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Compact, high-throughput expansion-compression scheme for chirped pulse amplification in the 10 fs range

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Abstract

A novel pulse stretching-compression system suitable for kHz-rate chirped-pulse amplification of ≈10 fs pulses in Ti:sapphire systems is demonstrated. The material dispersion of the system components used for pulse selection and isolation broadens the wide-band seed pulses by a factor of ≈300, allowing amplification up to the submillijoule energy range. The compressor consists of a pair of prisms and newly-developed chirped multilayer dielectric mirrors for compensating high order dispersion. Using this simple scheme a recompression of unamplified pulses down to 15 fs with a throughput as high as 80% is demonstrated.

Recent advances in ultrashort pulse generation have led the generation of sub-10 fs pulses directly from laser oscillators [1,2]. These systems open up new prospects for ultrafast spectroscopy. Nevertheless the pulse energy of a few nJ available from these oscillators is often too low for nonlinear optical applications. Recently 13 fs, 60 nJ pulse generation was demonstrated from a cavity-dumped Ti:sapphire laser [3]. To boost the pulse energy up to or beyond the microjoule level external amplification is needed. The concept of chirped pulse amplification (CPA) [4] allows simultaneously for efficient energy extraction and the avoidance of nonlinear effects in solid state amplifiers. The amplification of sub-50 fs pulses calls for CPA systems compensated for high-order dispersion. To this end, a number of pulse expansion-compression schemes have been proposed and demonstrated [5–10]. Terawatt-scale low-repetition-rate CPA systems rely on pulse stretching up to ≈100 ps or more, and hence on one of the previously proposed sophisticated and lossy grating-based stretcher-compressor systems [11,12]. By contrast, careful design of gigawatt-scale kHz-rate systems allows for the avoidance of excessive nonlinearities with stretched pulse durations of just a few picoseconds [13]. In this letter we demonstrate a simple, high-throughput pulse expansion-compression scheme that is ideally suited for the implementation of the CPA concept in the amplification of ≈10 fs pulses up to multigigawatt power levels.

One expects an optimized CPA system to meet the following requirements: (i) the overall system bandwidth is limited by that of the amplifier medium, and (ii) the dispersion characteristics of the stretcher, amplifier and compressor are matched. The latter requirement can be more precisely formulated after expanding the group delay τ of the whole system, around the center frequency ω_0 in a Taylor series:

$$\tau(\omega) = \partial\phi(\omega)/\partial\omega = \phi'(\omega_0) + \phi''(\omega - \omega_0) + \tfrac{1}{2}\phi'''(\omega - \omega_0)^2 + \tfrac{1}{6}\phi''''(\omega - \omega_0)^3 + \ldots, \quad (1)$$

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