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Progress of the SULF 10PW Laser Project

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Femtosecond petawatt (PW) lasers are very important for the study of high-field physics. There are several projects that are in either the preparatory phase or the implementation phase to realize the output of 10 PW [1-3]. Chirped-pulse amplification (CPA), in particular the Ti:sapphire (Ti:S) based CPA systems, is the dominating technical approach to obtain PW laser pulses. The Ti:S CPA technology is characterized by many advantages such as high stability and high efficiency. However, the main limitation that arises when designing a large-aperture, high-gain Ti:S amplifiers is restrictions on the pump energy storage and signal energy extraction imposed by parasitic lasing (PL) [4] and transverse amplified spontaneous emission (TASE)[5]. We have started the 10PW laser project Shanghai Superintense Ultrafast Laser Facility (SULF) officially since 2016. We will report the progress of SULF project and present a new method that uses a temporal dual-pulse pump beam to suppress PL and TASE[6, 7].

The experiment setup of the temporal dual-pulse pumped Ti:S amplifier is shown in Figure 1. One energetic pump pulse is divided into two pulses with same energies by beamsplitter BS0. One pump pulse is image-relayed to the other end of the Ti:S crystal. These two pump pulses are then further divided into two individual pulses respectively by beamsplitters BS1 and BS2. There are two pump pulses at either end of the Ti:S crystal. Spitting ratios of BS1 and BS2 are optimized so that in each stage of multi-pass amplification, the Ti:S crystal is pumped to support adequate gain amplification for the signal pulse, while avoiding overdriving of the gain medium. The advantage of this temporal dual-pulse pumped scheme is that, we can control the transverse gain in the entire amplification stage by optimizing pump energy distribution, which on the other hand can be done conveniently by choosing beamsplitters with different spitting rations.

The beam diameter of 45J-input signal is enlarged to 115 mm prior to the final injection into a three-pass 150-mm-diameter Ti:S amplifier, which is pumped by a frequency-doubled home-made Nd:glass laser in single shot mode. The output of the pump laser system is down-collimated to a diameter of 120 mm. The reflectivities of BS0, BS1 and BS2 are 50%, 30% and 55% respectively in practice. Each pump pulse has a same super-Gaussian temporal profile with an 8 ns pulse width. Based on the above temporal dual-pulse pumped technique as well as using the Cargille Series M refractive index liquid doped with an absorber (IR 140) as the cladding material, we measured the output energy and conversion efficiency with respect to the pump energy. The experimental as well as numerical results are shown in the Fig.1. The experimental results confirmed that the temporal dual-pulse pumped technique can effectively suppress the PL and TASE. The output signal energies and conversion efficiencies increase with pump energy, with a maximum amplified output energy of 202.8 J been obtained at a pump energy of 320 J, which corresponds to a conversion efficiency of 49.3%. The results of the numerical calculation coincide well with our experimental data at lower pump energies, while the difference between the experimental and simulated results becomes more obvious at higher pump energies due to the effect of PL and TASE, which were not considered in our simulation.

For optimizing the pulse compression, part of the amplified pulse was recompressed by a grating compressor consisting of four 1480 groove/mm gold-coated holographic gratings. The autocorrelation traces of amplified pulse were measured and the duration of the compressed pulse was 24.0 fs. The measured transmission efficiency of the compressor was about 64%, indicating output energy of 129.8 J for a compressed pulse, corresponding to a peak power of 5.4 PW. In the next step, we will use this method in the final amplifier of our 10 PW laser.

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Figure1