

# Four-wave rectification and generation of terahertz radiation in air

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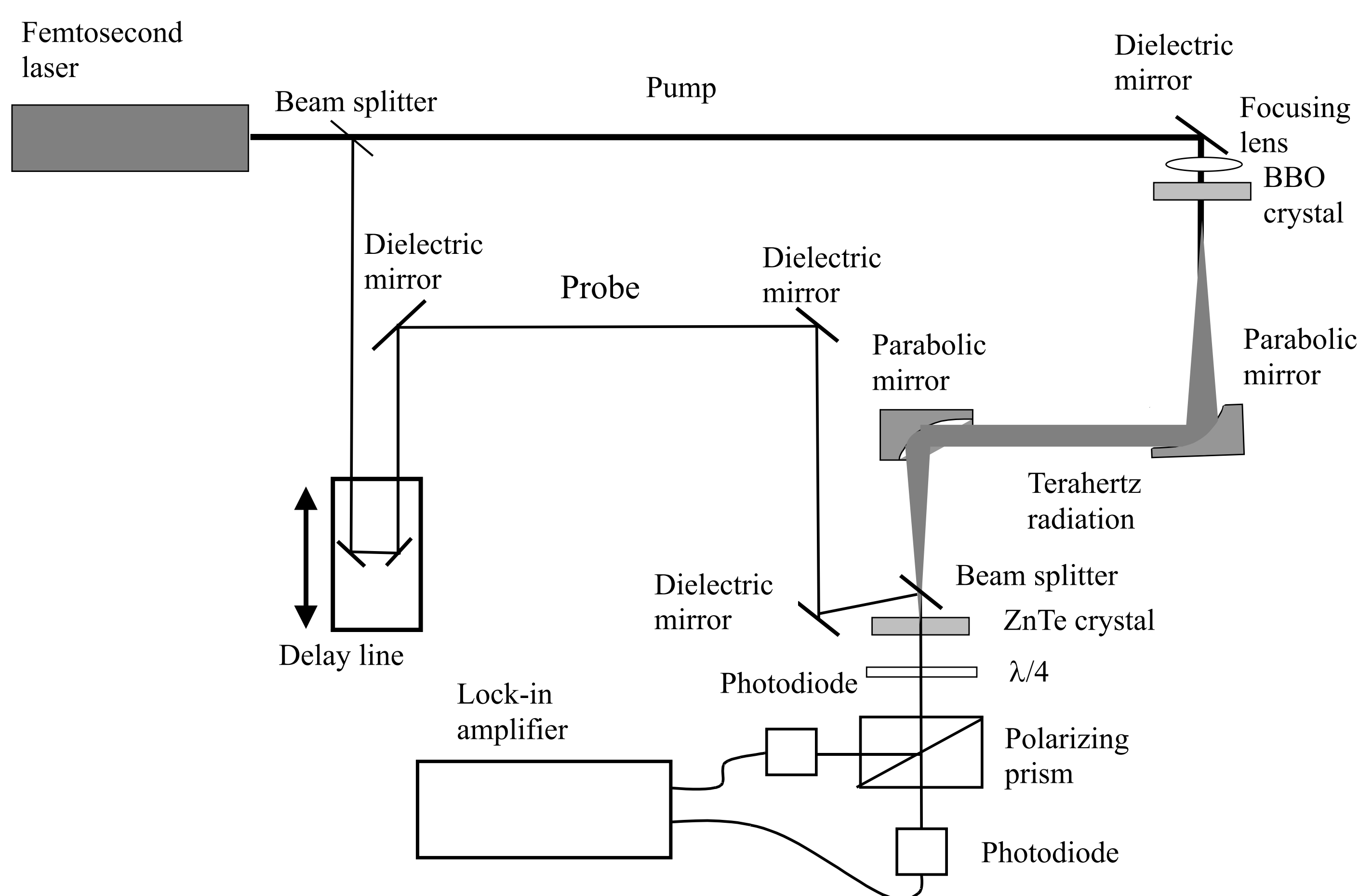
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## Abstract

