Filamentation of focused femtosecond laser pulse and plasma channel formation in the vicinity of geometric focus

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Abstract—Filamentation of focused femtosecond laser pulse in the vicinity of the geometric focus is studied both theoretically and experimentally.

Keywords—femtosecond pulse; geometric focus, plasma channel; filamentation; nonlinear optics

High power femtosecond laser pulse propagates through the transparent medium with pulse energy localization accompanied with thin plasma channels [1]. The phenomenon of filamentation occurs owing to the dynamic balance between two major physical effects: Kerr self-focusing and plasma defocusing of the beam. The paper [2, 3] demonstrated that main part energy contained in background reservoir during the propagation of femtosecond laser pulses in air. The filamentation process was terminated immediately when filament passed through a pinhole [3]. It was shown in [4] that for collimated and tightly focused laser beam the filament parameters (radius of the filament, laser pulse intensity, electron density in plasma channel) are strongly different. But there are no data about background reservoir behavior in the vicinity of the geometric focus with propagation of tightly focused laser beam. In this paper the some features of self-focusing and plasma channel formation with femtosecond laser pulse filamentation in focused laser beam at the area closed to the geometric focus are studied and discussed both experimentally and theoretically.

Femtosecond laser pulse (740 nm, 100 fs) focused by concave dielectric mirrors (for the experiment described below the focal length was 50 cm). In the vicinity of the geometric focus a pinhole (diameter was about 300 µm) was placed. Linear plasma density was measured by hemisphere electrodes. When plasma channel formed by laser pulse was appeared between the electrodes the recharge current of the capacitor was measured by oscilloscope. The current was proportional to linear plasma density in the plasma channel. The laser pulse fluence distribution was visualized along the pulse propagation in filamentation area by a CCD-camera also.

The figure demonstrates the distribution of linear plasma density along the filament without pinhole (●) and at different distance from mirror to pinhole: 48 (○), 50 (▼) and 52 (▲) cm (the color vertical lines show the pinhole placement, respectively). In the experiments the plasma channel was observed behind the pinhole. Corresponding numerical simulations were fulfilled. Calculation results are in good agreement with the experimental data.

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