

# Metallic Anti-Reflection Coating for Terahertz Technology

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The recent progress in the Terahertz technology widens the field of application of far infrared radiation [1] – [3]. There is a big interest to characterize various organic and non-organic materials [4] in this frequency region. One of the problems occurring in Terahertz time-domain spectroscopy (THz-TDS) measurement based on electro-optic detection [5] are reflections of the THz wave within the electro-optic crystal. As known from the Fourier transformation of a time shifted signal, these reflections manifest themselves as a modulation of the original spectrum with the period given by the delay time. Depending on the magnitude of the reflection peak it is very difficult to identify narrow absorption lines since they are hidden or blurred within this modulation. Till now no complete solution for this problem has been found. The reflected wave can be shifted out of the measured time window by attaching a long non-active electro-optic crystal (EOC) to the backside of the active EOC. Another method is to avoid that the reflection is detected by applying a tilt between the Terahertz and probe beam. Both these methods, however, decrease the data quality. The standard optics approach to a solution is to use an anti-reflection coating that means a layer of optical thickness of  $\lambda/4$ . For 300  $\mu\text{m}$  wavelength ( $\sim 1$  THz) the required layer thickness is about 50  $\mu\text{m}$  which is difficult to deposit. The other possibility is to use an anti-reflection principle coming from the electrical engineering where two regions of different wave impedance are connected by using a well adjusted resistor between them to avoid any reflection.

In this contribution, we report on a high resolution THz-TDS system using an electro-optic crystal (EOC) with an anti-reflection coating consisting of thin chromium layer. We apply this system to study molecular and lattice related optically active vibrational modes of benzoic acid in the frequency range 0.1 – 5 THz with a resolution of 20 GHz.

The benzoic acid is measured in a pure crystalline form and mixed with polyethylene (PE). Latter samples are in the form of the pressed pellets. PE is chosen as a matrix material because of the low index of refraction and negligible absorption at the frequencies of interest. These two types of samples are used to distinguish between molecular and lattice vibrational modes.

Figure 1 shows our THz-TDS system. It uses a Ti:Sapphire laser with 80 femtosecond long NIR pulses to generate coherent THz radiation from a biased GaAs emitter and to gate an electro-optic GaP detector. With this system, a bandwidth of 5 THz and a signal-to-noise of more than 1000 is reached.

To avoid reflections at the air/GaP interface we use an EOC coated with a 81 Å thick chromium layer. Due to the optimized sheet resistance of the metal layer, the wave impedance of the GaP is matched to that of air and no back propagating THz electromagnetic wave exits in GaP. The improved signal quality is demonstrated in Fig. 2. It can be seen that the chromium coating reduced the magnitude of the reflection at time delay of 7 ps after main pulse. As a result, the strong periodic modulation of the spectrum is fully suppressed and the high frequency resolution of THz-TDS is enabled.