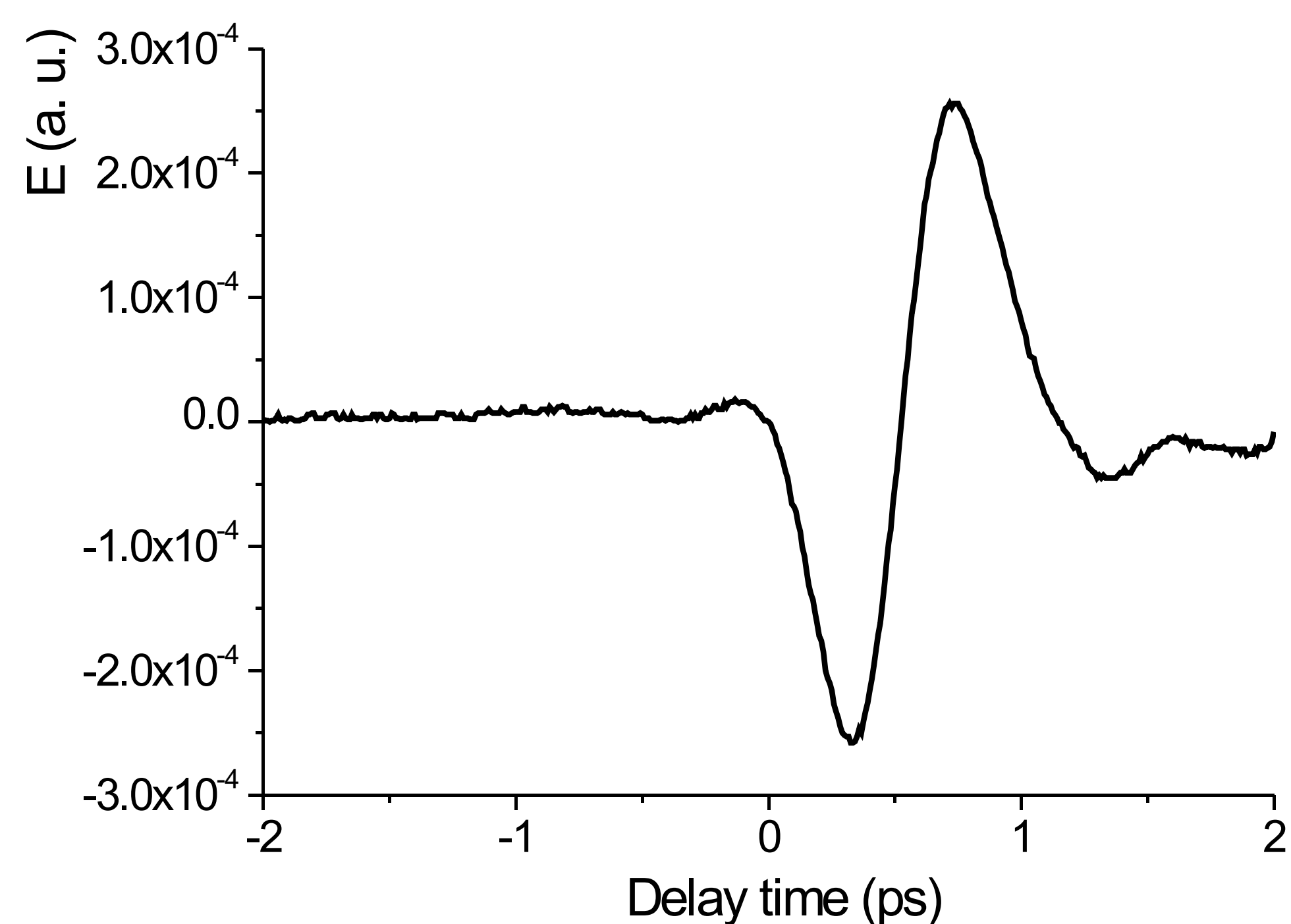
We report the efficient generation of terahertz radiation by four-wave rectification in air. For the excitation of air both the focused fundamental and second harmonics of femtosecond Ti:sapphire laser (single pulse energy about 1 mJ, duration about 120 fs, central wavelength 804 nm, repetition rate 1 kHz) have been used.

The properties of generated radiation were analyzed using the linear electro-optic effect in ZnTe crystal and the weak femtosecond probe pulse: the electric field of terahertz pulses modified the refraction index of the crystal and consequently the probe pulse changed its polarization. These changes were registered using two photodetectors and a lock-in amplifier. By varying the delay between the terahertz and probe pulses in the crystal it was possible to register directly the temporal profile of the electric field of terahertz pulses. The spectra of these pulses were obtained by applying the Fourier transform to these temporal profiles.

