Nanosecond to Picosecond Fiber Bragg Grating Compression of Giant-Chirped Pulses from an Ultra-Long Mode-Locked Fiber Laser

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All-normal dispersion mode-locked fiber lasers (ANDi-FLs) are emerging as promising pulse sources, where the pulse energy can be increased by simply elongating the cavity to reduce the repetition rate [1]. Recently, ultra-long cavity (~1 km length) lasers have been demonstrated, producing ~ns duration giant-chirped pulses at ~100s kHz repetition rates [2]. Such sources could be convenient front-ends for compact chirped-pulse amplification systems, although to achieve high peak powers after amplification the pulses must be compressed (i.e. dechirped): a challenge yet to be solved due to the giant chirp of such nanosecond pulses. Here, we report a compression technique using a 400 mm long chirped fiber Bragg grating (CFBG), showing that after generating and amplifying 1.02 ns giant-chirped pulses, they can be compressed to 11 ps, enhancing the peak power by a factor of ~100.

An 846 m-long ANDi-FL with a carbon nanotube saturable absorber (CNT-SA) is constructed (Fig. 1a, cavity described in [3], CNT-SA described in [4]). The laser generates giant-chirped pulses with full-width at half-maximum (FWHM) duration of 1.02 ns (Fig. 1b) and 244 kHz repetition rate, at a wavelength of 1058 nm with 0.80 nm FWHM bandwidth. Numerical modeling is used to accurately predict the output performance of the pulse source, confirming the giant-chirp (Fig. 1c), and to guide the grating design. Fig. 1c shows the grating properties with reflection band and chirp matched to the pulse, modeled with index modulation = 5 x 10^-3, length = 400 mm, change of Bragg wavelength along length = 0.006 nm/mm, and a 300 mm FWHM Gaussian apodization; numerical compression is observed from 1 ns to 5 ps pulse duration. We experimentally fabricate the 400 mm long CFBG using a long direct writing system [5] and integrate it into our setup through a circulator, after an amplifier. The reflected pulses from the CFBG are linearly compressed to 11 ps with only a small pedestal (Fig. 1d) - verified using an autocorrelator and assuming a sech^2 profile - confirming pulse compression by a factor of ~100.

Our amplified low repetition rate pulses, after compression, possess kW peak powers at tens of mW average power. Such a system is an ideal compact all-fiber pump source for supercontinuum generation. To verify this, 30 m of photonic crystal fiber (PCF: NKT SC-5.0-1040) is spliced at the output and a supercontinuum is observed from ~550-2100 nm for only 24 mW average input power to the PCF (Fig. 1e). The generation of broadband light at low average pump power is well-suited for optical metrology applications and as a diagnostic tool for device characterization. Further work is underway to improve the compression, to approach the transform limit.

References