Filamentation of collimated Ti:Sapphire-laser pulses in water

D.V. Apeksimov[1], O.A. Bukin[2], S.S. Golik[3], A.A. Zemlyanov[1], A.M. Kabanov[1,4], O.I. Kuchinskaya[1,4],
A.Yu. Mayor[2], G.G. Matvienko[1,4], A.V. Petrov[1] , E.B. Sokolova[1]

[1] Institute of Atmospheric Optics V.E. Zuev SB RAS, Tomsk, 634021, sq. Academician Zuev 1, Russia, [2] Institute of Automation and Control Processes FEB RAS, Vladivostok, 690041, st. Radio 5, Russia, [3] Far Eastern Federal University, Vladivostok, 690950, st. Sukhanov 8, Russia,
[4] National Research Tomsk State University, Tomsk, 634050, Lenin Avenue 36, Russia

ABSTRACT

The results of experimental studies of the spatial characteristics of multiple filamentation terawatt femtosecond Ti:Sa-laser in water are presented. With an increase in initial power laser pulses increases the number of filaments, the length of the field is increased filamentation and reducing the length of the filaments have been shown. The distribution of the filaments in the longitudinal direction of the field of multiple filamentation has a maximum cross-sectional filament is shifted from the center to the periphery of the beam at the end region of filamentation. The minimum diameter of the beam on the track corresponds to the position of the maximum number of filaments. After the point of maximum impulse essentially loses energy in the initial direction of propagation. Upon reaching the pulse power 2 10^4 P_{cr} of multiple filamentation area is formed of a hollow cone, the apex directed to the radiation source.

Keywords: laser radiation filamentation, femtosecond pulse, the liquid

1. INTRODUCTION

The problems of nonlinear optics of femtosecond atmosphere and ocean interesting from the point of view of the fundamental issues and promising for practical use is the effect of filamentation of laser beams. [1] In [2-4] performed experimental studies of filamentation in the water, but as a rule, they firmly focused radiation in the volume of fluid that was determined insufficient for collimated beams length of the track. Theoretical studies were primarily single filamentation cases [5,6], or as tightly focused beams [2]. This report presents the results of an experimental study of the spatial structure and quantitative characteristics of the field of multiple filamentation (FMF) of collimated laser beams in the water. Scheme of the experiment is shown in Figure 1.

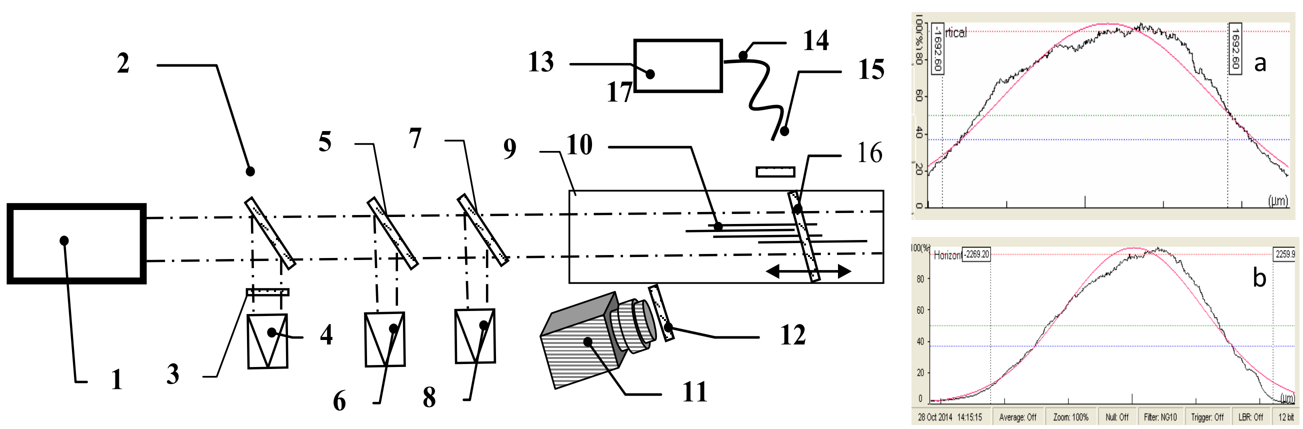

Figure 1 Scheme of the experiment 1 - laser system (Spitfire Pro 40F, Spectra Physics): λ = 800 nm, E <5.2 mJ pulse repetition rate of 1 kHz, τ = 45 fs, the beam diameter (at the e^{-2}) d = 7 mm; 2,5,7 - rotary plate; 3 - filter; 4 - autocorrelator PSCOUT PL-SP-LF, Spectra Physics; 6 - energy meter Spectra Physics 407A; 8 - meter beam profile; 9 - cell with distilled water (length, width, height = 300, 20, 20 mm, respectively, cubic nonlinearity coefficient n_2 = 2 10^{-16} cm^2 / W, the critical self-focusing power P_{cr} = 6,5 10^6 W); 10 - filamentation region; 11 - CCD-camera «ANDOR Clara E», 1392*1040 pixels, 12 bit/pixel lens HELIOS-44M 2/58; 12 - filter; 13 -

