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(G) High-sensitivity detection of terahertz radiation by parametric frequency upconversion

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The terahertz (THz) frequency band, lying between the microwave and infrared regions of the electromagnetic spectrum, has enabled significant developments in a variety of fields such as wireless communications, product quality control, and condensed matter research. To improve the photonics systems used for these applications, intense efforts are being made to develop faster and more sensitive THz detectors. Conventional detection schemes relying on semiconductor devices fail at frequencies above 1 THz due to limited electronic response time and thermal fluctuations at room temperature. The highest sensitivity THz detection schemes presently available, such as superconducting tunnel junctions and single-quantum dot detectors, require cryogenic operation, making them expensive and cumbersome to use. Here, we demonstrate a high-sensitivity room-temperature detection scheme for THz radiation based on parametric frequency upconversion of the THz radiation to higher frequencies (in the near-infrared (NIR)), preserving the spatial, temporal, and spectral information of the THz wave. The upconverted photons, generated by the mixing of a THz pulse with a NIR pulse in a nonlinear optical crystal, are spectrally resolved using a monochromator and a commercial single-photon detector in the NIR. With this technique, we can detect THz pulses with energy as low as 1.4 zJ (1 zJ = 10⁻²¹ J) at a frequency of 2 THz (or a wavelength of 150 μm) when averaged over only 50k pulses. This corresponds to the detection of about 1.5 photons per pulse and a noise-equivalent power of 1.3 × 10⁻¹⁶ W/Hz^{1/2}. To demonstrate potential applications of our system, we perform spectroscopy of water vapor between 1 and 3.7 THz with a spectral resolution of 0.2 THz. Our technique offers a fast and sensitive alternative to current THz spectroscopy techniques and could notably be used in future wireless communication technologies.

Keyword-1

Terahertz detection

Keyword-2

Frequency upconversion

Keyword-3

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