Dispersion Engineering of Mode-Locked Fibre Lasers [Invited]

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Mode-locked fibre lasers have become essential tools in research, industry and medicine due to their compact design, reliability and alignment-free waveguide format. It has long been understood that dispersion and nonlinearity in such laser cavities determine the formation and steady-state characteristics of the generated optical pulses. For example, the combination of nonlinearity with anomalous dispersion can lead to the formation of transform-limited solitons, whereas pulses in normal dispersion environments acquire a frequency sweep to form a compressible chirped pulse [1, 2].

Recent trends in fibre laser development have built on this understanding of dispersion engineering, exploiting the properties of linearly chirped pulses to scale pulse energies beyond the limits imposed by quantisation of optical solitons [3]. We have recently shown that extreme scaling is possible by simply elongating a normal-dispersion laser cavity to kilometre length scales, reducing the laser repetition rate and resulting in compressible pulses possessing a giant chirp [4].

In this talk, I will review recent progress in all-normal dispersion lasers with a focus on our long-cavity laser architecture. Experimental results will be presented showing nanosecond-pulse generation at kilohertz repetition rates, suitable for direct amplification and compressible by two orders of magnitude. This design thus offers a route to simplifying chirped pulse amplification (CPA) schemes. Additionally, the high-duty-factor compressed pulse are shown to be ideal for low-threshold supercontinuum generation in photonic crystal fibre.

I will also discuss the numerical modelling of these lasers using a generalised nonlinear Schrödinger equation, which is able to accurately predict the output pulse properties and offers additional insight into the intracavity nonlinear dynamics and pulse shaping mechanisms [5].

References

[1] S. DeSilvestri, P. Laporta, and O. Svelto, "The role of cavity dispersion in cw mode-locked dye lasers," IEEE J. Quantum Electron. **QE-20**, 533 (1984).

[2] E. B. Treacy, "Compression of picosecond light pulses," Phys. Lett. **28A**, 34 (1968).

[3] W. H. Renninger, A. Chong, and F. W. Wise, "Giant-chirp oscillators for short-pulse fiber amplifiers," Opt. Lett. **33**, 3025 (2008).

[4] R. I. Woodward, E. J. R. Kelleher, T. H. Runcorn, S. Loranger, D. Popa, V. J. Wittwer, A. C. Ferrari, S. V. Popov, R. Kashyap, and J. R. Taylor, "Fiber grating compression of giant-chirped nanosecond pulses from an ultra-long nanotube mode-locked fiber laser," Opt. Lett. **40**, 387 (2015).

[5] R. I. Woodward and E. J. R. Kelleher, "Dark solitons in laser radiation build-up dynamics," Phys. Rev. E **93**, 032221 (2016).

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