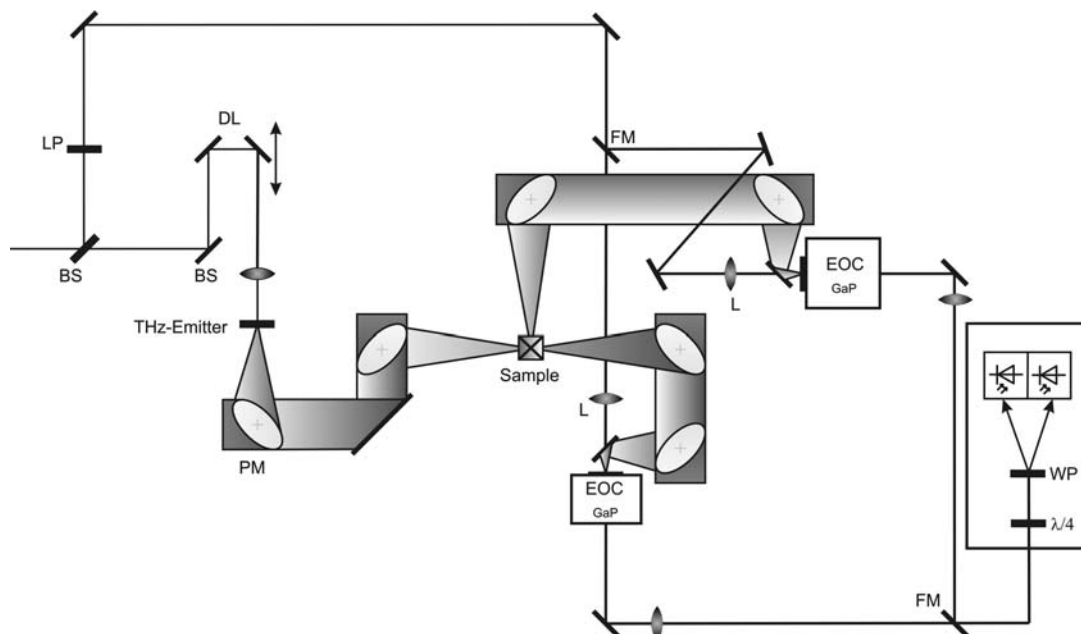


Fig. 1: Schematic of the Terahertz time-domain spectrometer with time resolved measurement of absorption and reflectivity option (BS-NIR beam splitter; DL delay line; EOC electro-optic crystal; L lens; PM off-axis parabolic mirror; WP Wollaston prism; FM folding mirror).

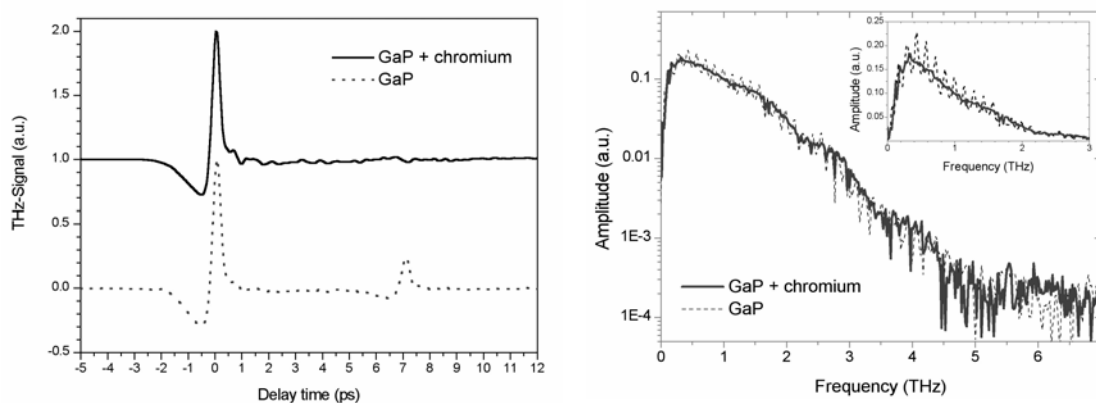


Fig. 2: Comparison of the THz signal in time-domain (left panel) and frequency-domain (right panel) of a gallium-phosphid electro-optic crystal with and without chromium coating. The inset: linear scale.

We apply the improved THz-TDS system to study the optically active vibrational mode of the benzoic acid. Fig. 3 shows typical absorption spectra of a benzoic acid crystal measured at room temperature for two different angles between the crystal orientation and polarization of the coherent THz radiation. Their absorption spectra contain a narrow absorption line at 0.9 THz and a broad band beginning at 1.2 THz. The difference in the weight of the individual frequency components is due to projection of corresponding dipoles to the plane of polarization of the probe radiation.

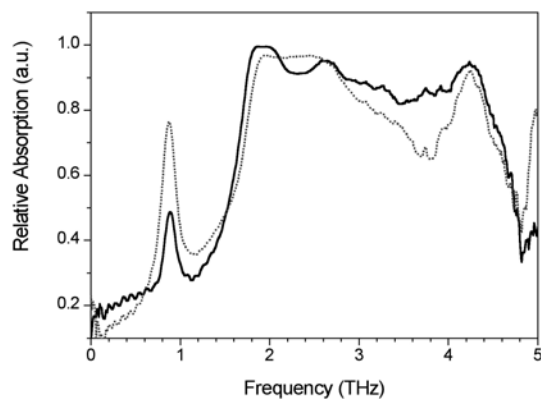


Fig. 3: Relative absorption spectrum of a benzoic acid crystal at two different crystal orientations.

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