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Spatial-temporal dynamics of the terahertz field generated by femtosecond filament

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Spatial-temporal dynamics of the terahertz field generated by femtosecond filament

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Abstract. We present the study on spatial distribution of the maximum of terahertz field amplitude in time domain when generated by a femtosecond filament. It is shown that as a result of the propagation of the terahertz field forms a spherical wave front, on the edge of which the maximum of amplitude has a temporary delay in contrary to its central part.

1. Introduction

In recent years there has been a significant shift in the field of terahertz studies due to the development of femtosecond lasers and microelectronics. The difficulty of obtaining electromagnetic radiation in the terahertz frequency range is that in microwave it is practically impossible to produce radiation at frequencies much greater than several hundreds of GHz due to modification of the emitters, although such radiation can be harmonically multiplied to terahertz range. Currently, three methods of producing extremely short THz pulses with femtosecond laser sources are the most developed: generation in the surface layer of semiconductors (photoconductive antenna) [1, 5-11], nonlinear optical difference frequency generation and optical rectification [4, 12-14] and generation using a femtosecond filament in gases [2, 3, 19, 20]. This paper considers the dynamics of the spatial-temporal distribution of the terahertz field generated by a femtosecond filament.
Ultrashort THz pulses have the potential for internal and external communications in integrated circuits, for time-resolved spectroscopy in far-infrared and chemical determination of the composition of complex compounds for the detection and localization of explosives and other non-metallic substances which are nondifferentiable in other ranges of electromagnetic radiation, and also for creating THz radars for THz time-resolved imaging.

2. Experimental setup

The experimental setup is shown in figure 1. The radiation from a femtosecond laser system Regulas 31F (FL) is divided by the beam splitter at a ratio of 5% (probe beam) and 95% (pump beam), respectively. The pump beam passes through the optical modulator (ch) and lens F = 10 mm (L), and in the caustic a femtosecond filament with the length of 1 cm is formed. Diverging from the central point of the filament, the terahertz radiation is collimated by a parabolic mirror (PM). The collimated beam passes through the scanning diaphragm (D). After that, radiation is focused by a lens (L) to the electrooptical crystal (ZnTe).
The probe beam after the beam splitter passes phase plate L / 2, Glan prism (GP) and a delay line, and then reflected from the dichroic mirror (DM) and is sent to the path of electrooptical detection system consisting of electrooptical crystal (ZnTe), the phase-shifting plate λ/4, Wollaston prism (WP)

and the balanced detector (BD). The signal from the balanced detector was also detected at the operation frequency of optical-mechanical modulator (ch) using the lock-in amplifier (lock-in amp), then was digitized (ADC) and recorded on a computer (PC).

