Ultrafast Fiber Amplifiers Beyond the Gain Narrowing Limit

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Two major challenges that arise in the development of ultrafast fiber amplifiers are management of the high nonlinear phase shifts encountered in stretcher-less amplification systems and (2) generation of bandwidths much broader than the gain spectrum that can be compressed to clean, sub-100-fs pulses. We will describe a new regime for amplification of ultrashort pulses in fiber that is distinguished by the use of a dynamically-evolving gain spectrum as a degree of freedom [1]. As a pulse experiences nonlinear spectral broadening, absorption and amplification actively reshape the pulse and the gain spectrum itself. We refer to this regime as gain-managed amplification. The dynamic co-evolution of the field and excited-state populations supports pulses that can broaden spectrally by almost two orders of magnitude, and well beyond the gain bandwidth, while remaining cleanly compressible to their sub-50-fs transform limit. Theory and experiments suggest that a nonlinear attractor underlies the management of the nonlinearity by the gain. Initial instruments based on this process have generated microjoule-level and 40-fs pulses [2], and 20-fs pulses appear to be possible.

Gain-managed amplification can be exploited in oscillators as well as in amplifiers. The pulse energy from mode-locked fiber oscillators based on concatenated Mamyshev regenerators (so-called Mamyshev oscillators) have risen dramatically in the past few years [3-5]. Environmentally-stable instruments that generate ~200-nJ and 40-fs pulses have been demonstrated [6]. The peak power thus reaches several megawatts, which is the highest reported for a femtosecond fiber oscillator. We now understand that gain-managed amplification underlies the generation of stable pulses at such high power in an oscillator.

Initial applications of amplifiers and lasers based on gain-managed amplification will be mentioned, along with future prospects for enhanced performance.

References

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