Filamentation of collimated Ti:Sapphire-laser pulses in the glass

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ABSTRACT

The results of experiments to study the spatial characteristics of multiple filamentation gigawatt laser pulses in the glass are presented. It is shown that with increasing pulse power multiple filamentation region increases in length and diameter, the distribution of filaments within the region has a maximum value when the power > 10^5 P_{cr} area filamentation takes the form of a hollow cone, the apex directed to the source of the laser radiation.

Keywords: laser radiation, femtosecond pulse, self-focusing, multiple filamentation, glass

1 INTRODUCTION

Self-focusing and filamentation of laser radiation are attractive objects of research because their accompanying effects - localization of laser energy, supercontinuum generation, plasma formation have prospects of application in problems of atmospheric optics, optical of Ocean, nanooptics. At present, in sufficient detail researched and modeled the formation of single filaments, when implemented in all the self-focusing of the laser beam. [1] When multiple filamentation process of self-focusing and filamentation is not quantitatively described. In this paper, we investigate multiple filamentation in a model environment with strong cubic nonlinearity, allowing visually examine the characteristics of multiple filamentation. The experiments were conducted at the stands of IAO SB RAS and the IACP FEB RAS.

2 SCHEME EXPERIMENTS

The experiments laser light Ti:Sapphire-laser at the fundamental harmonic used. The experimental scheme and emission characteristics are shown in Fig. 1. The laser pulse sources (1a, b) directed to the sample (9) glass BK7, for which the cubic nonlinearity coefficient n_2 = 3,5 10^{-16} cm^2/W, the critical self-focusing power P_{cr} = 2 MW, it felt self-focusing, and achieving pulse energy ~ 2 mJ (44 GW) for a beam diameter of 7 mm, 10 mJ (200 GW) for a beam of 11 mm and 20 mJ (400 GW) for a beam of 25 mm, the area filamentation formed inside the glass sample.

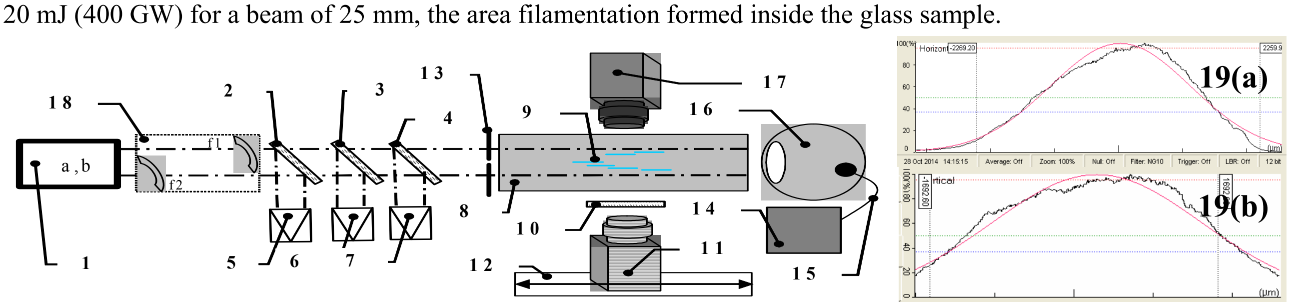


Figure 1 - Schematic of the experiment. 1(a) - a laser system (Spitfire Pro 40F, Spectra Physics): λ = 800 nm, E <5 mJ pulse repetition rate of 1 kHz,τ= 45 fs, the beam diameter (at the e^{-2}) d = 7 mm ; (b) - a laser system (the Avesta-Project) λ = 800 nm, E <45 mJ, the pulse repetition rate of 10 Hz,τ= 50 fs, the beam diameter at the inlet of the sample (at the e^{-2}), 25 and 11 mm ; 2,3,4 - rotary plate; 5 - autocorrelator PSCOUT PL-SP-LF, Spectra Physics; 6 - energy meter Spectra Physics 407A; 7 - meter beam profile LBP2-HR-VIS (Ophir); 8 - glass (length, width, height = 90, 60, 60 mm respectively); 9 - filamentation region; 10 - filter; 11 - CCD-camera «ANDOR-Clara E», the lens HELIOS-44M 2/58 on the motion control (M) -IMS Newport (12); 13 - Removable gap of 2 mm; 14 - spectrometer Maya-2000PRO; 15 - optical fiber; 16 - integrating sphere (Newport 819C-SF-6); 17 - Camera Pentax K-3 (25 MP) with macro lens Pentax100MacroWR; 18 - Removable Telescope (f_1 = 1000 mm, f_2 = -500mm); 19 - the structure of the laser beam in the horizontal (a) and vertical (b) the plane.