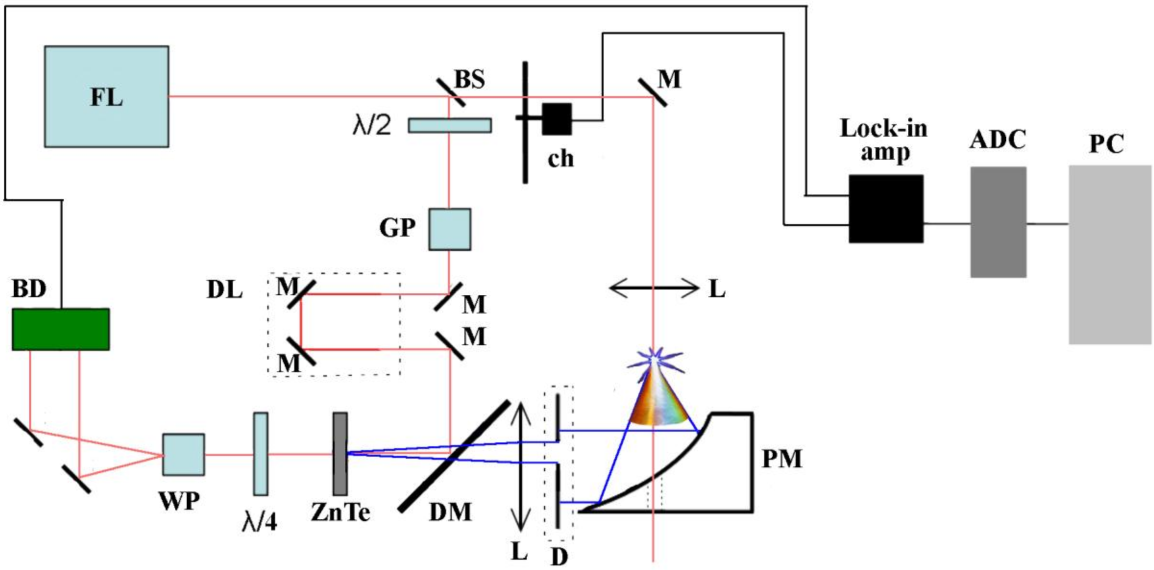


Figure 1. Schematic representation of the experimental setup

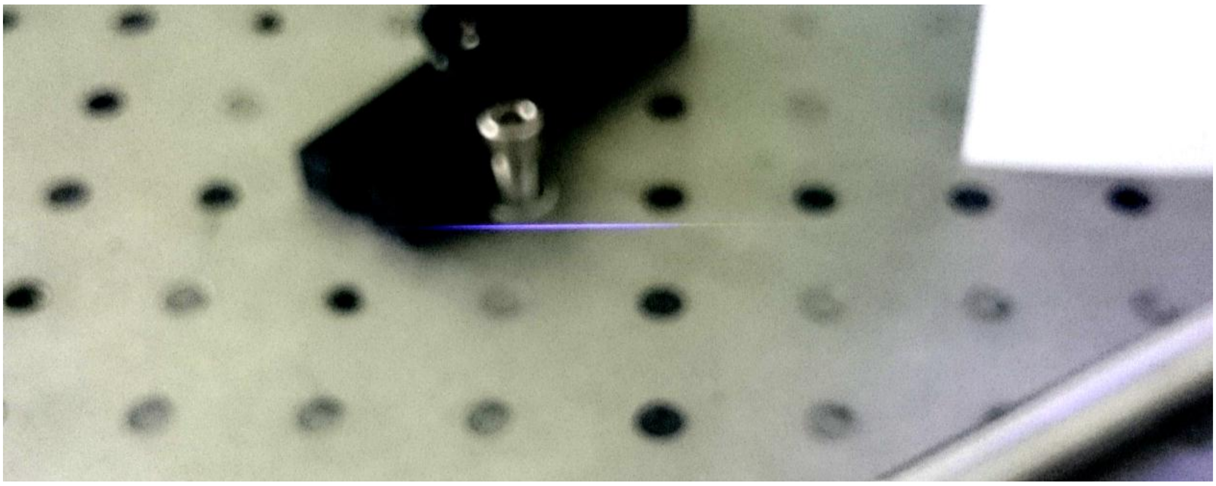
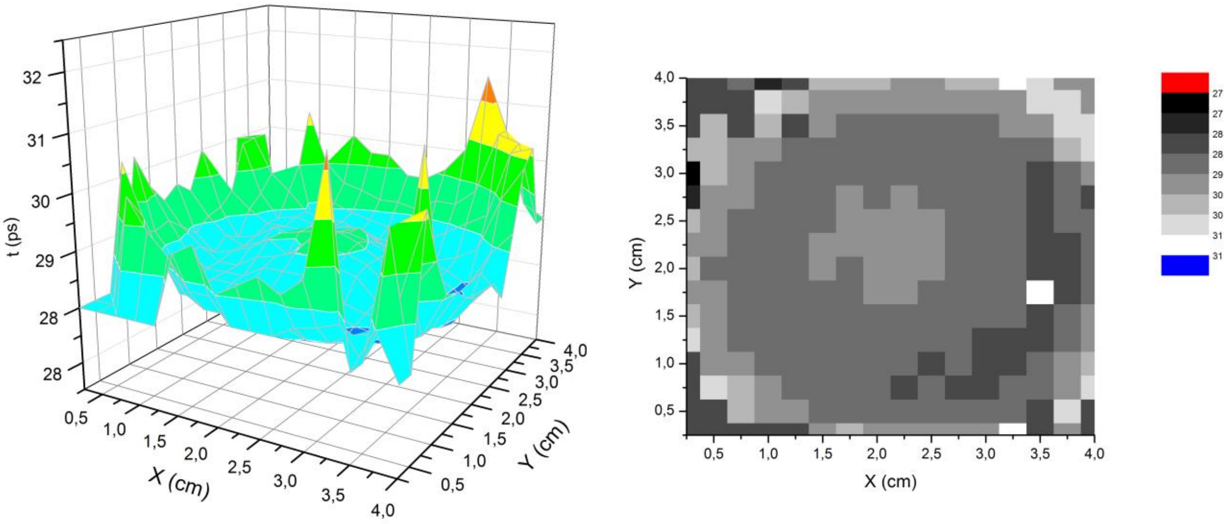


Figure 2. Photography Femtosecond filament

In the collimated terahertz beam between the parabolic mirror and the detection system path is placed scanning aperture with 5 mm diameter. THz field measurements were performed by raster scanning with moving increment of 2.5 mm, using a program written in the program environment of LabVIEW. Measurements were performed when taking into account the optimal parameters of raster scanning of THz field to optimize the experiment time without losing quality signal recovery [15].

3. Results

Figure 3 shows the experimental results of the spatial distribution of the maximum of terahertz field in time domain. This time-of-flight images show that there is a time delay between the maximum of amplitude of THz field and it has a spherical form. Probably, the temporary shift occurs due to the interference of the terahertz field generated by the various points of a femtosecond filament and it requires further research.



a) б)

Figure 3. Spatial and temporal distribution of the maximum amplitude of the THz field in time domain (time-of-flight pictures). a) side view, b) top view

4. Conclusion

As a result, the THz pulse time-of-flight structure in dependence of the spatial location of the generated THz field at filamentation was demonstrated.

Acknowledgments

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