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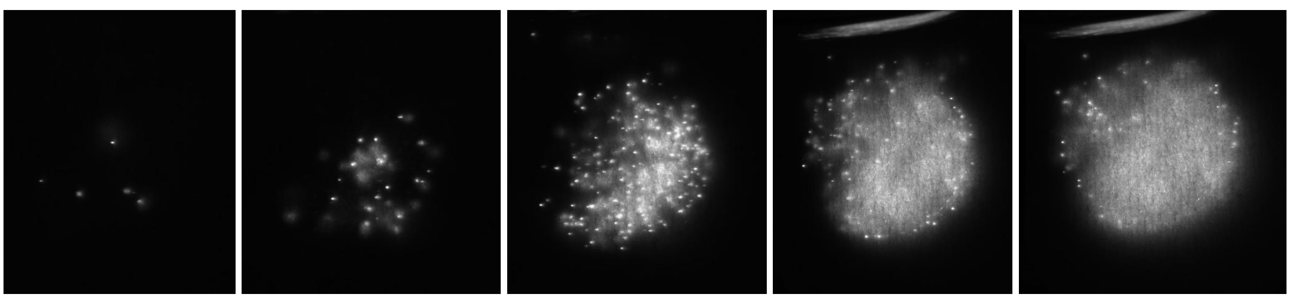
spectrometer «Maya -2000 PRO»; 14 - waveguide; 15 - filter 105WF-700-B; 16 - moving the screen; 17 - the structure of the laser beam in the horizontal (a) and vertical (b) the plane.

2 EXPERIMENTAL RESULTS

Figure 2a shows the pictures of the transverse structure of the field filamentation at different distances from the source. Bright points in images with high energy density in beam (intensity ~ 10^{11}-10^{12} W/cm^2 for water) compared with the average level and match existing at this points filaments. The pictures can be seen that with increasing distance of the laser pulse in the cell the number of "hot spots" formed by the laser beam is first increased and then decreased. In addition, the diameter of the field filled with points of light increasing. Recorded hot spots move with increasing distance from the center to the periphery of the beam. The length in which there is one point does not exceed a few millimeters. When filamentation in the water area of registration of longitudinal structure of multiple filamentation (side view) is not possible because glow plasma channels is weak. Schematically, its image is represented in Figure 2b. Registered transformation of the laser beam is shown in Fig.2c. In the picture you can see that at the beginning of filamentation region (indicated by an arrow), the beam narrows slightly and after the constriction, the beam intensity decreases dramatically.

Figure 3 shows the dependence of the number of hot spots of a distance of propagation of the laser radiation for different initial energy of the laser pulse. The graph shows that when multiple filamentation of laser radiation of structure of the plasma channel is non-uniform. The structure has a pronounced maximum i.e. the number of single filaments in multiple filamentation first increases and then decreases. Measuring the length of the filamentation area showed that with increasing laser power the length of the area with plasma channels increases. This increase is due to a more active bias coordinates of the beginning of the plasma channel in the direction of the laser light source than the coordinates of the end of the plasma channel (Figure 5,6).



17 mm 28 mm 53 mm 73 mm 83 mm

Figure 2 a - transverse structure filamentation field at different distances from the source at a pulse energy of 4.4 mJ.

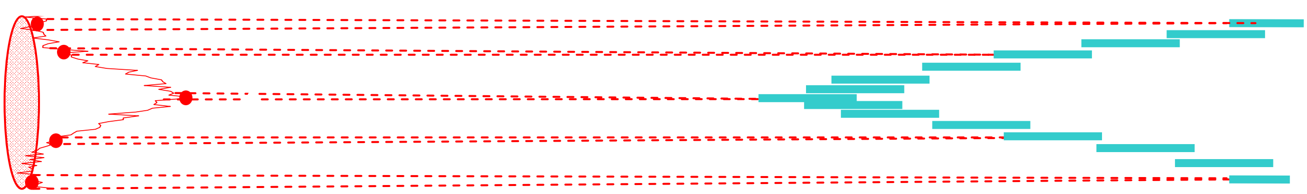


Figure 2 b - diagram of the formation of multiple filamentation region.

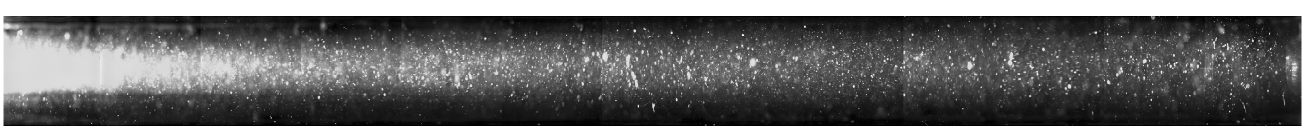


Figure 2 c - picture of the structure of the laser beam (filter) in a cell at multiple filamentation (arrow corresponds to the beginning of filamentation region).

