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Bridging the THz Gap with Photonics-Integrated Transmission Lines

RESEARCHERS

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REFERENCES

1. S. Rajabali and I.-C. Benea-Chelmus, APL Photonics **8**, 080901 (2023).
2. Y. Lampert et al. Nat. Commun. **16**, 7004 (2025).
3. I.-C. Benea-Chelmus et al. Optica **12**, 546 (2025).
4. H. Feng et al. Nature **627**, 80 (2024).

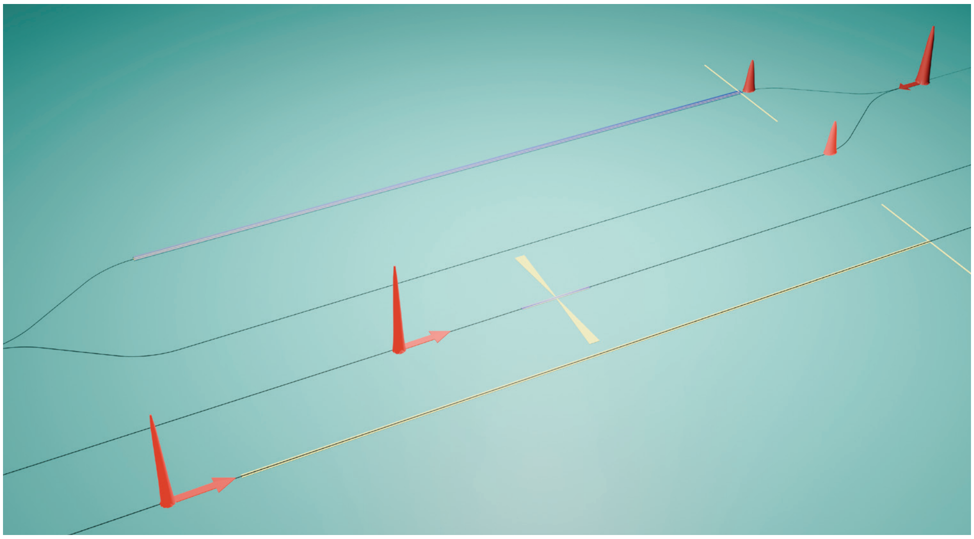
Terahertz (THz) radiation, occupying the spectral region between microwaves and infrared, has long promised transformative applications in wireless communications, spectroscopy, noninvasive imaging and security screening. Yet progress has been limited by the absence of compact, efficient and scalable systems capable of both generating and detecting THz waves with sufficient bandwidth and sensitivity. Conventional free-space approaches remain bulky and alignment-sensitive, while electronic solutions struggle to cover the full THz range. Bridging this long-standing "THz gap" requires an integrated photonic platform that delivers broadband, on-chip performance.[1]

In this work,[2] we demonstrate a photonics-integrated architecture that supports versatile THz operation. By co-propagating femtosecond optical pulses with guided THz waves, our design achieves phase-matched interaction over extended lengths, with bandwidths approaching 3.5 THz. The platform withstands high optical powers as it does not suffer from two-photon absorption, an intrinsic limitation of conventional semiconductor materials such as silicon and indium phosphide.

THz generation in our system begins with an optical pump pulse propagating through the waveguide, driving a nonlinear response that produces broadband THz radiation. The generated THz field is coupled into a transmission line and emitted through an integrated antenna. To realize a THz cavity, we operate the ends of the transmission line as open circuits and place the antenna in the center of the cavity to extract the desired modes and demonstrate resonant behavior.

THz detection is achieved via chip-assisted electro-optic sampling. Here, incident THz radiation is guided into the transmission line and overlaps with a co-propagating femtosecond optical probe. The THz field induces a phase modulation in the probe proportional to the instantaneous electric field. By scanning the delay between THz and probe pulses, we fully reconstruct the temporal THz waveform—realizing broadband detection within the same platform that provides generation.

Our photonics-integrated THz transmission lines provide a practical route toward compact, broadband and scalable THz systems. The platform's versatility paves the way for next-generation wireless communications, high-resolution spectroscopy, quantum sensing[3] and ultrafast signal processing.[4] OPN



Bottom device: An optical pump pulse is guided along a photonic waveguide. Inside the metallic THz transmission, engineered phase matching enables efficient THz generation, which is emitted into free space by a dipole antenna. Middle device: The transmission line operates as cavity and the antenna in the center extracts the anti-resonant modes. Top device: Incident THz radiation is collected by the antenna and interacts with the optical probe propagating along the transmission line, leading to phase modulation. Interference at the waveguide combiner converts this phase modulation into an intensity change, which is detected by a photodiode.