Terahertz Polarimetric Imaging for Biomedical Applications

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We present a reflection-mode, polarimetric imaging system that can achieve 45μm sample resolution and measure the co-polarized and cross-polarized reflected field components individually over the 750GHz-1.1THz band. The system is based on a vector network analyzer (VNA) in conjunction with frequency extenders and illuminates the sample under test through a high-resistivity Silicon (HRSi) lens to achieve image resolution 3.42-times better than the free-space diffraction limit. The two ports of the VNA are used to capture the co-polarized and cross-polarized images of the same sample. A simple quasi-optical setup is used to isolate and direct the cross-polarized reflected signal without significantly degrading the co-polarized signal. The utility of the proposed system is demonstrated using biomedical samples in form of formalin-fixed paraffin-embedded (FFPE) tissues. The sample's surface is sectioned using a microtome to planarize the image interface. The sample is subsequently placed over the HRSi lens at the focal plane to achieve finest image resolution. A raster scanning system is implemented using NI-LabVIEW to obtain the reflectivity of the two principle polarizations of tissue samples and simple filtering algorithms were applied in MATLAB to remove the usual image gradients formed during paraffin embedding steps of tissue preparation.

The polarimetric nature of the imaging enables, for the first time, the capture of key morphological features in the sample, as well as better contrast of subtle boundaries between tissue regions utilizing the polarization-dependency of edge diffraction. Optical activity and chirality in biomolecules can now be studied in the THz band using the proposed polarimetric imaging system. In a previous study, we had used THz imaging to differentiate between Alzheimer's disease and healthy brain tissue post mortem (W.-G. Yeo et al., "Terahertz imaging and electromagnetic model of Axon demyelination in Alzheimer's disease," IEEE Transactions on Terahertz Science and Technology, vol. 7, no.6, pp.711-721, 2017). In this current work, we extend this study to fully-polarimetric imaging as a viable tool for clinical diagnosis.