Time-Domain Pulsed THz Near-Field Scanning Microscope with ~ λ/50 Resolution

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The technique of time gating single-cycle picosecond pulses is known to have several advantages over continuous wave (CW) methods in far-infrared spectroscopy. Because the short pulses have a very broad frequency content typically peaked around 1 THz, a large spectral range can be covered simultaneously with a single source. Also, because measurements are in the time domain, full phase information is maintained when performing a Fourier transform, something generally not done with CW methods. The absorption resonances many chemicals, dielectrics, and organic materials have in the THz frequency range make THz spectroscopy very useful.[1] Unfortunately, with a free-space wavelength of order ~300 μm, diffraction-limited THz spectroscopy lacks the spatial resolution necessary to study the internal structure of electronic devices and biological cells. To do this requires resolution < 10 μm.

We have adapted near-field optical methods to construct a time-domain pulsed THz scanning microscope with spatial resolution well below the diffraction limit. Using an antenna-coupled low-temperature grown GaAs photoconductive switch, we generate single-cycle pulses having a spectrum that peaks near 600 GHz (500 μm) with a ~ 300 GHz half-width. These pulses are broadcast through free-space and detected by a second synchronously time-gated photoconductive switch. The high spatial resolution is achieved by fabricating a sub-wavelength aperture integrated on the chip face opposite the detector switch. The sub-wavelength aperture is a 10 to 50 μm lateral dimension, ~ 1 μm high GaAs protrusion in a surrounding thick Au screen. The aperture is place between 5 to 50 μm from the detector switch by polishing down the GaAs wafer.

Our most recent measurements show that a minimum aperture dimension of 10 μm can produce an acceptable signal-to-noise ratio > 10 dB when placed < 10 μm in front of the detector. Under these conditions, the spatial resolution is set by the aperture size, not by the diffraction limit or by the exact aperture-to-detector distance. Resolution tests performed by scanning across the edge of a patterned Au film on a sapphire substrate showed a resolution of 11 μm based on a 10% to 90% intensity rise criterion. This corresponds to approximately λ/50, using the peak 600 GHz for λ. Scanning across a metal edge, the resolution is polarization dependent, with higher resolution when the polarization is parallel to the edge. The aperture is also observed to act as a high-pass filter for the transmitted pulse, attenuating strongly the frequency content below ~ 300 GHz. Details of the techniques and results will be presented.

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[1] S. Hunsche, D. M. Mittleman, M. Koch, and M. C. Nuss, IEICE Trans. on Electronics **E81C**, 269 (1998)