XII International Conference on Atomic and Molecular Pulsed Lasers, edited by Victor F. Tarasenko, Andrey M. Kabanov, Proc. of SPIE Vol. 9810, 98100H · © 2015 SPIE
CCC code: 0277-786X/15/$18 · doi: 10.1117/12.2222974

3 EXPERIMENTAL RESULTS

Register filamentation area (FA) was carried CCD-camera (12) Digital Cameras (17) on the positioner (13), allows for coherent survey the entire area with the filamentation length within the sample survey of 25 mm. Examples of the image shown in Fig. 2.

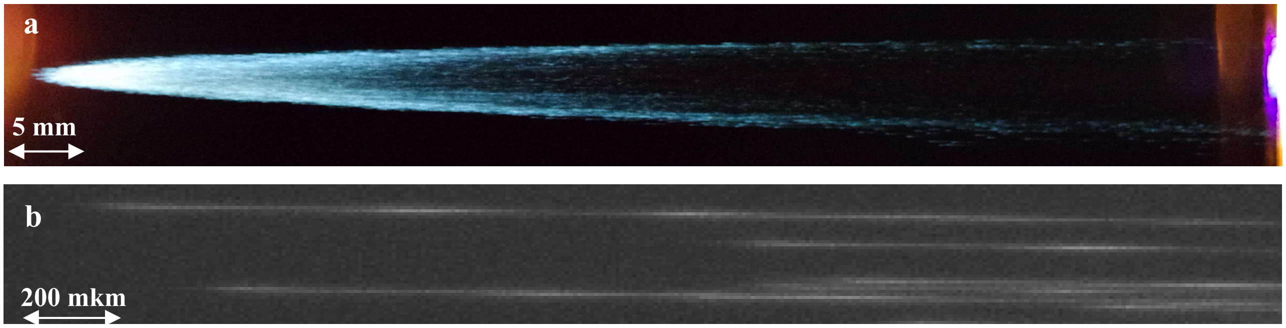


Figure 2 - Photos filamentation of the laser beam area bounded by the vertical slit width of 2 mm, (a) and tracks at the beginning of filamentation area (b), the pulse energy of 40 mJ.

Filamentation area is observed in the form of luminous in blue-green area of the spectrum of tracks, each of which corresponds to a single filament. Number of tracks in (FA) with increasing energy (power) and takes the form of a hollow cone mirror the intensity distribution in the beam cross section (Figure 2 a). Almost all the pictures at the beginning of the field observed filamentation "pulsating" tracks (2b). Tracks can be a result of the imposition of tracks located at different distances from the camera but may also be the result of re-focusing of (refocusing) primary filaments. The distribution of the filaments along the FA for the various pulse energy is shown in Fig. 3. It is seen that the measured distribution has a maximum value and location of which depends on the pulse power - power increases the maximum value increases and shifts towards the radiation source.

The same pattern is observed in multiple filamentation in air and water [2,3]. As characteristics of FA were investigated following parameters:
- start of filamentation L_{sf} is the distance from the front face of the sample to the first track recorded glowing;
- the length of the filamentation L_{lf};
- the total number of filaments $N_{f\ overall}$., is the number of filaments in the region of maximum $N_{f\ max}$. Measured according to selected characteristics of the power of the laser pulse are presented in figures 3-7.

