High gain solid-state modules for picosecond pulses amplification

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Abstract

We present both numerical models and experimental results of ultra-short pulses solid-state laser grazing-incidence amplifier modules for generation of intense picosecond pulses, in various regimes from single shot to repetition rates of GHz.

Summary

Picosecond mode-locked laser sources are becoming increasingly attractive for many industrial and scientific applications. Master Oscillator Power Amplifier (MOPA) architecture is widely employed for pulsed laser system energy up-scaling. Starting from robust, low-power diode-pumped solid-state oscillators, using programmable pulse-pickers one can select either a single pulse or a properly shaped pulse train for further amplification and compensation of envelope distortions due to gain saturation. In particular, we have exploited the technology of side-pumped grazing-incidence bounce amplifiers. Such amplifiers yield very high gain per pass, up to several thousands, and offer excellent beam quality preservation owing to the total reflection leading to left-right inversion. This technology allows the realisation of compact, efficient and modular amplifiers, significantly simpler than, for example, cavity-based regenerative schemes.

Using quasi-cw (qcw) diode arrays as the pump source of Nd:YVO_4 slab amplifier, starting from ≈ 1 nJ, 10-ps pulse seed, amplified pulse energy as high as 200 μJ at 1 kHz can be obtained. Efficient harmonic and travelling-wave parametric generation are readily achieved with such high pulse peak powers.

When multi-MHz picosecond pulses are required, cw diode arrays are chosen as pump sources for the slab amplifiers. An 8-W, 8-ps laser system has been demonstrated starting from a 50-mW cw oscillator, at 150 MHz. Owing to the effective gain shaping of the tightly pumped amplifier, no significant thermal distortion were detected, allowing nearly diffraction limited operation. Although high power picosecond oscillators have been demonstrated lately, this result is interesting since it suggests an alternative way for power-scaling of picosecond sources without pushing delicate intracavity components (such as semiconductor saturable absorbers) to the damage limit.

Some other applications require instead the amplification of pulse trains, that can be conveniently extracted and amplified from a low-power oscillator at the desired repetition rate. For example, starting from a 20-mW, 5-GHz picosecond oscillator we amplified trains of few thousands of pulses up to 2 mJ with three slab amplifiers (as much as 300 mJ were achieved with two additional Nd:YAG flash-lamp-pumped post-amplifiers). Such pulse trains are very effective for synchronous pumping of optical parametric oscillators, lowering significantly their threshold with respect to the travelling-wave geometry.

Numerical models of the amplifiers and their dynamics are also presented. The effects of amplified spontaneous emission are discussed, as well as the most effective methods for its suppression.