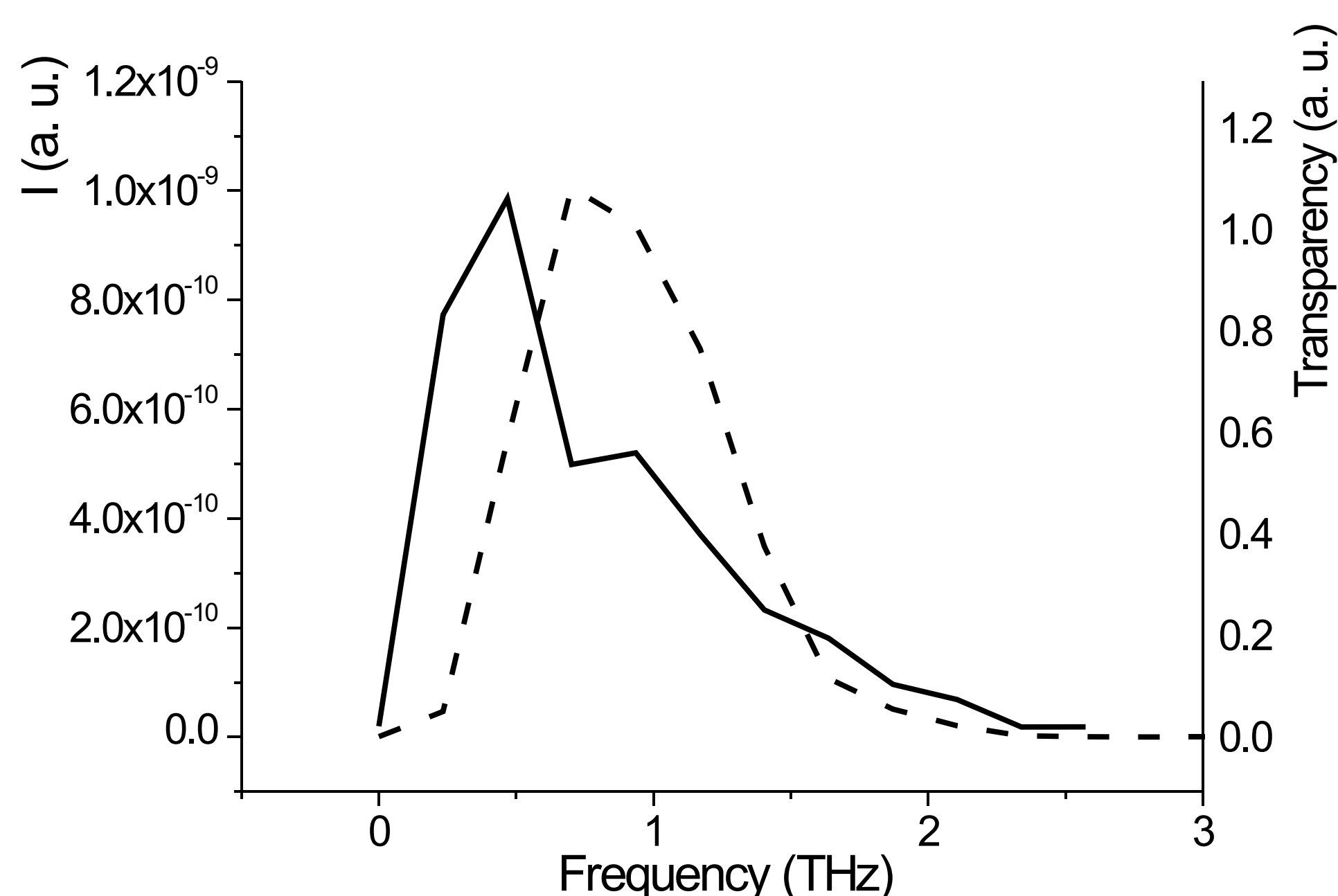
Since all measurements were automated under the control of the personal computer the



