Multiple filamentation of laser beams with different diameters in the air at a 100-meter path

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ABSTRACT

Results of experiments on controlling the position and length of the filamentation zone of femtosecond laser pulses in atmospheric path length 110 m using different initial spatial focusing and defocusing. The obtained distribution of filaments along the filamentation zone, measured dependence the length of the filamentation zone of the numerical aperture of the beam, its initial radius and pulse power.

Key words: laser radiation, femtosecond pulse, self-focusing, filamentation, atmosphere, focusing, defocusing, spectra

1 INTRODUCTION

The results of experiments on the position control filamentation zone terawatt pulses of the first harmonic of Ti:Sapphire-laser are resented. Pulse duration was τ = 50 fs, pulse energy is 80 mJ beam diameter is d_0 = 5, 2.5 and 1.25 cm (the level of e^{-2}), a pulse repetition rate is of 10 Hz on the path length of 110 m. Experiments were carried out on the stand of IAO SB RAS. The experimental scheme is shown in Figure 1. The spatial focus (defocus) of the laser beam with the telescope (5) consisting of a focusing (f_1 = 1000 mm) and defocusing (f_2 = -500 mm) mirrors, by varying the base (distance between the mirrors) of the telescope. The base of 500 mm corresponds to a collimated beam. Reducing the base defocused beam, increase the base focused. Sequence arrangement of mirrors leads to a decrease of the beam diameter is 2 times ($f_1 \rightarrow f_2$), either to the same increase it ($f_2 \rightarrow f_1$). The experiments were recorded beginning filamentation region, its end and the distribution of filaments within the region filamentation by a movable screen (13). The number of filaments was determined by the burns on photo paper.

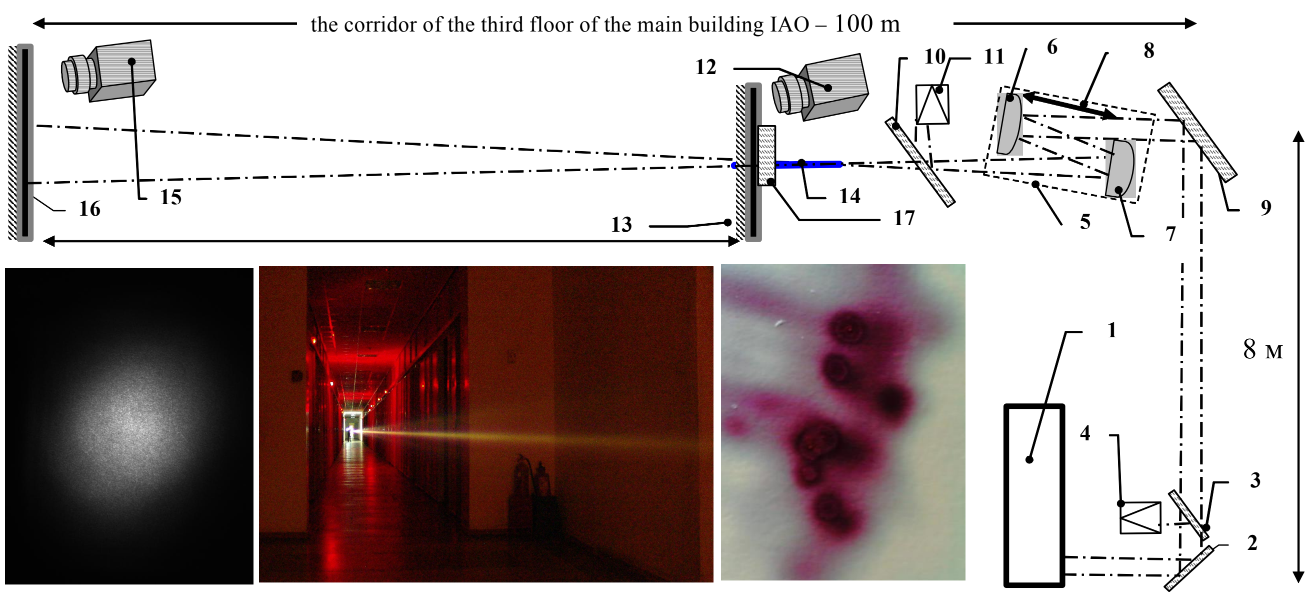

Figure 1 - Schematic of the experiment. 1 - Ti:Sapphire-laser system, the pulse duration τ = 50 fs pulse energy $E \leq 80$ mJ, $P \leq 1{,}5$ TWh, the wavelength λ = 800 nm; pulse repetition frequency ν = 10 Hz, beam diameter at the level of e^{-2} d = 1,25, 2,5, 5 cm; 2,3,9,10 - rotary plate; 4 - meter pulse duration (avtokorellyator); 5 - Telescope; 6 - defocusing mirror f_1 = -50 cm; 7 - focusing mirror f_2 = 100

