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Nonlinear Optics of the UV TW Laser Beam

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A high-energy (up to 3 kJ in ns pulses) UV radiation (λ=248 nm) of KrF laser is successfully used in the Inertial Confinement Fusion (ICF) [1]. For ~ 1GW peak power in numerous angular multiplexed beams, nonlinear effects were not observed yet under propagation along ~100-m air path and in transmissive optics. TW peak power of sub-ps UV pulses at Ti:Sapphire/KrF GARPUN-MTW laser facility exceeds a critical power Pcr ≈ 100 MW and the laser beam becomes unstable in respect of Kerr self-focusing, and multiple filamentation arises [2]. It has a great impact on saturation of short pulse energy and optics degradation [3]. Therefore, suppression of beam filamentation is of high priority for the facility operation itself. On the other hand, filamented UV laser beam produces a bunch of partially ionized narrow plasma channels ranging to more than hundred meters in atmospheric air with a potential application for virtual sliding-mode MW waveguides [4]. Those might require regularizing of occasionally distributed filaments in the laser beam. The performed experiments at GARPUN-MTW laser purposed both these objectives.

To suppress multiple filamentation we transferred 1-ps, 0.1-J linearly polarized output radiation through a 2.5-m length cell filled with Xe gas at pressure up to 1 atm. KrF radiation has a 2-photon resonance with Xe 6p [1/2]0 state, which causes unusual large negative nonlinear refractive index at KrF laser wavelength [5]. This should defocus high-intensity filaments in contrary with a common Kerr self-focusing in air and laser windows. As a result, in present experiments filaments with local peak intensity of ~ 0.2 TW/cm2, 200-fold higher than the average one, were homogenized to significantly lower intensity. Total energy loss in the cell of 20% was measured. Filamentation mitigation had a minor effect on the laser beam focusing. Remarkably, UV filaments in Xe produced a narrow-angle coherent cone emission at 828-nm wavelength. In a far-field zone, the IR light pattern looked like thin-wall rings surrounding individual filaments. Stimulated hyper-Raman scattering and amplified spontaneous emission at 6p [1/2]_0 ⟶ 6s [3/2]^0_1 transition of atomic Xe [6] may explain this emission.

Amplitude masks with multiple apertures of different configurations were introduced in the beam and UV radiation distribution was measured behind the masks. A transformation from UV light diffraction patterns into regularized filaments structures was clearly observed with increasing the propagation distance.

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Summary

Nonlinear effects under propagation of TW power sub-ps UV pulses of KrF laser along the amplification tract in air and transmissive laser optics were studied at Ti:Sapphire/KrF GARPUN-MTW laser facility. Suppression of multiple filamentation of a supercritical laser beam was demonstrated in Xe, which has unusual large

negative nonlinear refractive index at KrF laser wavelength. A narrow-angle coherent cone emission at 828-nm wavelength was observed around UV filaments in Xe. Regularizing of occasionally distributed filaments was achieved by means of amplitude masks.

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