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

R. I. Woodward,[1] E. J. R. Kelleher,[1] T. H. Runcorn,[1] S. Loranger,[2] D. Popa,[3] V. J. Wittwer,[3] A. C. Ferrari,[3] S. V. Popov,[1] R. Kashyap,[2,4] and J. R. Taylor[1]
1. Femtosecond Optics Group, Department of Physics, Imperial College London, SW7 2AZ, UK
2. Fabulas Laboratory, Department of Engineering Physics, Polytechnique Montréal, H3T 1J4, Canada
3. Cambridge Graphene Centre, University of Cambridge, Cambridge, CB3 0FA, UK
4. Fabulas Laboratory, Department of Electrical Engineering, Polytechnique Montréal, H3T 1J4, Canada

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 $= 5 \times 10^{-5}$, 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.

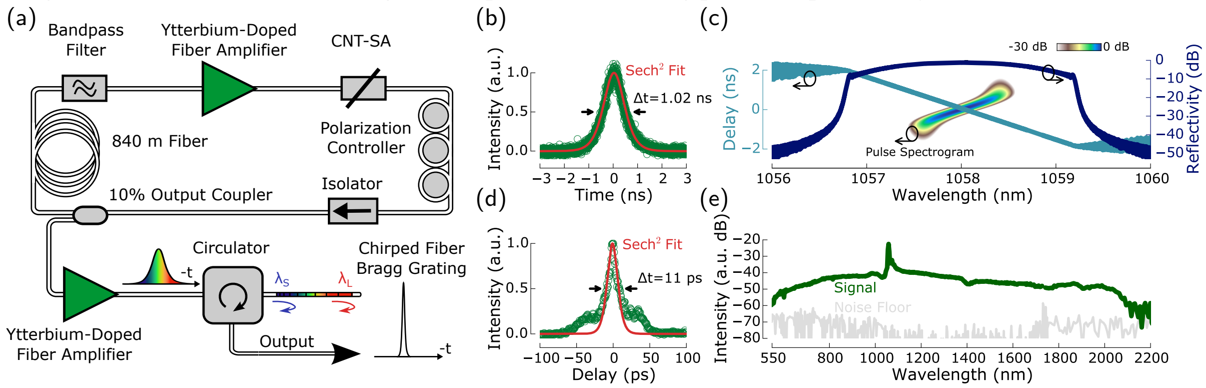

Fig. 1 (a) System setup. (b) Pulse profile from ultra-long laser. (c) Simulation results: pulse spectrogram overlayed with CFBG reflectivity and CFBG group delay. (d) Compressed pulse autocorrelation trace. (e) Supercontinuum after PCF.

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.

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