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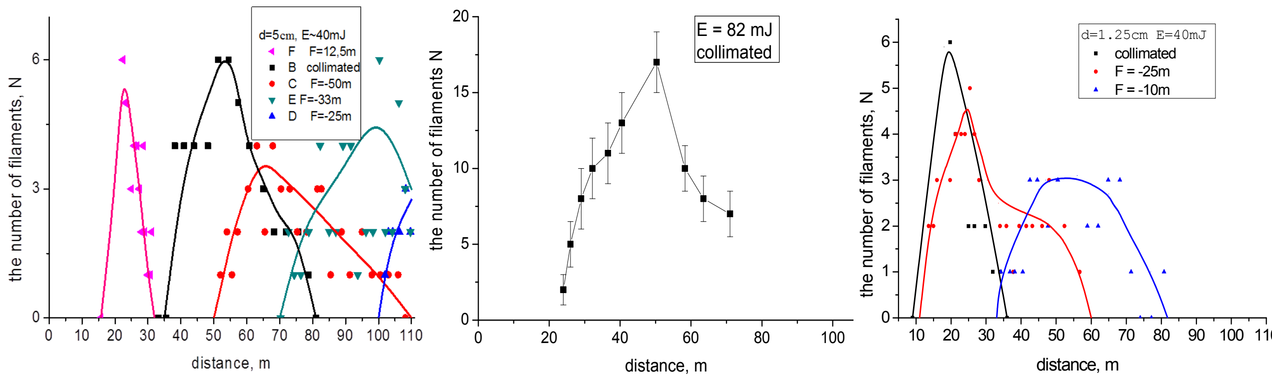
cm; 8 - the variable base of the telescope (the distance between the mirrors in = 50 cm corresponds to a collimated beam); 11 - energy meter pulse OPHIR-II; 12,15 - CCD-camera «ANDOR-Clara E», the lens HELIOS-44M 2/58, Camera Pentax K-3 (MP 25) with macro lens Pentax100MacroWR, spectrometer Maya-2000PRO; 13 - the movable screen for position filamentation region; 14 - filamentation region; 16 - fixed screen at the end of the route; 17 - examples of solid targets (Al, Cu, Fe, Na).

The inset in the figure (left to right) - transverse structure of beam, filamented beam on the track, burns on photo paper in filamentation.

2 EXPERIMENTAL RESULTS

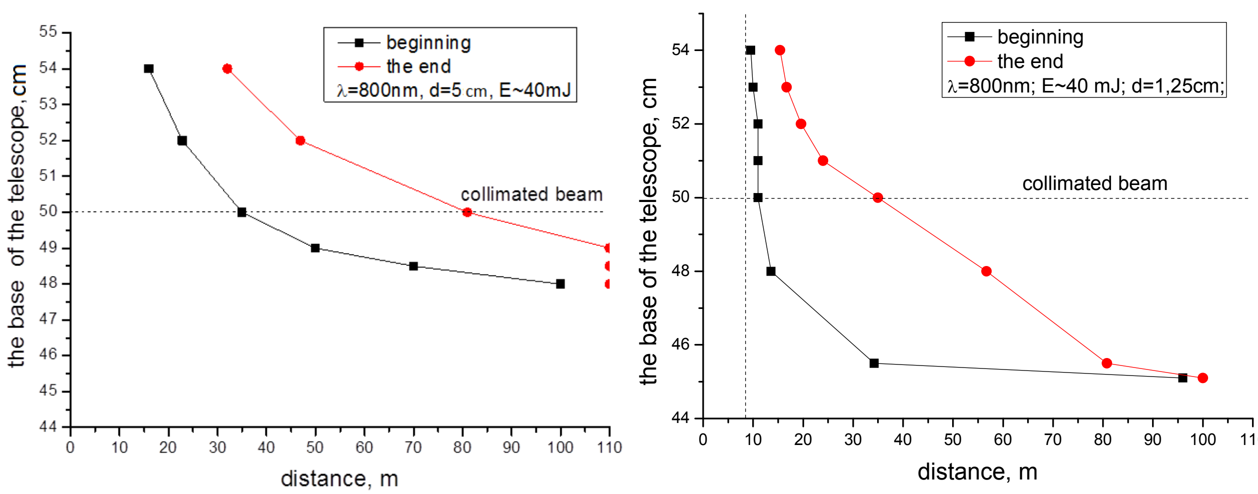
Figure 2 shows the number of filaments along the area at different initial filamentation focusing (defocusing). With an increase in the base of the telescope (fig. 2a-c) start and end of filamentation shifted towards the radiation source. Reduced base results in a displacement of the source region filamentation.



