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Impact of Scattering in Quasi-Ordered Structures on THz Imaging

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Terahertz science and technologies demonstrate a wide range of imaging applications in physics, biology, medicine, industry, etc. [1-7]. Scattering has one of the most essential impacts on imaging quality [1-4]. The mostly applied methods for estimation of scattering parameters and imaging losses are analytical diffuse and small-angle approximation of radiative transfer theory, Monte Carlo (MC), discrete ordinates, and T-matrix numerical methods, finite-difference time-domain method (FDTD), and experimental methods, e.g., using integrating sphere [8-11].

Nevertheless, one should pay attention to local ordering of scatterers in the considered media, since it could lead to significant changes of scattering signal [1-2].

We have studied the impact of quasi-ordered scattering materials on THz imaging, using a combined computational approach, based on computational electrodynamics, radiative scattering theory and Monte Carlo simulations. We assumed that the scattering effects could be accounted for by finding a single scattering phase function for clusters of particles, which form quasi-ordered scattering material, and using it in MC simulation of scattering, considering the whole medium as a random structure of such clusters. We applied FDTD technique for solution of Maxwell's equations in the near-field (NF) zone with the NF to far-field (FF) transformation based on the calculation of the diffraction integral. It helped us to determine scattering phase function and include it in MC numerical simulations in order to find scattered radiance L(θ) and the corresponding imaging modulation transfer functions (MTF).

The described approach was used to estimate an impact of quasi-ordered media [7,12-13].

We estimated imaging MTF in case of clothes scattering material. The numerical simulations and experimental measurements were performed for the following system parameters: imaging frequency of the THz source (backward-wave oscillator) was 0.25 THz, distance between the imaging system and the bar-pattern test-object was 4 m; for the scattering materials with groups of four cylindrical particles with period 0.3 mm dielectric permittivity of a single particle of diameter 0.2 mm was 2.9; for the scattering materials with groups of seven cylindrical particles with period 1.34 mm dielectric permittivity of a single particle of diameter 1.34 mm was 1.6; the thickness of scattering layers was 0.7 mm in the first case, and 4 mm in the second. The experimental scheme and the results are demonstrated in Fig. 1.

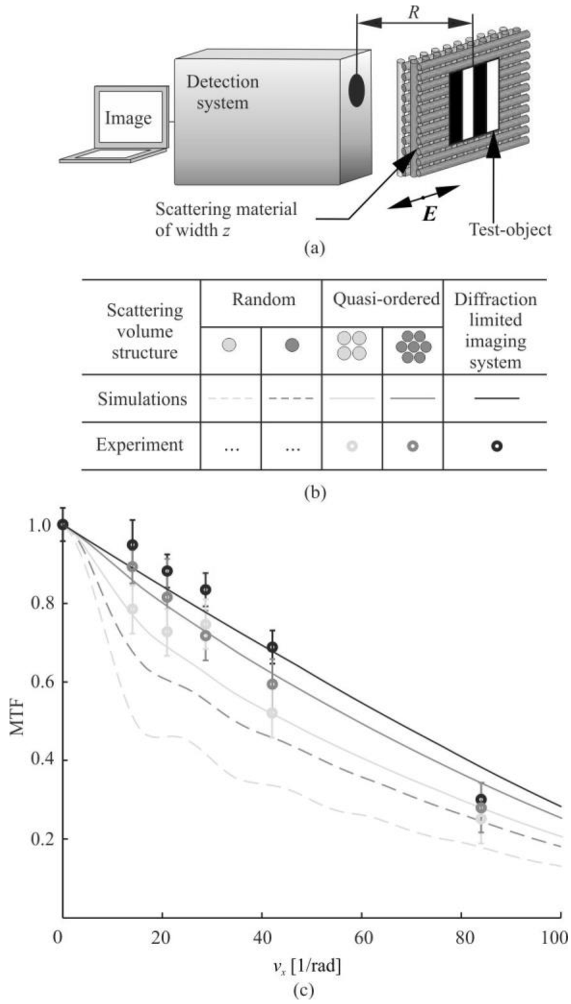

Fig. 1. (a) An experimental scheme for finding MTF using a set of test-objects; (c) and (d) experimental and numerical results, where black color corresponds to measurement without scattering layer.

We also calculated the MTF in case of random distribution of particles in the scattering materials and in case of quasi-ordering.

According to the numerical simulations [7], it is possible to determine particular combination of wavelength, particle system parameters, local period and dielectric parameters, for which imaging contrast of a remote object (and the corresponding MTF) would increase. On the contrary, almost opaque media could be achieved.

The demonstrated analysis could be effectively used for finding optimal wavelengths for imaging applications.

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