Spatio-temporal waveform of focused half-cycle THz pulses

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Abstract: Spatio-temporal intensity distribution of focused nearly half-cycle THz pulses was observed using a THz imaging setup with an expanded probe beam. Ring-like distribution away from the peak position in space or in time was observed.

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Information on the waveforms of terahertz (THz) pulses in space and time is important for their applications such as imaging and nonlinear spectroscopy. The waveform of THz pulses is easily deformed by free-space propagation and/or focusing since THz pulses contain significant contribution of low-frequency components with wavelengths not sufficiently short compared with the size of the optical setup [1,2]. We studied the spatio-temporal behaviors of the THz waveforms using a new image-acquisition system, and observed ring-like spatial distribution of the intensity of focused half-cycle THz pulses at positions in space or in time away from the peak.

The nearly half-cycle THz pulses were generated from a biased large-aperture GaAs antenna pumped by a 150-fs amplified Ti:sapphire laser pulses. The pump beam had a nearly Gaussian spatial profile with a $1/e$ radius of 9.2 mm. The output THz pulses were focused by an off-axis parabolic mirror with a focal length of 152.4 mm. The spatial distribution of the THz intensity on a plane perpendicular to the propagation direction was obtained by a fast-acquisition imaging system. The system is composed of a ZnTe crystal, a spatially expanded probe beam, a pair of polarizers, and a CCD camera.

The spatio-temporal distribution of the THz intensity was found to form a single peak around the focus at $t = 0$. On the other hand, as shown in Figs. 1 and 3, we found a ring-like spatial distribution at times or positions away from the peak [3]. The observed features were reproduced by simulations based on the diffraction integral with no adjustable parameters, as shown in Figs. 2 and 4. Simulations showed that these features are unique for the nearly half-cycle pulses and not observed with optical pulses with durations of many field oscillation periods.

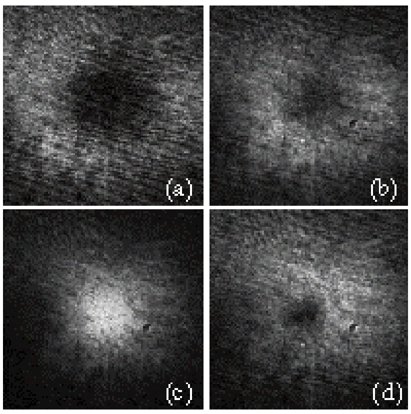

Fig. 1. Experimentally observed time-resolved spatial distribution of THz intensity on the focal plane at t = (a) –0.72 ps, (b) –0.48 ps, (c) 0 ps, and (d) 0.4 ps. The image size is 12 x 12 mm^2.

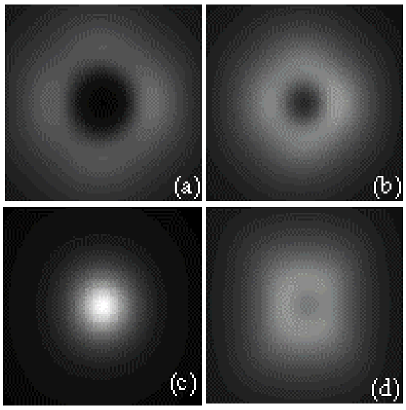

Fig. 2. Simulation results obtained by diffraction integral calculations. Images (a)-(d) correspond to the experimental ones shown in Fig. 1 (a)-(d), respectively.

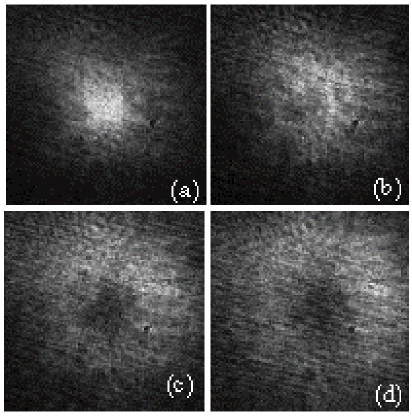

Fig. 3. Experimentally observed spatial distribution of THz intensity with the delay time fixed at 0 ps on the plane at (a) 0 mm, (b) 20 mm, (c) 40 mm, and (d) 50 mm away from the focal plane. The image size is 12 x 12 mm^2.

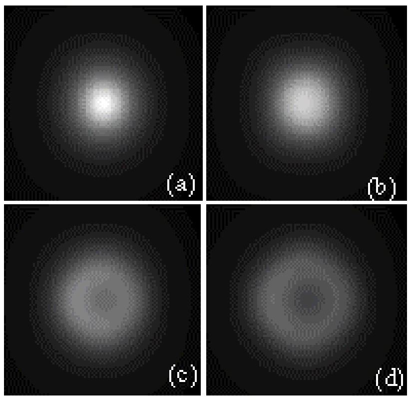

Fig. 4. Simulation results obtained by diffraction integral calculations. Images (a)-(d) correspond to the experimental ones shown in Fig. 3 (a)-(d), respectively.

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