# Terahertz imaging technology: progress and applications

*A new publication from Opto-Electronic Technology; DOI 10.29026/oet.2026.250009, discusses progress and applications of terahertz imagining technology.*

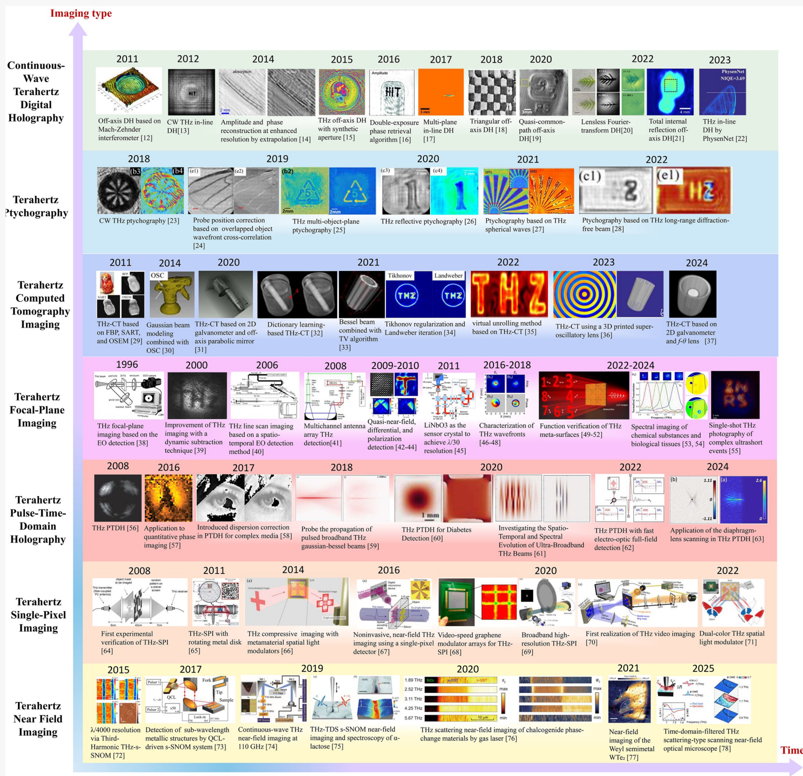


Fig. 1 The timeline of terahertz imaging encompasses continuous-wave terahertz digital holography, terahertz ptychography, terahertz computed tomography, terahertz focal-plane imaging, terahertz pulse time-domain holography, terahertz single-pixel imaging

SHANNON, CLARE, IRELAND, April 6, 2026 /EINPresswire.com/ -- A new publication from Opto-Electronic Technology; DOI 10.29026/oet.2026.250009, discusses progress and applications of terahertz imagining technology.

Against the background of rapid advances in security screening, biomedical diagnosis and non-destructive testing, the development of imaging techniques that combine safety with high resolution has become a key area of research. Terahertz waves, which occupy a unique spectral region between microwaves and infrared radiation, offer a novel approach to meeting this need. Their extremely low photon energy prevents ionization damage to biological tissues, and their sensitivity to polar molecules and the distinctive spectral signatures of biological macromolecules provide unparalleled advantages in material identification and biological tissue imaging. Breakthroughs in coherent detection and computational imaging have led to the development of multiple terahertz imaging modalities, with imaging scales extending from the macroscopic to the nanoscale near-field. Each imaging mechanism has its own trade-offs in terms of resolution, speed and information content, and ongoing research innovation lies in exploring these trade-offs.

This paper systematically summarizes the major modalities and key advances in terahertz imaging technology, with an emphasis on the working principles and application scenarios of different technical approaches, including continuous-wave digital holography, ptychography, computed tomography, pulse time-domain holography, focal-plane imaging, and single-pixel imaging. It also explores the evolution of imaging capabilities from macroscopic scales to nanoscale near-field detection. In the context of practical applications, the paper highlights recent progress in terahertz imaging for security screening, biomedical diagnosis, non-destructive testing, and material characterization, as illustrated in Fig. 1.

The article further outlines key breakthroughs in various technical directions in recent years. In continuous-wave holography, the integration of algorithmic innovations with optimized optical configuration has significantly improved imaging resolution, stability, and reconstruction fidelity. In ptychography, the illumination has been extended from plane waves to spherical waves and specialized beam probes; combined with advances in reconstruction algorithms, high-resolution, large-field-of-view phase retrieval has been achieved in both transmission and reflection modes. Terahertz computed tomography has surpassed lateral and axial resolution limits using super-oscillatory lenses and Bessel beams, respectively, while imaging efficiency has been enhanced through sparse-angle reconstruction and two-dimensional galvanometer scanning. Focal-plane imaging technology has overcome early signal-to-noise limitations through dynamic subtraction, differential detection, and quasi-near-field techniques, enabling a wide range of applications including real-time wavefront characterization, metasurface functional verification, and polarization/spectral imaging of chemical substances and biological tissues. Pulse time-domain holography fully leverages the advantages of broadband coherent detection, demonstrating unique capabilities in material parameter extraction and the analysis of structured beam propagation dynamics. Single-pixel imaging, based on spatial light modulation and computational reconstruction, employs optically controlled modulation materials such as silicon, vanadium dioxide, and graphene to achieve high-speed encoding, leading to diverse functionalities including real-time dynamic imaging, near-field super-resolution imaging, and integration with spectral and time-of-flight imaging. Near-field microscopy encompasses three main technical approaches: aperture-type, photoconductive probe, and scattering-type. Significant application progress has been made in areas such as carrier distribution in two-dimensional materials, surface plasmon polariton mapping, dielectric contrast in phase-change materials, and biomedical imaging, achieving resolutions down to tens of nanometers.

Leveraging its non-ionizing, high sensitivity, and fingerprint spectrum properties, terahertz imaging has demonstrated unique value in fields such as security screening, biomedical diagnosis, and industrial non-destructive testing. Current technologies still face challenges in resolution, speed, and system integration. Through the integration of deep learning algorithms, hardware innovation, and multimodal approaches, terahertz imaging is expected to continue advancing toward real-time, high-precision, and portable applications.

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Keywords: Terahertz, imaging, continuous-wave, focal-plane, time-domain holography, single-pixel, near-field

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Prof. Nikolay Petrov's research group focuses on areas such as holography, wavefront shaping, femtosecond optics, and terahertz imaging.
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Prof. Yan Zhang's research group focuses on photonic crystal device design, terahertz spectroscopy and imaging, surface plasmon optics, and optical information processing.
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