Recent progress on developing multi-petawatt femtosecond laser system in SIOM

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Abstract

We report recent progress on CPA and OPCPA laser for developing multi-petawatt laser system. A high conversion efficiency amplifier based on a 150mm diameter Ti:sapphire was demonstrated. At the pump energy of 312J, the highest output of 192.3J was achieved, corresponding to an efficiency of 50.4%. The compressed 27.0 fs pulse width was obtained with part of the energy, so this laser could support a peak power of 5.13PW. Meanwhile, the CPA/OPCPA hybrid laser achieved the peak power of 1.0PW with pulse width of 32.0fs. A LBO was used in final OPCPA, and the output energy of 45.3J was obtained.

Introduction

Since the invention of chirped pulse amplification (CPA) [1], the Ti:sapphire (Ti:S) CPA laser systems have become standard table-top sources of powerful femtosecond laser pulses because of their applications in many areas. Peak power up to petawatt (PW)-class Ti:S laser systems using CPA technique have been developed in several labs worldwide [2-7]. In 2013, the highest peak power from a Ti:S laser system reported was up to 2PW [7]. Recently, several 10 PW lasers are under developing. The technologies of CPA and optical parametric chirped pulse amplification (OPCPA) are still the main avenues.

Ti:sapphire CPA Laser

The CPA laser contain a front-end worked at repetition rate of 5 Hz, a energy amplifier and a final booster amplifier which worked at single shot. In the energy amplifier, a Ti:S with diameter of 80mm was used, which is a 4-pass structure and can provide the sufficient energy for next stage. To get high energy output, the Ti:S aperture used in the final booster amplifier is 150mm with thickness of 46.7mm. For these two amplifiers, parasitic lasing (PL) suppression is a key issue. Therefore, the optimization of the time delay between the input seed pulse and pump pulses has to be combined with index-matching cladding of crystal. For the 150mm-Ti:S amplifier, the injected signal energy has to be improved to effectively suppress PL. With the injected energy of 35J, the output energy achieved 192.3J with pump of 312J and no PL happened. The conversion efficiency of pump-signal reached to 50.4%. The spectra bandwidth of FWHM from the final 150mm Ti:sapphire amplifier is 53nm. Small part of the energy was compressed in a four-grating compressor which result an optimized efficiency of 72%. The measured autocorrelation trace demonstrated the pulse width of 27.0fs, which can support the peak power of 5.13PW.

CPA/OPCPA laser

Because of PL in Ti:S booster amplifier, we proposed CPA/OPCPA hybrid laser, which was first demonstrated in 2013 with peak power of 0.61PW. The OPCPA final amplifier was added to a CPA front-end, which can support a high-energy and broad bandwidth output. Based on the theoretical simulation and optimization of the main parameters, the amplified energy from final OPCPA reached 45.3 J with a 100×100×17 (mm3) LBO, which corresponds to a conversion efficiency of 26.3% with pump energy of 169.1 J. The peak power of the hybrid CPA-OPCPA laser system was up to 1.02 PW with pulse duration of 32.0 fs after compression.

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