Gain Managed Nonlinear Amplification Technology of Ultrafast Fiber Laser

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Nonlinear fiber amplification of ultrashort laser pulse has been recognized as an efficient way of significantly extending the spectrum coverage and realizing sub-100 fs de-chirped duration along with the energy scaling. However, the nonlinear pulse evolution in the fiber amplifier is conventionally started from a seed laser with a narrow spectrum and a low energy (nJ level), causing the maximum obtained pulse energy highly limited even with an optical gain of over 30 dB. In the current work, we demonstrate an unconventional nonlinear fiber amplifier that is seeded with a laser pulse with 20 dB spectral bandwidth of 74 nm and pulse energy of 52.5 nJ, which are respectively scaled to 83 nm and 3000 nJ by a backwardly pumped Yb-doped photonic crystal fiber with core/cladding diameter of 40/200 micron, corresponding to an optical gain of only 17.6 dB. The pulse duration is de-chirped to 76 fs with an energy of 2700 nJ, which to the best of our knowledge is the highest that obtained from any nonlinear fiber amplifiers. In the meantime, a decent performance in terms of output beam quality, polarization extinction ratio, short- and long-term stability is verified at the maximum operation energy. According to simulations and measurements, the laser pulse experienced an unconventional gain managed nonlinear amplification with the spectrum asymmetrically extending to the short wavelength side, mostly driven by the self-phase modulation and high excitation of the gain fiber at the output end. Such a pulse evolution process could be further leveraged to realize higher energy ultrashort lasers by using gain fiber with larger core diameters, and greatly expand the application potential of nonlinear fiber amplifiers.