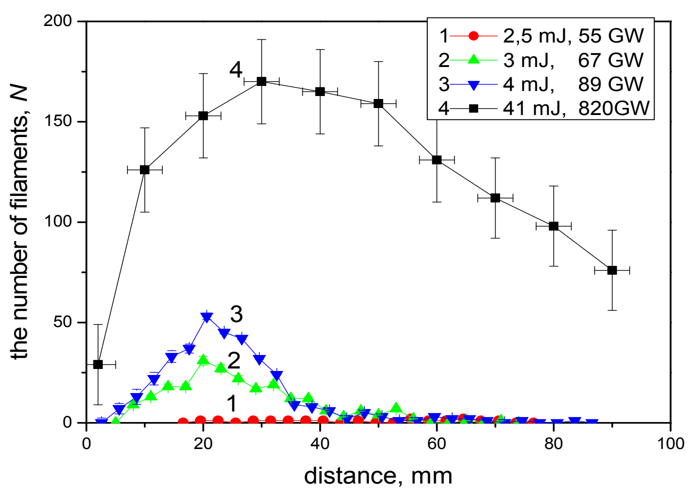


Figure 3 - Distribution of the number of the filaments inside of filamentation area.

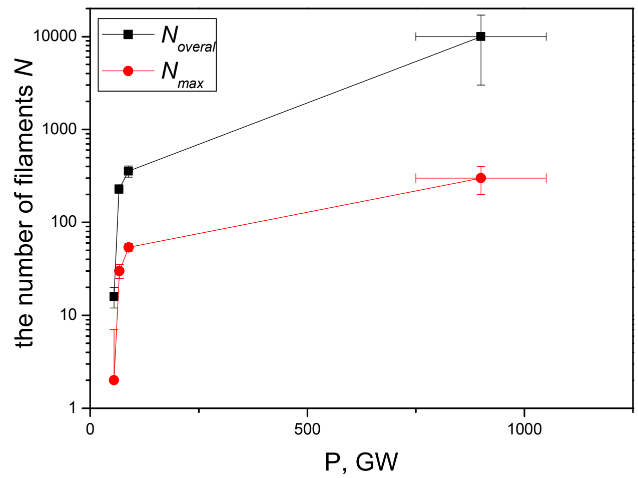


Figure 4 - The dependence of the total number $N_{overall}$ of filaments and the number of filaments in maximum of distribution of the number of the filaments inside of filamentation area N_{max} .

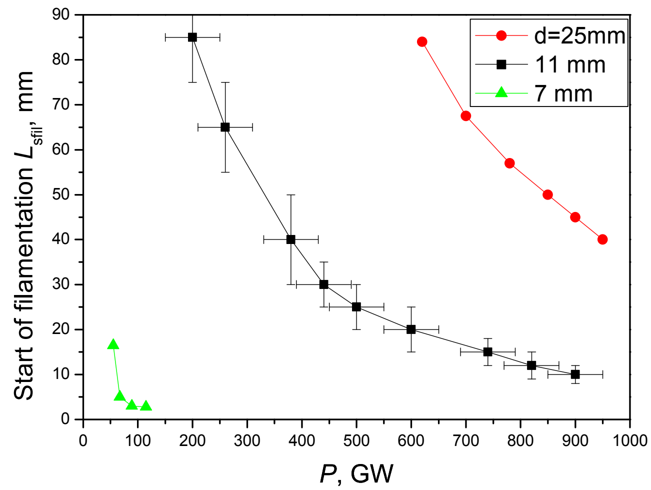


Figure 5 - Dependencies start position FA for beams with different diameters.

