

# Achromatic polarizing elements for pulsed THz waves

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**Abstract**—We present two polarizing elements designed to produce linear and circular polarization for broadband, pulsed THz waves. The linear polarizer is made out silicon wafers arranged at Brewster's angle and the circular polarizer is made out of a silicon prism using total internal reflection differential phase-shift effect.

## I. INTRODUCTION AND BACKGROUND

TIME-RESOLVED Terahertz (THz) techniques allow knowing both amplitude and phase of coherent, pulsed THz emissions. This provides great abilities to study the relations between the two orthogonal components of an electromagnetic field<sup>1</sup>.

The vectorial treatment of THz waves is of great importance when examining polarization-dependant effects such as birefringence or optical activity. A full study of the polarization requires the control over the relative phase and amplitude of the two orthogonal polarization components. However, polarizing elements such as polarizing cubes and wave plates cannot be readily adapted from conventional optics for they are either too absorptive, dispersive or inherently chromatic, what is a major issue when dealing with pulsed, broadband THz waves.

We designed<sup>4</sup> a linear polarizer made out of four industry-grade silicon wafers arranged at Brewster's angle ( $\theta_B = 73.6^\circ$ ) that selectively transmit one polarization and reflect the other, while being achromatic and free of echoes (Fig. 1).

We also designed a circular polarizer that relies on the differential phase-shift that occurs in the condition of total internal reflection<sup>2</sup> in a high-resistivity silicon (HR-Si) isosceles prism with a base angle of  $42^\circ$  (Fig.2). Under these conditions, the phase difference between the two polarization components can be made  $\pi/2$  rad, constant over the entire spectrum.

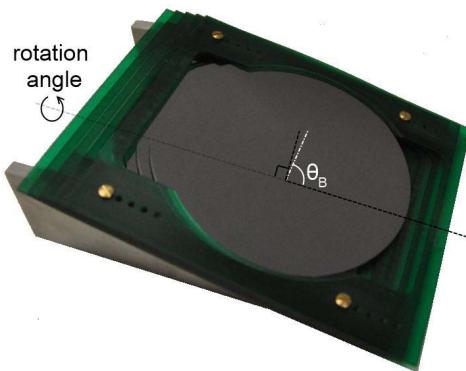


Fig.1: picture of the described linear polarizer

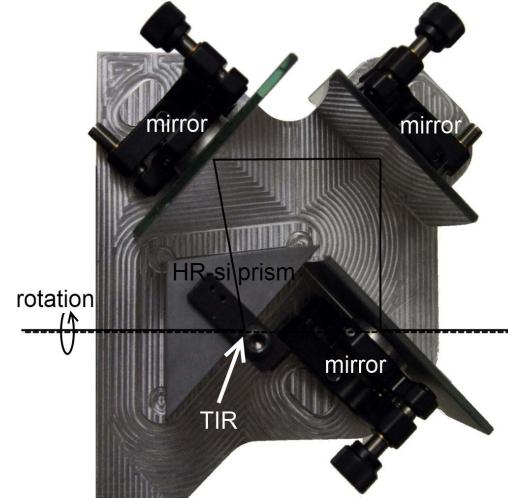


Fig.2: picture of the described circular polarizer

## II. RESULTS

For the experiments, we used a photo-conductive antenna (PCA) illuminated with a 12fs, 76MHz, 120mW average power Ti:Sa to generate a THz pulse, two of orthogonal PCAs triggered by the same laser to simultaneously measure the two polarization components and a thick HR-Si wafer used as a beam-splitter.

We placed the linear polarizer on a rotating mount to measure the waveforms of the THz pulses experiencing an extinction of both polarization components (Fig. 3). It shows very small insertion loss (<0.5dB) and a high extinction ratio (>20dB) over the entire spectrum, without distorting the pulsed nature of the THz beam. We can notice the polarity reversal for the cross-polarized component.

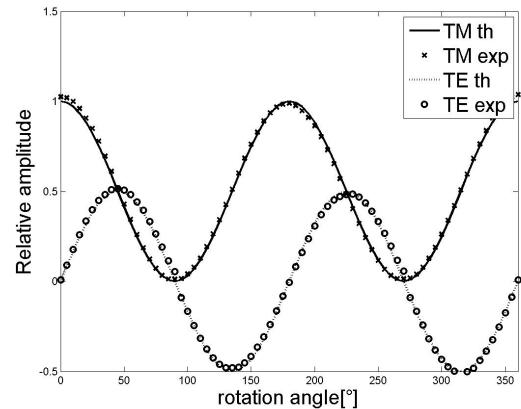


Fig.3 : orientation of the linear polarizer vs. amplitude at a constant delay-line position (here: near the maximum of the THz pulse) for both polarization components

We used the previously described linear polarizer oriented

at  $45^\circ$  relatively to the generated THz pulse to produce a controlled linear polarization and we placed the circular polarizer on a rotating mount to proceed to time-resolved measurements. When total internal reflection occurs, both TE and TM components experience a phase shift ( $\square_{TE}=78^\circ$ ,  $\square_{TM}=168^\circ$ ) while the differential phase shift  $\square_{TM}-\square_{TE}$  is  $\pm\pi/2$  rad between the two polarization components for all frequencies when oriented at  $\pm 45^\circ$  relatively to the incident linearly polarized pulse (Fig.4).

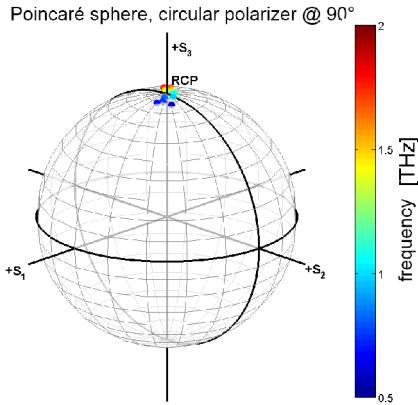


Fig.4 : Poincaré sphere of the circular polarizer oriented halfway between its eigen axes. All frequencies are right-circularly polarized

The waveforms of the pulses experience an in-place reshaping<sup>3</sup> due to the change of the carrier-envelope phase, continuously changing the polarization state of the incoming thz pulses from linear to circular when rotating the circular polarizer (Fig.5).

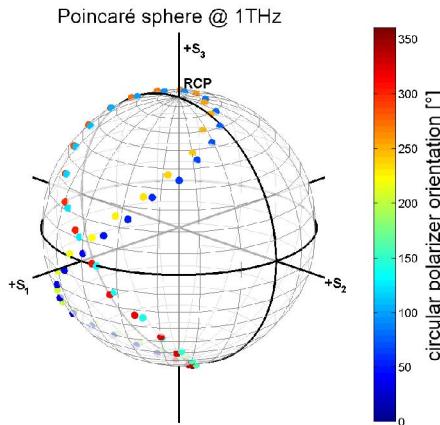


Fig.5 : polarization state of the thz pulse vs. orientation of the circular polarizer, displayed on a poincaré sphere for 1THz

### III. CONCLUSIONS

The linear and the circular polarizers show excellent broadband behaviors and are free of dispersion in time or echoes. Hence, they are suitable for time-resolved analysis of ultra-short THz pulses.

### REFERENCES

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