Time-Domain Analysis of THz Detectors Composed of Electro-optic, Dispersive, and Anisotropic Crystals

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Electro-optic (EO) devices are extensively used in various THz applications such as THz Time-Domain Spectroscopy (THz-TDS), THz Imaging, Ranging, and Detection. These devices are commonly designed without rigorous theories since there have been a few full-wave numerical approaches for simulating wave interactions in EO crystals. The objective of this work is to present a time-domain full-wave analysis for this purpose.

It has been shown that the Pockels effect in electro-optic crystals leads to nonlinear cross-phase modulation (XPM) induced by the time-dependent electric fields of an intense terahertz pulse [Y. Shen *et al*., Phys. Rev. Lett. **99**, 043901 (2007)]. As a result, a spectral shift is observed in optical pulses propagating through an EO crystal in the presence of an intense THz pulse.

In this work, we propose an appropriate implementation of nonlinear finite-difference time-domain method (NL-FDTD) for the modeling of electromagnetic wave interactions in a nonlinear, dispersive, and anisotropic medium. The Lorentz model commonly used for formulation of the dispersion in EO crystals has been adopted in the NL-FDTD analysis as a result of which a complete numerical analysis including the dispersion and anisotropy of nonlinear crystals has been implemented for modeling the performance of EO devices. We have applied our formulation to a typical EO device, namely a THz beam sampler. The structure of the sampler contains a 0.5 mm-thick (110) ZnTe crystal. The intense THz beam to be sampled by an optical probe along with the probe laser pulse are considered as the incident waves to the ZnTe slab. By means of the simulation of the induced XPM in these crystals, we precisely evaluate the wavelength shift of an optical beam in the EO slab. The calculated wavelength shift is then used for obtaining an estimation of the equivalent walk-off parameter in these slabs. This parameter can be used effectively for modeling an EO crystal and thus for modeling the co-propagation of THz pulses and laser probe pulses through these structures.