An Ultrafast Fiber Laser with Self-Similar Evolution in the Gain Segment

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The promise of rugged, compact and robust femtosecond pulsed sources with excellent mode quality has been driving innovation in ultrafast fiber laser technology for the last 20 years.[1,2]

Recently, researchers reported amplifier-similaritons formed in an all-normal-dispersion fiber laser oscillator with a narrow bandwidth intra-cavity spectral filter,[3] which is an alternate route to high-performance fiber lasers. Here we demonstrate a similar Yb fiber laser setup (a, top) but scaling up to higher pulse energy and shorter pulse duration.[4]

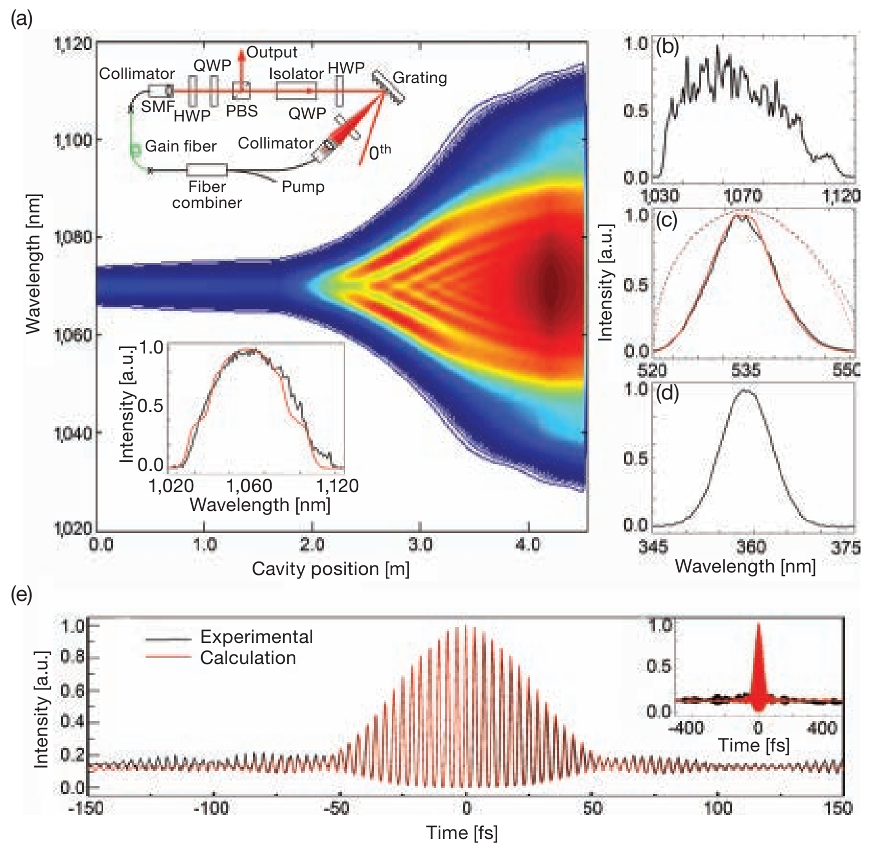
To verify the presence of amplifier similaritons in the cavity, we performed numerical simulations with the actual fiber parameters based on the nonlinear Schrödinger equation. With a 3-nm bandwidth spectral filter, the spectral breathing ratio through the cavity is about 15×. The 2-D plot of the spectral evolution along the cavity position is shown in (a, center).

Meanwhile, the pulses are also linearly chirped in the time domain.[4] The simulated spectrum at the end of the second SMF segment has good match with the spectrum measured from the 0th order diffraction of the grating (a, bottom). The spectrum shows a good parabolic profile, which is one of the important characteristics of amplifier similaritons.

Experimentally, this laser delivers 930-mW average output power at a repetition range of 42.5 MHz, corresponding to 21.9 nJ. After being characterized and compressed with a MIIPS-enabled pulse shaper,[5] the interferometric autocorrelation (AC) measurement gives AC full-width-half-maximum (FWHM) of 57 fs (e). Hence, the FWHM pulse duration is 41.6 fs.

Taking into account the throughput of our pulse shaper (~50 percent due to the reflection efficiency of the grating and mirrors), the pulse energy of compressed pulses is around 10 nJ, resulting in a peak power for compressed pulses of about 250 kW.

The excellent match of experimental second harmonic generation and intereferometric AC with calculation indicates the full compression of the output pulse. When focused with a 10× objective at the surface of a 1-mm-thick glass slide, the compressed pulses produce the third harmonic generation (THG) spectrum. ◭



(a) Spectral evolution though the laser cavity. (Top) Scheme of the laser cavity. SMF: single mode fiber. QWP and HWP: quarter- and half-waveplate. (Bottom) Comparison of simulated spectrum after the second SMF and the spectrum measured from the 0th order diffraction of the grating. (b) Output laser spectrum. (c) Comparison of experimental (black) SHG spectrum with calculation (red).The dashed lines are in $\log_{10}$ scale. (d) THG spectrum. (e) Comparison of experimental interferometric autocorrelation with calculation. Inset: Same data on the range from -500 fs to 500 fs.

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