a) b) c)

Figure 2 - Distribution of the number of filaments inside area filamentation at different focusing (defocusing) beam diameter: a) 5 cm, b) 2.5 cm, and c) 1.25 cm.

Figure 3 shows the dependence of the position of beginning and end of the filamentation zone degree focus (defocus) beam. Image database telescope leads to increase in the length field of filamentation and shift start (end) regions filamentation towards the radiation source.



a) b)

Figure 3 - The position of the start and end of the filamentation field on the degree of -beam focusing or defocusing (changing the base of the telescope) laser beams with diameters – 5cm (a) and 1.25cm (b).

Figure 4 shows the dependence of the length of the field for different initial filamentation focusing (defocusing) for different beam diameters. It is seen that increasing the value of the numerical aperture leads to a decrease in the length field filamentation relative power increase and a decrease in the numerical aperture to increase the path length of the region filled with filaments (Fig 5).

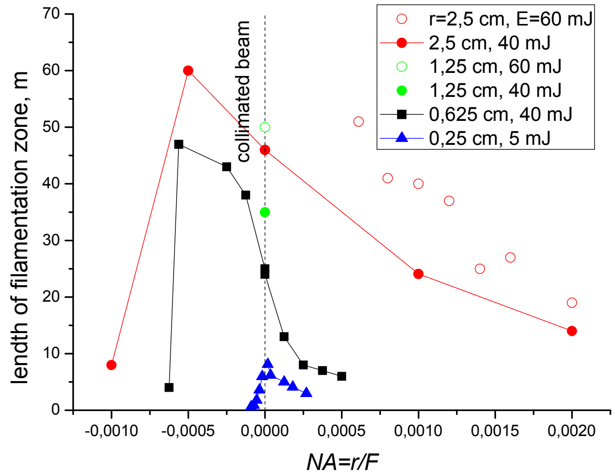


Figure 4 - Length field filamentation of numerical aperture for different pulse energies.

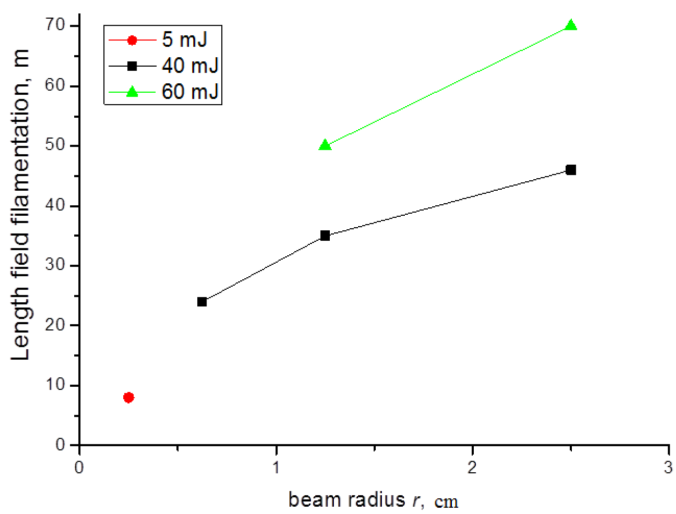


Figure 5 - Length field filamentation of initial radius of the collimated beam for different pulse energies.

Experiments were performed on remote induction plasma on target in the zone of the beam filamentation and identification of the elemental composition of the emission spectra. The measured emission spectra of the samples of metals (Al, Cu, Fe, Na) at a distance of 50m from the screen (16) to a collimated beam with energy of 40 mJ, are presented in Figure 6.

