Low-coherence high-power laser drivers for inertial confinement fusion

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Low-coherence light is expected to be one of the effective ways to suppress or even resolve laser-plasma instabilities in the process of inertial confinement fusion. It has attracted widespread interest. Many laboratories try to build laser facilities for the study of low-coherence light, such as the GEKKO XII in Japan [1], and the PHEBUS in France [2], the PHAROS-III in the United States [3], and the KANAL-2 in Russia [4]. However, previous technical approaches have barriers in four aspects: effective amplification, efficient frequency conversion, high fluence and high intensity output, and effective beam smoothing techniques of low-coherent pulses.

Here, we will present the recent progresses achieved by our group on broadband low-coherence laser driver, including the source generation, efficient amplification and propagation, harmonic conversion, beam smoothing and precise beam control, and the key performance of our low-coherence laser driver. In order to obtain a seed source with lower coherence, superluminescent diode is introduced into the inertial confinement fusion field for the first time. A microjoule-level temporal low-coherence seed with precise temporal shaping (for meeting the requirements of physical experiments) and spectral control (to meet the needs of spectrum and coherence control in the post-amplification) is acquired. High-gain amplification of large-bandwidth and temporally low-coherence pulses based on Nd:glass system is realized, by adopting multi-level spectral control and reasonable amplifier design. An output pulse of tens of Joules with a bandwidth of up to 15 nm and a coherence time of only 270 fs is obtained in the preamplifier stage. Based on the pre-compensation technology, an amplified low-coherence pulse of 1000 Joules with a 13-nm bandwidth and a coherence time of only 290 fs is safely produced, corresponding to a flux of 4.5 J/cm^2 and a power density of 1.5 GW/cm^2. On the basis of breakthroughs in the theory of harmonic conversion of temporally low-coherence pulses, the frequency doubling of broadband temporally low-coherence light with an efficiency of up to 70% is demonstrated by using a DKDP crystal. Moreover, utilizing a large-aperture KDP crystal, a high-energy, low-coherence and frequency-doubled pulse with an energy of 600 J and a coherent time of 300 fs is achieved. In view of the low-coherence characteristics of the pulse, the beam smoothing technology which combining lens array and induced spatial incoherence is successfully demonstrated and a good smoothing effect is achieved.

Based on the above series of technological breakthroughs, we have successfully built the Kunwu driver which can deliver kilojoule low-coherence laser with a coherence time of only 300 fs [5]. At present, the first round of physical experiments has completed on our laser driver. This high-power laser facility provides not only a demonstration and verification platform for key technology and system integration technology of low-coherence laser driver, but also a new type of experimental platform for physical research such as high energy density physics and especially laser plasma interactions.

References

[1]. M. Nakatsuka, N. Miyanaga, T. Kanabe, H. Nakano, K. Tsubakimoto, and S. Nakai, Proc. SPIE 1870, 151 (1993).

[2]. N. A. Fleurot, M. L. Andre, P. Estraillier, D. Friart, C. Gouedard, C. Rouyer, J. Thebault, G. Thiell, and D. Veron, Proc. SPIE 1502, 230(1991).

[3]. M. S. Pronko, R. H. Lehmberg, S. Obenschain, C. Pawley, C. Manka, and R. Eckardt, IEEE J. Quantum Electron. 26, 337 (1990).

[4]. S. Fedotov, L. Feoktistov, M. Osipov, and A. Starodub, J. Russ. Laser Res. 25, 79 (2004).

[5]. Yanqi Gao, Yong Cui, Lailin Ji, et. al., Matter Radiat. Extremes 5, 065201 (2020)