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Compact 120 TW Ti:sapphire laser system with a high gain final amplifier

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Abstract

A 120 TW/36 fs laser system based on Ti:sapphire chirped-pulse amplification (CPA) has been successfully established in our lab. The final four pass Ti:sapphire amplifier pumped by an energetic single-shot Nd:YAG—Nd:glass laser was designed and optimized. With 24 J/8 ns pump energy at 532 nm, 300 mJ/220 ps chirped pulse was amplified to 5.98 J in this amplifier, and a total saturated gain of ~20 was achieved. The focused intensity of compressed beam could reach to 10^{20} W/cm^2 with the M^2 of ~2.0.

Keywords: CPA; Amplification; Gain; Pulse duration

1. Introduction

The very high-energy laser system with ultrashort pulse duration has been widely used in high-field applications such as electron acceleration, self-focusing and

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harmonic generation, ICF fast ignitor, astrophysics and quantum electrodynamics [1]. Since the mid-1980s, the technique of chirped-pulse amplification (CPA) [2] opened new avenues for the production of these kinds of lasers without optical damage to amplifiers and optical components. Recently, the development of CPA has become more attractive and matured with the development of large aperture ultra-broadband solid-state laser materials. The two gain media, Nd:glass and Ti:sapphire, are mainly employed in this amplification, and TW- and PW-class laser systems have been developed based on Nd:glass [1,3]. Compared with Nd:glass, Ti:sapphire has more attractive characteristics. Firstly, the gain bandwidth of Ti:sapphire is more than ten times than that of Nd:glass , which means that Ti:sapphire can support femtosecond output with at least ~6.0 fs pulse duration, but Nd:glass can be worked only on subpicosecond. Secondly, though the saturation fluence (Es) is ~1 J/cm^2 for Ti:sapphire and ~5 J/cm^2 for Nd:glass, Ti:sapphire has much more small signal gain coefficient (g_0) so that it requires lower length of amplifier medium and a tabletop high-energy laser system could be built up. To date, CPA laser system based on Ti:sapphire with peak power of 100 TW with femtosecond pulse duration has been demonstrated in 10 Hz [4,5] and single shot [6,7], and even a PW class CPA system has been built up in Japan [8]. Though Nd:glass cannot be used as an active medium for ultrashort pulse CPA laser system, Nd:glass amplifier technology is broadly used as the pump source of high-energy in Ti:sapphire CPA laser system because of its reliable running and high-energy throughput [6–8].

For the design of TW-class and PW-class CPA laser system, the final amplifier is the main stage to get the high-energy output; however, the parasitic amplification increases with the increased pump intensity and this makes the gain decrease quickly. In addition, the narrowing of pulse bandwidth has also to be considered to maintain the compression of the pulse. Therefore, the optimization of final amplifier with high pump intensity is very important. In this report, we present a 120 TW CPA laser system based on a high gain multi-pass final amplifier with a large aperture Ti:sapphire disk. This amplifier was pumped by a well-established high-energy Nd:YAG—Nd:glass laser, and the saturation gain of ~20 was reached in it while the spatial beam quality is about two times of a diffraction-limited Gaussian beam. By our knowledge, this is the highest gain got from a high-intensity pumped final amplifier. After compression, the output energy achieved was 4.33 J with a pulse duration of 36 fs.

2. Laser system design

Our 120 TW laser system is a typical CPA configuration based on Ti:sapphire crystal, which is upgraded by a added optimized Ti:sapphire amplifier to our previously presented 23 TW CPA system [9]. It consists of an oscillator, a pulse stretcher, a regenerative amplifier, three stages of multi-pass amplifiers and a pulse compressor in a vacuum chamber. The scheme set up is shown in Fig. 1.