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Coherent Stacking of Few Cycle Pulses from a Gain-Managed Nonlinear Amplifier for CPA-free Energy and Power Scalable Drivers of High-Intensity Laser-Matter Interactions

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Coherently combined fiber lasers are considered to be among the most promising pathways towards developing power and energy scalable drivers for laser plasma accelerators (LPA) and other applications of high-intensity laser-matter interactions. Coherent pulse stacking amplification (CPSA) technique is a time-domain coherent combining using Gires-Tournois Interferometers (GTI) of multiple pulses that enables energy scaling per each individual parallel fiber amplification channel. CPSA involves coherent combining of a burst of ~1ns stretched pulses into a single pulse with subsequent compression to femtosecond durations in a conventional diffraction – grating based pulse compressor. CPSA essentially is an extension of the chirped pulse amplification (CPA), and is intended for achieving multi-J femtosecond pulse LPA drivers.

Here we propose a different coherent stacking approach, which does not rely on CPA for pulse energy scaling, but instead uses high energy amplification and simultaneous nonlinear spectral broadening of several ultrashort pulses in a Gain Managed Nonlinear fiber amplifier with subsequent coherent stacking with GTI cavities, followed by ps-short pulse compression with a compact compressor [1]. This technique offers advantages of much more compact power and energy scalable systems with much shorter pulse durations of several optical cycles compared to CPSA based systems. Even with lower energies than those achievable from CPSA systems, this approach can be very beneficial for high-intensity laser-matter interaction applications (e.g. HHG based attosecond sources), where compact laser driver size is required to produce few-cycle pulses at moderately-high average powers and pulse energies.

A recently proposed method of spectral broadening, termed Gain Managed Nonlinearity (GMN), was demonstrated that allows record-high uJ levels of energy from a single amplifier with sub 30fs bandwidths [1]. Using this method, we have been able to demonstrate 0.5uJ, 40fs compressed pulses from an LMA fiber at 40 MHz, with further refinement expected to improve the energies to several uJ per pulse and the pulse duration to sub 30fs. Coherent pulse stacking of 10-100 of such pulses is in progress, aiming to achieve 100s uJ to ~1mJ per single stacked pulse. Further power and energy scaling could be achieved via spatial coherent combination of several GMN fiber amplification channels.

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