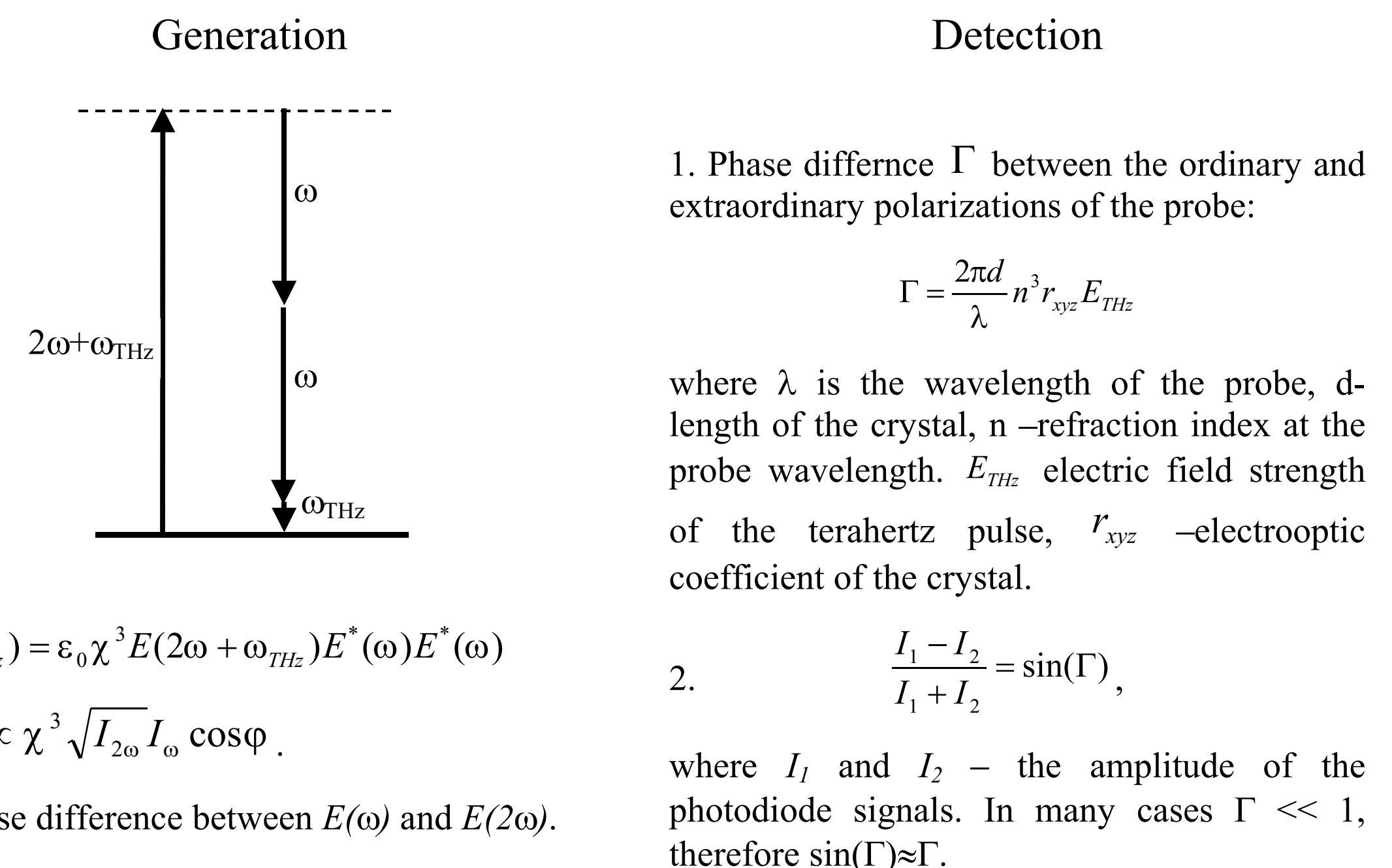
Experimental setup.



