UCLA Samueli
Electrical & Computer Engineering

Ph.D. Defense

High-throughput fiber-coupled plasmonic terahertz spectroscopy systems



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Engineering Bldg. IV – Faraday Room #67-124

Abstract Terahertz time-domain spectroscopy (THz-TDS) has become a vital tool in biomedical diagnostics, security screening, and non-destructive inspection. Terahertz photon energies match molecular rotational and vibrational transitions yet remain non-ionizing, allowing samples to be probed without damage. By coherently measuring the terahertz electric field in the time domain, THz-TDS extracts a material's complex refractive index over a broad frequency range. Conventional systems, however, are built around free-space femtosecond lasers and mechanical delay lines, making them bulky, alignment-sensitive, and confined to specialized laboratories. This work presents two fiber-coupled THz-TDS architectures that address these limitations. The first is a compact, telecom-compatible system based on bias-free plasmonic photoconductive nanoantenna arrays, driven by a femtosecond fiber oscillator and a custom pair of polarization-maintaining fiber amplifiers. A fiber-coupled motorized delay line rapidly scans the pump–probe delay, and real-time readout of the stage position compensates for timing errors introduced by high-speed motion, enabling reliable, high-throughput measurements in a small footprint. Operating at 1550 nm, however, imposes a trade-off, since the narrow bandgap of photo-absorbing substrates results in low dark resistance levels, which degrade the radiation efficiency of photoconductive sources and the detection sensitivity of photoconductive detectors used in THz-TDS systems. The second system is designed to operate at 800 nm, where wider-bandgap, higher-dark-resistance photo-absorbing substrates enable higher-performance photoconductive terahertz sources and detectors. Hollow-core anti-resonant fiber delivers high-power femtosecond pulses almost entirely through air, avoiding pulse broadening from chromatic dispersion and nonlinear distortion. The resulting system, the first fiber-coupled high-optical-power THz-TDS system operating at 800 nm, uses plasmonic nanoantenna arrays for terahertz generation and detection, offering significantly higher dynamic ranges compared with commercially available fiber-coupled THz-TDS systems. Finally, a developed THz-TDS system based on plasmonic nanoantenna arrays is integrated with deep neural networks for pixel-level identification and classification of pharmaceuticals and explosives. Using a pulse-based chemical classification method resilient to environmental variations and sample inconsistencies, the system achieved an average accuracy of 88.83% in identifying concealed chemicals beneath opaque paper, demonstrating strong generalization and highlighting the promise of pairing terahertz spectroscopy with neural networks for sensitive and specific chemical detection in operationally relevant settings.

Biography Xinghe Jiang received his B.S. degree in Electronics and Information Science and Technology from Peking University in 2018 and his M.S. degree in Electrical and Computer Engineering from the University of California, Los Angeles (UCLA), in 2020. He joined the Terahertz Electronics Laboratory in the Department of Electrical and Computer Engineering at UCLA in 2020 to pursue his Ph.D. degree. His research primarily focuses on fiber-coupled terahertz time-domain spectroscopy and terahertz time-domain imaging for chemical identification.

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