Estimation of THz Waveforms for Material Characterization of Stratified Objects

U. Schade[1], E. Ritter[2], L. Puskar[1], E.F. Aziz[1, 3], J. Beckmann[4]
[1]Helmholtz-Zentrum Berlin für Materialien und Energie,12498 Berlin, Germany
[2]Humboldt-Universität zu Berlin, Experimentelle Biophysik, 10115 Berlin, Germany
[3]Freie Universität Berlin, Fachbereich Physik, 14195 Berlin, Germany
[4]Bundesanstalt für Materialforschung und -prüfung, 12200 Berlin, Germany

***Abstract*—THz waveforms back reflected from stratified objects are estimated by applying appropriate optical models. Using amplitude reflectance spectra of such systems the THz waveform is obtained by adding up all reflected waves according to their amplitudes and their relative positions within the bandwidth of the incoming THz pulse.**

I. Introduction

THz time-domain spectroscopy (TDS) has proven to be a valuable tool to non-destructively check the integrity and composition of stratified objects like for example pharmaceutical tablets, insulation coatings, paint systems and many others. Raster-scanning over an object of investigation produces chemical images not only of the surface but also underneath. Even single point measurements can provide sufficient information so that basic classification becomes possible by using simple hand-held detection systems.

However, a detailed automatized analysis of the investigated object requires either an extensive set of reference waveforms or an analytical tracing back to the real object. The latter provides material properties only when a geometrical model of the stratified system is provided.

In this study, we discuss how optical constants can be used to model THz waveforms as they are recorded by TDS upon reflection from stratified objects.

II. Results

The amplitude and phase change of a planar electromagnetic wave undergoing specular reflection from a single interface of different media can be explained using the complex amplitude reflectance. The latter can be split into the Fresnel reflection coefficients for the field components perpendicular and parallel to the plane of incidence. If more than one interface layer is taken into account, analytical approaches for isotropic stratified structures [1, 2] can be used for the calculation.

The reflected THz waveform as obtained by TDS from a stratified object is characterized by its complex spectral components, which are the product of the complex spectrum of the incoming pulse and the complex amplitude reflectance. The reflected THz waveform can then be assembled by adding up all reflected waves according to their amplitudes and their relative positions given by their spectral phases. Examples of reflected waveforms are shown in the Fig. 1 for a one-layer substrate system.

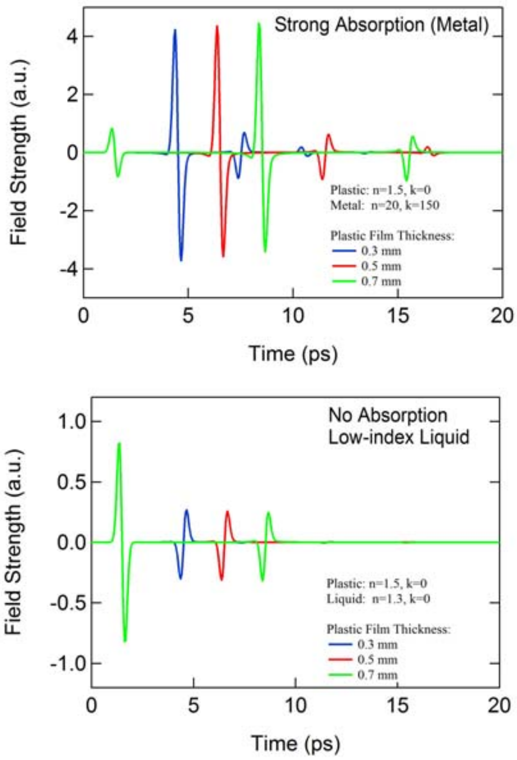

Fig. 1. Calculated reflected waveforms for model systems consisting of one layer on a substrate for a range of material properties and layer thicknesses. The first pulse represents the reflection from the first surface. Top: Dielectric layer on a strongly reflecting substrate. Bottom: Reflected waveform for a low refractive index liquid in a plastic cuvette. Note here, that the 180° phase shift of the reflected pulses is due to the lower refractive index of the substrate at the internal interface.

III. Summary

Starting from the optical constants reflected waveforms can be calculated based on optical reflectance models which can then be used to build up data bases for hand-held TDS systems in field applications.

References

[1]. Abelès, F. (1950). *Recherches sur la propagation des ondes électromagnétiques sinusoidales dans les milieux stratifiés. Application aux couches minces*, Deuxième Partie. Ann. Physique 5, 706–782.
[2]. Wolter, H. (1956). *Optik dünner Schichten*. In *Grundlagen der Optik* (pp. 461 – 554), ed. S. Flügge, Berlin, Springer-Verlag.