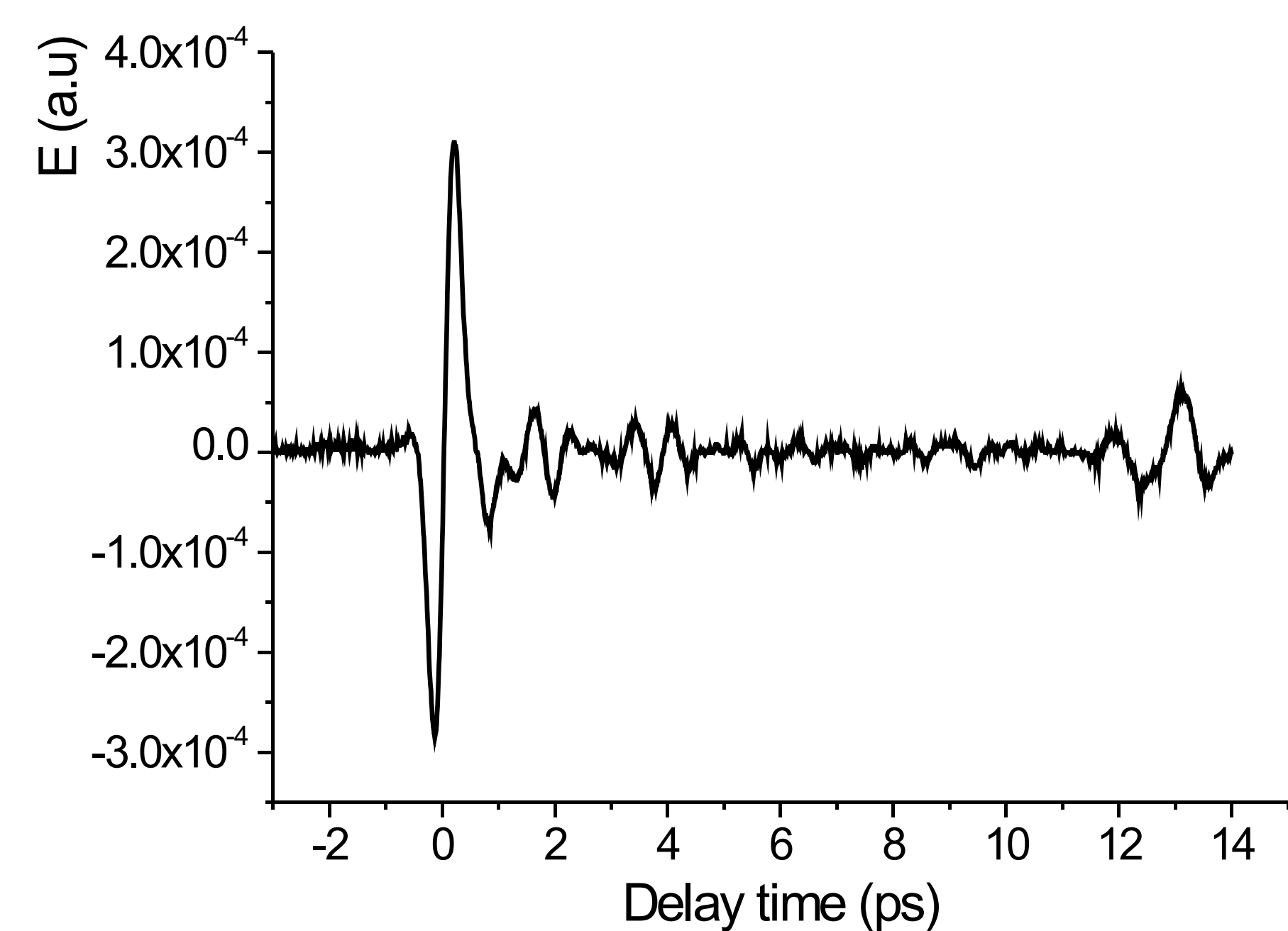
Waveform of the terahertz pulses transmitted through the 0.5 mm thick black paper.



