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Photoconductive switches for polarization resolved THz time-domain spectroscopy

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Abstract— Photoconductive switches are widely used for emission and/or detection of terahertz pulses. The emitted polarization is fixed by the design of the electrodes. In this work, innovative designs of photoconductive switches are proposed providing full electrical control on the direction of polarization of the emitted field and its detection. These designs are based on monolithic on-chip solution with an interdigitated scalable geometry. It allows fast polarization modulation ability without the need of external mechanical components, and polarimetry measurements with a large area receiver. It opens the fields of precision terahertz polarimetry.

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. Such iPC switches have been demonstrated with large areas for powerful emission, and may provide high-resolution performances [1]. Polarimetry and birefringence measurements in the THz range are of huge interest, especially in the field of material sciences. Most of polarization measurements in THz domain are performed by the use of mechanically controlled elements, which limits inherently the swiftness and the precision of the measurement. While standard iPC switches emit linearly polarized THz radiation, an innovative concept of a THz pulse emitter with a full electrical control over the emitted polarization is proposed and demonstrated over a 100 GHz – 4 THz spectral window. Its design is scalable for large area devices, and enables decorrelation between the frequency bandwidth of operation and the size of the active area. It is based on an intermixed geometry of small interdigitated active area, as illustrated in figure 1. It consists in a subwavelength spatial alternation of small iPC switches with orthogonal direction of emitted polarization. In the far-field regime, this spatial distribution is no longer distinguishable, providing a homogeneous beam, resulting from the linear superposition of each type of polarization. From Malus' law, the direction of polarization is determined by the relative amplitude of the field of each type of emitter. In the linear regime, this amplitude is proportional to the electrical bias field applied by the iPC switches electrodes, and consequently the applied voltage. It results in a THz pulse emitter which polarization is fully electrically controlled without the need of additional mechanical element such as a wire-grid polarizer. This design

might be adapted for detection scheme with iPC switches, providing the ability to measure simultaneously two orthogonal polarizations of the THz pulse, with a large area detector. The designs of iPC switches in this work are fully scalable, providing large area devices, both in emission and detection. Spatial polarization distortion has been evaluated numerically.

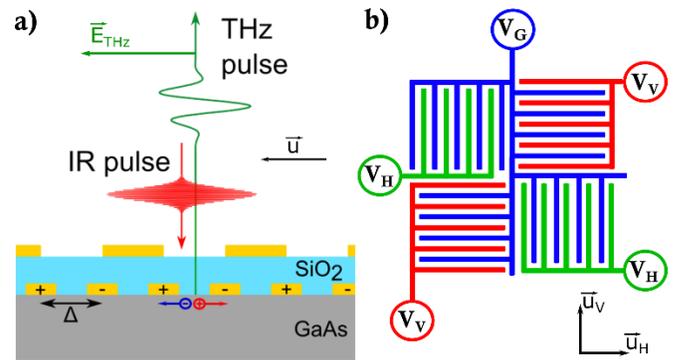


Fig. 1. a) Cut view of an interdigitated photoconductive switch. Interdigitated gold electrodes on top of the GaAs layer consist of 4 μm wide electrodes, equally spaced by a distance Δ = 4 μm. A second metallic layer is composed of metallic fingers covering gaps with a periodicity double that of the first, isolated from the first metallic layer by a 300 nm thick layer of SiO₂. A femtosecond excitation pulse is focused on the front face of the photoconductive switch generating carriers in the GaAs layer (electrons in blue and holes in red). The THz pulse is emitted from the surface. b) Top view of the intermixed geometry principle (only the first metallic layer is represented). It consists in a pattern made out of two orthogonal small interdigitated photoconductive switches. The pairs of digits share a common ground potential V_G, but might be polarized independently with two different electrical potential V_H and V_V, resulting in respectively horizontal and vertical polarization.

From its fast electrical modulation ability, these iPC switches would permit fast and high-precision polarization measurements. Such precision THz polarimetry opens the field of material sciences studies such as polymers or anisotropic materials like wood. Finally, reflectivity measurements for different polarizations permit to retrieve the dielectric constant of a material from Fresnel's coefficient without the need for a reference [2].

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