Knife Edge Measurement of Tightly Focused Terahertz Pulses

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We conducted an experiment equivalent to the knife edge test of a focused optical beam to observe the spatial distribution of a focused THz beam. As shown in Fig. 1, the THz beam emitted from a large aperture photoconductive (LAP) antenna was first focused by an off-axis parabolic mirror (50.8 mm focal length) and an aluminum plate (200 μm in thickness) was inserted perpendicular to the propagation axis at the focus. The origin of x is taken at the optical (high-frequency-limit) focus. Using two identical mirrors, the THz beam was steered to be focused to the ZnTe crystal for an EO sampling setup, which enabled us to measure the temporal waveform of the THz pulses as the edge moves along the x axis.

Figure 2 shows the THz waveform change as the edge moves along the x axis. The most striking difference in these waveforms is that the amplitude of the oscillations after the main peak seen in data $x = -0.5$ mm drastically decreases in $x = 0.5$ mm. These oscillations are trails of water vapor absorption in air (peak resonance at 1.7 THz). This confirms that the 1.7 THz component of the pulse was distributed tightly near the optical focus point $x = 0$.

The Fourier transforms of the acquired waveforms were calculated and the amplitudes for each frequency were plotted with respect to x , which is shown in Fig. 3. This figure corresponds to the spatial distribution of the beam at the focus integrated by x. Thus the data are fitted by error functions which correspond to Gaussian spatial profiles and are also shown. The agreement of the data to the fits shows that the spatial distribution of the focused beam has a near Gaussian spatial profile for each frequency.

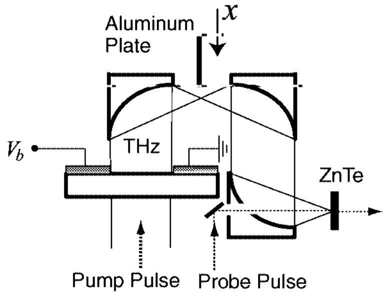

Fig. 1: The experimental setup for the knife edge measurement. Axis x is the path which the edge of the aluminum plate passes through. The origin of x is taken as the optical focus of the mirror.

In conclusion, we have experimentally confirmed that a THz beam generated from a LAP antenna can be steered by mirrors and tightly focused to form a high peak field pulse. The f-number for this focusing action is 1.7, which enables us to obtain a high peak THz pulse. In this setup, we observed peak THz field as high as 11.1 kV/cm, with a pulse width of 650 fs. The distribution of frequency components at the focus was observed and higher frequency components was found to be focused to a smaller area. The focused THz beam was shown to have a near Gaussian spatial profile for each frequency. Knowing the focusing features of the high peak THz field obtained, we can apply this THz field to the observation of nonlinear THz responses of various materials.

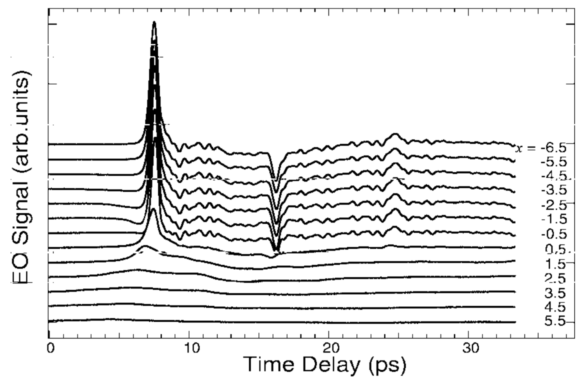

Fig. 2: THz field waveform change with distance x (mm). Each data set is shifted vertically.

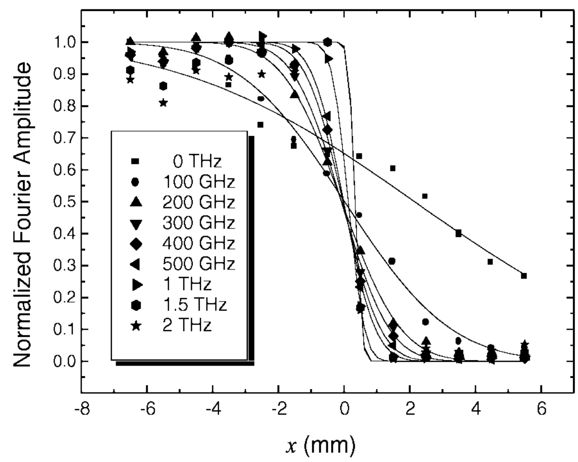

Fig. 3: Integrated spatial distribution of the THz pulse for each frequency. The symbols show the actual data, curves are the error function fits to the data.