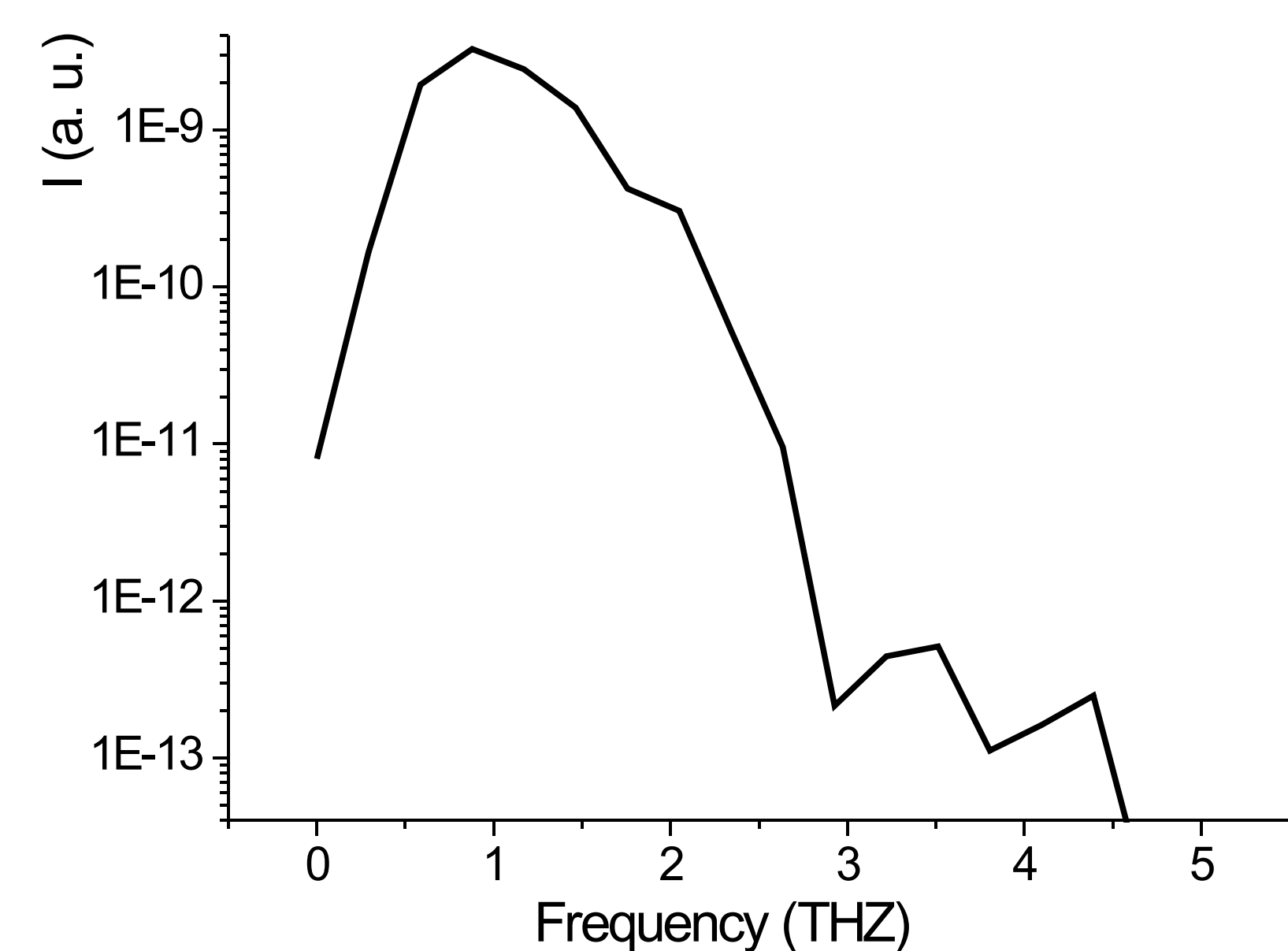
Spectrum of the terahertz radiation transmitted through the 0.5 mm thick black paper (solid line) and transmittance of the paper (dashed line).



The main equations and wave vectors diagram illustrating the four-wave rectification in gases.



Typical pulse shape of the terahertz radiation generated in air.



Typical spectrum of the terahertz pulses generated in air.

## Conclusions

The most efficient generation of terahertz radiation can be achieved using the 0.3 mm thick second harmonic BBO nonlinear crystal. The signal/noise ratio of the generated signal usually exceeded 100, while the duration of the generated terahertz pulses was a few picoseconds. The Fourier analysis of these pulses showed that their spectral range spans from 0.1 to 4 THz.

The maximal electric field strength obtained during the experiments exceeded 1 kV/cm<sup>2</sup> with the total energy of about 10<sup>-6</sup> J. Thus the energy conversion efficiency was about 0.24x10<sup>-8</sup> and thus the total energy conversion efficiency exceeded 10<sup>-6</sup>.

During the experiments the performed preliminary spectroscopic measurements of some materials (polyethylene, paper and some nonlinear crystals) were performed demonstrating the potential possibilities of the created system as a spectroscopic tool.

## References

Molis G., Krotkus A., Vaičaitis V., "Intervalley separation in the conduction band of InGaAs measured by terahertz excitation spectroscopy", Applied Physics Letters 94 (9), Article Number 091104 (2009).