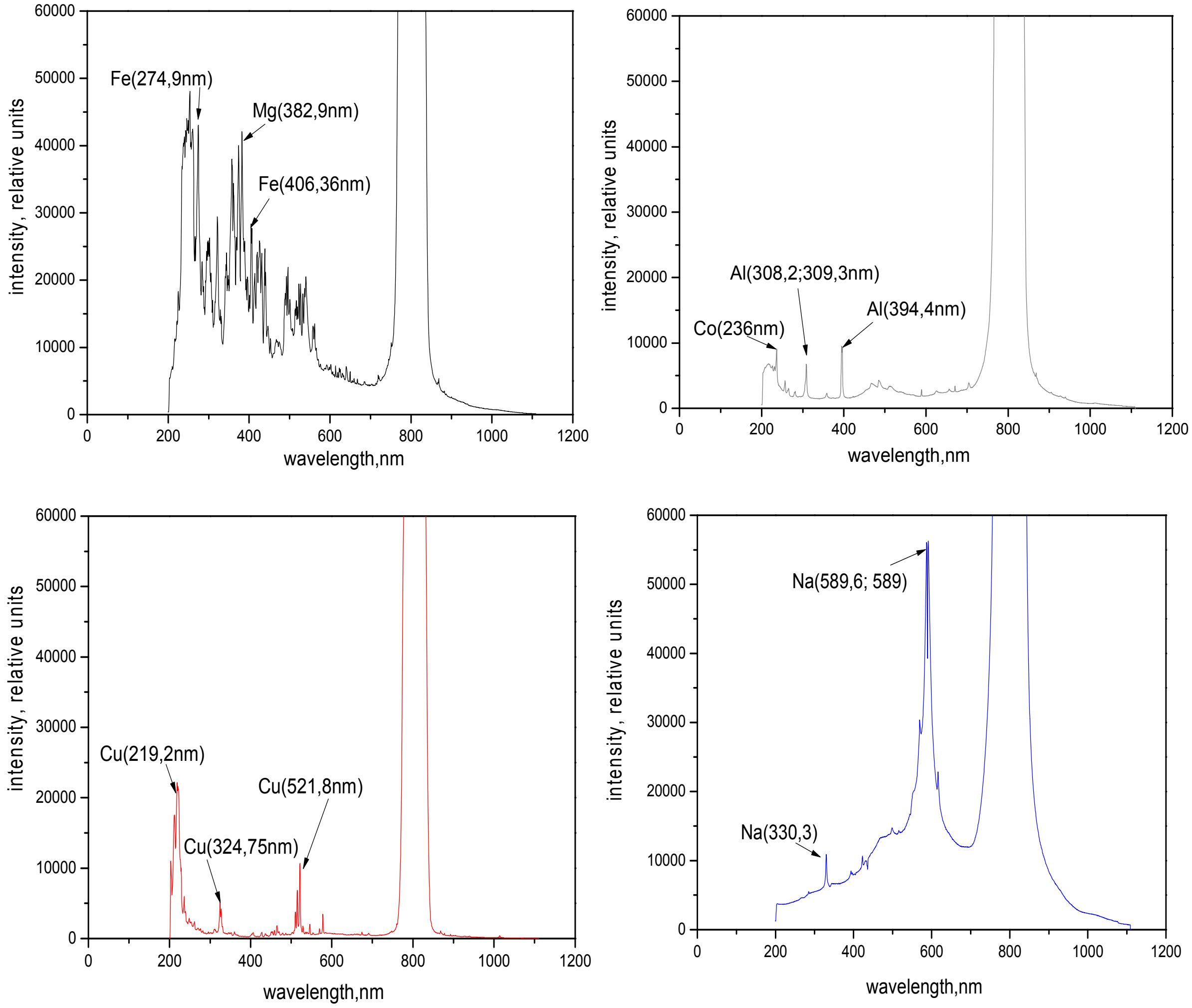


Figure 6 - Emission spectra of various samples of metals in the filamentation area at a distance of 50 m from the screen for a collimated beam.

In experiments on filamentation of laser beams in air shows that the variation of the beam diameter and its initial focus is to efficiently manage the situation in the field of multiple filamentation tracks scale of hundreds of meters. This defocusing the beam has limits. These levels depend on the diameter of the beam and its power, above which filamentation of the beam stops. Managed filamentation of the laser beam allows to form a predetermined distance from the source of the intensities of the optical field sufficient to induce the plasma on the targets for the analysis of the elemental composition.

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