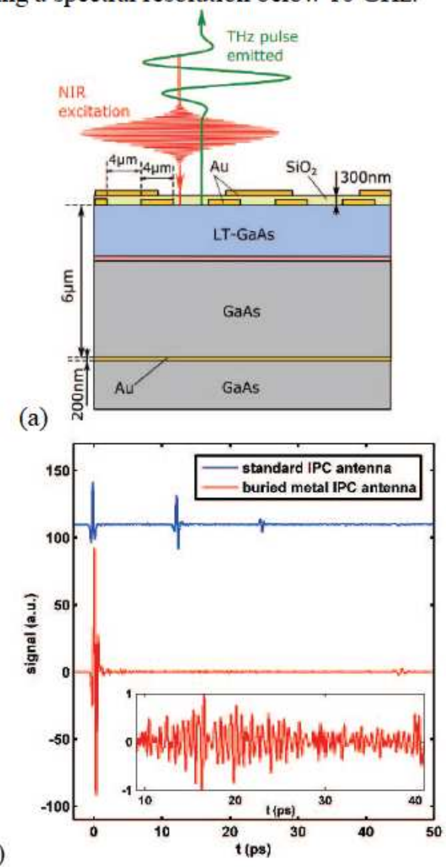

Fig. 1. a): Buried metal geometry for echo-less detection with LT-GaAs active layer. b): Temporal scan of buried metal IPC and standard antenna

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