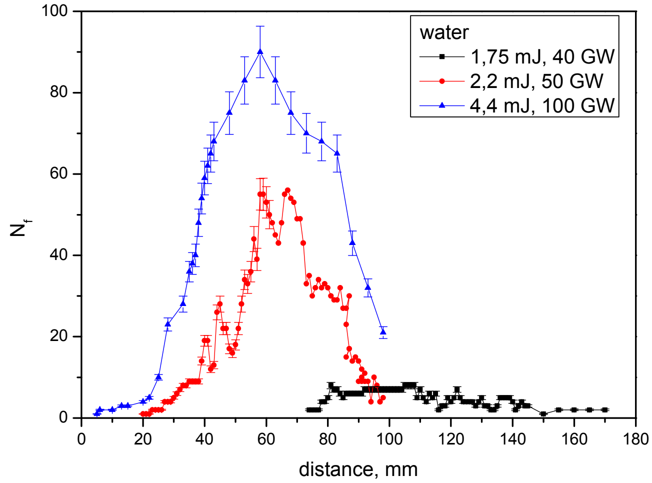


Figure 3 - dependence of number of filaments in the cross section of the plasma channel at different distances from the laser source.

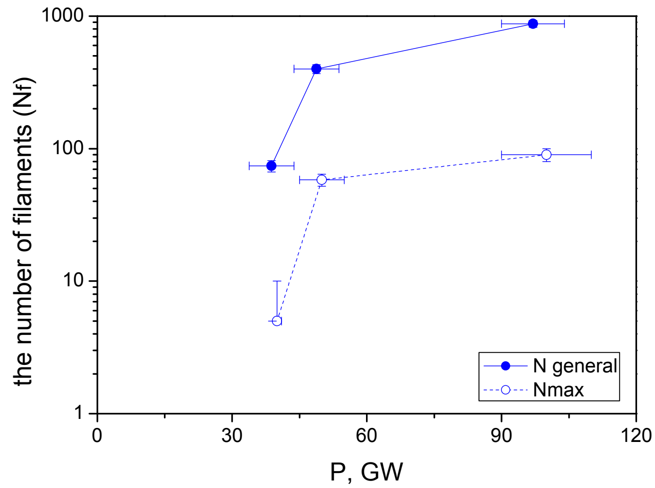


Figure 4 - dependence of the total number of filaments and the filaments at the maximum allocation of the power of the laser pulse.

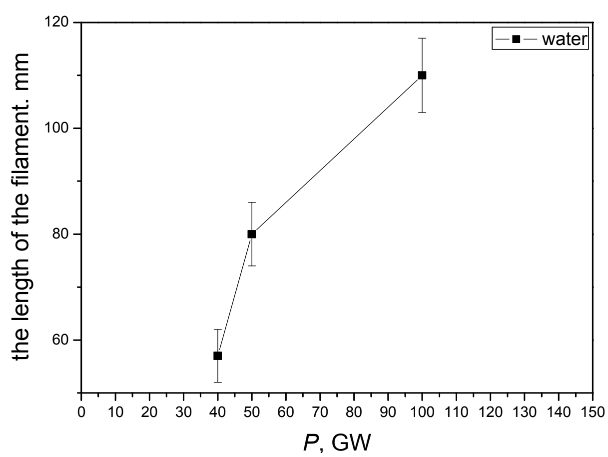


Figure 5 - the length of the field dependence of filamentation of the laser power.

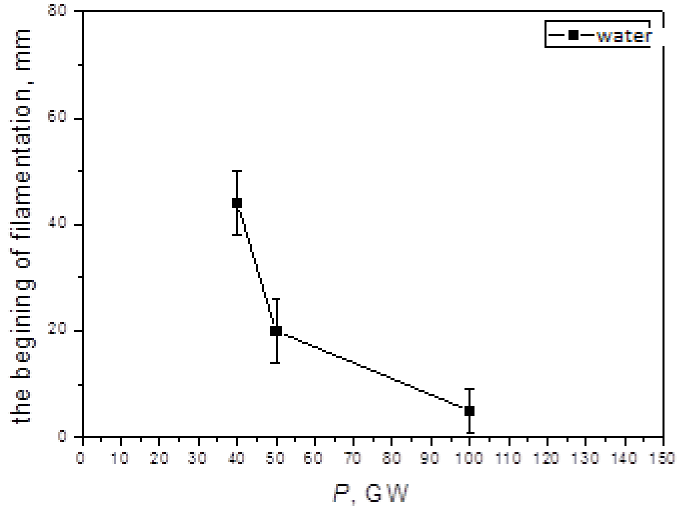


Figure 6 - the beginning of the field dependence of filamentation of the laser power.

Thus, in experiments on multiple filamentation of laser beams in water showed that with increasing initial laser power pulses increases the number of filaments is increased length of the region and the reduction of filamentation length filaments. The distribution of the filaments in the longitudinal direction FMF has a maximum cross-sectional FMF is shifted from the center of the filament bundle to the periphery of the end region of filamentation. The minimum diameter of the beam on the track corresponds to the position of the maximum number of filaments in FMF, after which the pulse is much loses energy in the initial direction of propagation. Upon reaching the pulse power 2 10^4 P_{cr} multiple filamentation region is formed of a hollow cone, the apex directed to the radiation source.

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