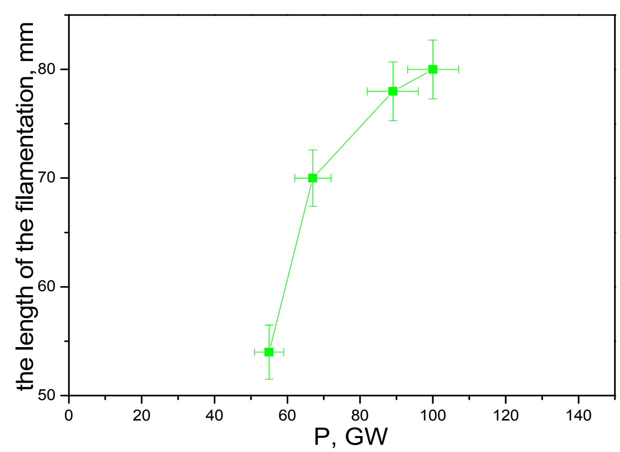
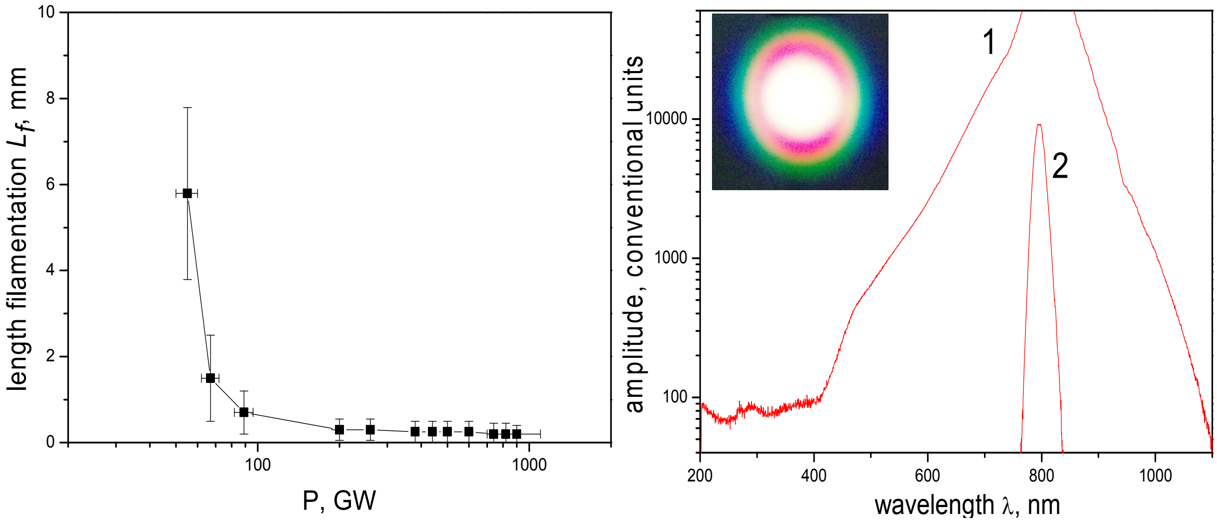


Figure 6 - Dependence length of the FA vs the power of the laser pulse.

In the graphs of fig. 5 we can see that the beginning of filamentation $L_{beginning\ Fa}$ with increasing power shifts toward the source of laser pulse, as predicted by the theory [1], but the experimental values of several orders smaller than calculated. Length of filamentation area increases with pulse power, as well as air and water [2,3]. The graphs in Figure 4 indicate that the total number of filaments in multiple filamentation area and the number of filaments in the maximum distribution along the direction of propagation of the radiation increases with increasing power.

The average length of the individual filaments L_f decreases with increasing power (Fig. 7a). Broadening of the spectrum laser pulse after filamentation is presented in fig.7b.



a) b)

Figure 7 - Dependence of the length of the filament L_f of the power of the laser pulse; b- the spectrum of the laser pulse with an energy of 40 mJ after filamentation in the glass (1) and 1 mJ without filamentation in glass (2).

In experiments on filamentation of laser beams in a medium with strong Kerr nonlinearity it is shown that with increasing pulse power multiple filamentation region increases in length and diameter, the distribution of filaments within the region has a maximum value when the power> 10^5 P_{cr} area filamentation takes the form of a hollow cone, directional vertex to the source of the laser radiation.

This work was financially supported by the Russian Science Foundation (agreement № 15-17-10001).

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