Terahertz polarimetry detects microscopic tissue changes linked to cancer and burns

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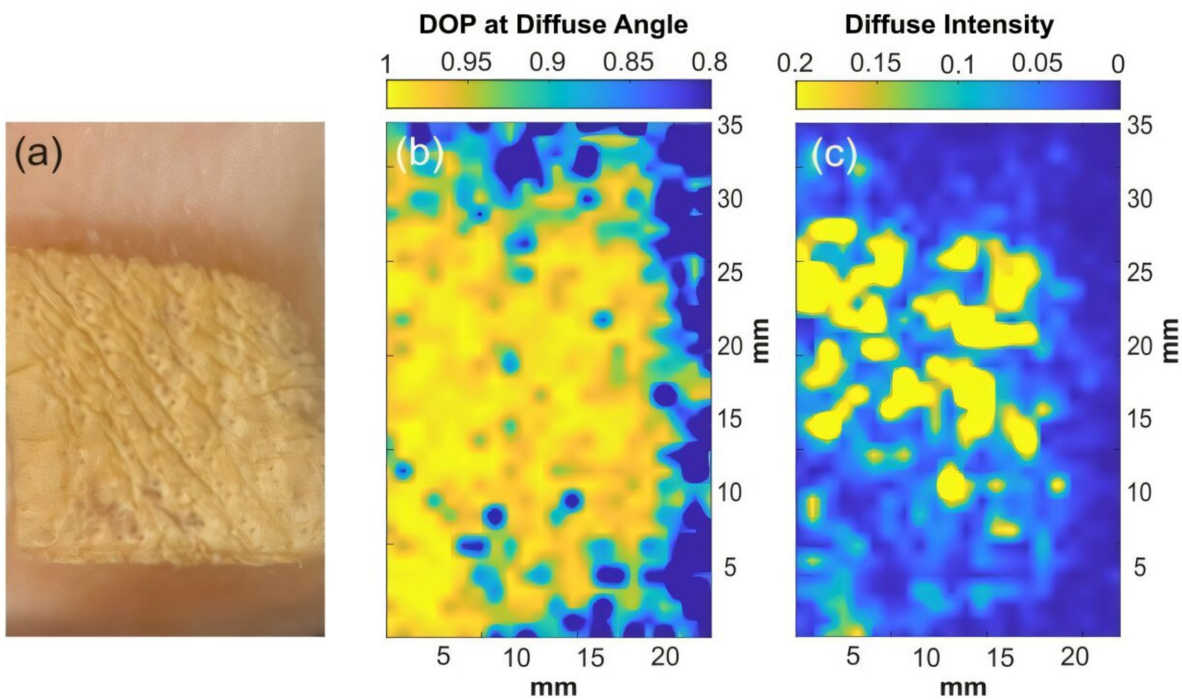

Polarimetric measurements of terahertz scattering can detect subtle changes in tissue architecture that result from disease or damage. For example, terahertz measurements demonstrated signal contrast between burned and healthy skin regions. Credit: *Journal of Biomedical Optics* (2025). DOI: 10.1117/1.JBO.30.6.066001

Recent advances in electronics and optics have opened new possibilities for terahertz (THz) waves—an invisible type of light that falls between infrared light and microwaves on the spectrum. The use of THz scattering for medical diagnosis is a promising frontier in this field, as THz waves can probe tissue structures in ways that traditional imaging methods cannot. Emerging THz measurement methods have the potential to detect subtle changes in tissue architecture that occur in diseases like cancer and burn injuries, serving as a powerful diagnostic tool.

However, existing THz imaging techniques face significant limitations for medical applications. Most existing approaches rely primarily on water content differences between healthy and diseased tissue as their main source of diagnostic contrast—an approach that proves overly simplistic for complex disease conditions.

Moreover, while polarization measurements of reflected THz waves seem to be valuable for tissue diagnosis, the underlying mechanisms that create different polarization responses in tissues remain poorly understood. This gap in understanding underscores a need for computational models capable of explaining and predicting the phenomena that researchers have observed experimentally.

To address these challenges, a research team led by Professor Hassan Arbab from Stony Brook University (New York, U.S.) has conducted a comprehensive study combining mathematical modeling, advanced computer simulations, and experimental validation to understand how THz waves respond to tissue structures. As reported in the *Journal of Biomedical Optics*, the team of researchers modeled how polarized THz light interacts with microscopic features that vary between healthy and diseased/damaged tissue.

The researchers first employed Monte Carlo simulation—a powerful computational technique—to model how THz waves scatter from spherical particles embedded in highly absorbing biological media. These particles of varying diameters can represent disease-related structures, such as tumor clusters or the destruction of hair follicles and sweat glands seen in burn injuries. To validate their models, the team created tissue phantoms using polypropylene particles of varying sizes suspended in gelatin, mimicking the optical properties of real tissue.

The simulation revealed two key parameters—the intensity of diffuse scattered light and its degree of polarization—that change predictably with particle size and concentration. Remarkably, the team showed that a characterization of the tissue's relevant polarization properties can be achieved using just a single polarization measurement, unlike conventional approaches requiring at least four.

Experimental results from the tissue phantoms confirmed the simulation predictions, showing clear frequency-dependent patterns that correlated with particle size. As expected, larger scattering particles produced higher intensity diffusely scattered light. They also produced distinct dips in polarization at specific frequencies, which could be used to assess the size of the scattering particles.

Finally, the researchers demonstrated the clinical potential of their approach by capturing a polarimetric image of an induced burn in porcine skin samples, revealing a clear contrast between burned and healthy tissue regions.

The ability to detect and characterize microscopic structural changes in tissue opens new possibilities for early cancer detection to improve patient outcomes. In particular, THz polarimetric imaging could be useful for identifying tumor budding, wherein small clusters of cancer cells break away from the main tumor. While current methods rely on tissue sampling and intricate staining procedures, THz polarimetric imaging offers a potentially simpler, more efficient alternative for detecting these clusters.

Looking ahead, the research team plans to extend their studies to actual cancer tissue samples and expand their THz measurement capabilities to capture even smaller tissue features. Using THz systems with larger bandwidth currently under development, polarimetric techniques could potentially resolve structures as small as 10–30 micrometers, opening possibilities for the detection of a wider range of disease-related tissue changes.

As THz technology continues to advance, the results of this study represent a significant step toward its inclusion in routine medical diagnosis, potentially transforming how clinicians detect and monitor disease progression.

More information: Erica Heller et al, Terahertz Mie scattering in tissue: diffuse polarimetric imaging and Monte Carlo validation in highly attenuating media models, *Journal of Biomedical Optics* (2025). DOI: 10.1117/1.JBO.30.6.066001

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