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Digital Terahertz Holography Approach to Size-Dependent Scattering in Granular Materials

Rusnė Ivaškevičiūtė-Povilauskienė[1], Lukas Stacevičius[1], Mateusz Kaluza[2], Agnieszka Siemion[2,3], Ignas Grigelionis[1], Gintaras Valušis[4] and Linas Minkevičius[1]

[1]*Department of Optoelectronics, Center for Physical Sciences and Technology, Saulėtekio Ave. 3, 10257 Vilnius, Lithuania.*

[2]*Faculty of Physics, Warsaw University of Technology, Koszykowa 75, 00662 Warsaw, Poland.*

[3]*Center for Advanced Materials and Technologies CEZAMAT, Warsaw University o Technology, Poleczki 19, 02-822 Warsaw, Poland.*

[4]*Institute of Photonics and Nanotechnology, Faculty of Physics, Vilnius University, Saulėtekio Ave. 3, 10257 Vilnius, Lithuania*

Email: rusne.ivaskeviciute@ftmc.lt

Terahertz (THz) radiation exhibits distinctive propagation properties, including penetration through dielectric materials opaque in the visible range [1], while remaining non-ionizing and suitable for biomedical and security applications. However, interaction with nonuniform or granular media induces strong scattering, degrading image quality. This is particularly problematic for optically thin or weakly absorbing samples, where conventional intensity-based imaging provides limited contrast. Coherent methods, such as holography [2], overcome these limitations by enabling phase retrieval, which is essential in highly scattering systems including powders, soils, and biological tissues.

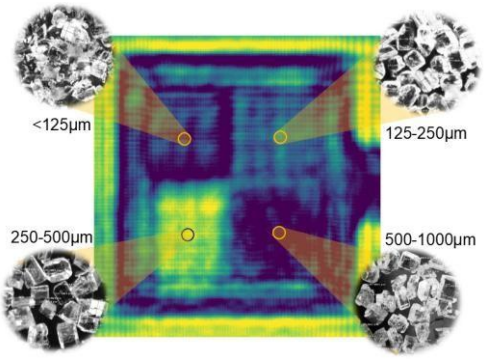

Fig. 1 Holographic reconstruction of amplitude. Insets depict the enlarged microscopic images of investigated grains.

In biological media, intrinsic microstructures and pathological changes (e. g., tumors or burn damage) introduce features often falling within the Mie scattering regime at THz frequencies [3], emphasizing the importance of size-dependent scattering analysis.

Here, THz scattering in granular media is investigated using digital THz holography supported by numerical modeling. The 4-phase-shift (4PS) method reveals a systematic increase in phase with particle size. In contrast to direct imaging, which fails under strong scattering, the 4PS approach reconstructs the complex wavefront via interference with a reference beam. This allows visualization of the transition from smooth effective-index variations in subwavelength structures to localized phase distortions as particle size approaches the wavelength. Experiments with size-classified sugar samples confirm a clear correlation between grain size and scattering behavior, demonstrating the effectiveness of digital THz holography for heterogeneous media characterization.

REFERENCES

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