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50fs PULSE GENERATION IN AN INTEGRATED ERBIUM-DOPED FIBRE-LASER/AMPLIFIER MODULE

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We report the generation of 50 - 90fs solitons from an all-fibre passively mode-locked erbium-doped fibre laser in combination with an erbium fibre amplifier.

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The ready availability of high-gain erbium-doped fibres and advances in the generation and amplification of ultra-short pulses[1,2] make the development of high-power sub-100fs pulse sources at a wavelength of 1.55μm an attractive proposition. Such sources have numerous applications in instrumentation, advanced communications, signal processing and non-linear photonic switching.

Recently a source of 320fs soliton pulses from a passively mode-locked Figure-8 erbium fibre laser has been reported[3,4]. Despite the very broad gain bandwidth of erbium ions in silica, for fibre lasers operating in the negative GVD wavelength region the effect of soliton self-frequency shift (SSFS)[5] restricts the minimum possible pulse duration to around 300fs. One possible way of obtaining shorter pulses is to exploit the pulse compression effects occuring during soliton amplification in a fibre amplifier[2]. In this paper we report experimental results on both the temporal and spectral properties of pulses generated within an all-fibre unit containing an erbium-doped fibre laser and amplifier. The unit is potentially diode-pumpable and could therefore lead to a compact and convenient source of ultra-short pulses.

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The optical fibre circuit is shown in Figure 1 and consists of a master oscillator, an erbium-doped fibre amplifier (EDFA) and (optionally) a dispersion-shifted fibre. The perfomance of the passively mode-locked laser has been described elsewere[3]. Using only 20mW of pump power at 980nm the laser produces a stream of soliton pulses of 510fs duration with an average output power of 120μW. Although capable of even shorter pulse generation, the 510fs pulse mode provides optimal stability. The external EDFA consists of 5.5m of erbium-doped fibre (NA = 0.15, λ_{co} = 1230nm) with an Er^{3+}-doping level of 800ppm. With 350mW pump power obtained via a coupler from the same 980nm source we have achieved (saturated) gain as high as 28dB. To our knowledge this value represents the highest gain ever reported for subpicosecond pulses and corresponds to an average output power of 70mW.

During propagation down an amplifier fibre, a soliton pulse experiences amplitude growth, accompanied by pulse compression in order to retain its soliton form. Consequently, at the amplifier output we observed pulse compression down to 90fs, accompanied by a 30nm spectral shift due to SSFS (Figure 2). Thus during soliton amplification and propagation we have compressed 510fs fundamental solitons at 1.56μm into 90fs solitons at 1.59μm.

Further pulsewidth reduction was achieved by exploiting the high-order soliton compression effect in a dispersion-shifted fibre. In this case the length of the fibre amplifier was reduced to 4.5m to reduce the SSRS and optimise the pulse shape for further compression. Using 1.2m of undoped fibre with a dispersion of 1.5ps/nm.km at 1.56μm, fundamental solitons as short as 50fs at 1.59μm have been obtained (Figure 3).

In conclusion, we have demonstrated the first all-fibre module capable of generating 50fs fundamental soliton streams within the 1.5μm region. With further work we envisage being able to reliably generate pulses as short as 20fs, making the all-fibre approach a valuable source of ultra-short pulses for basic fundamental physics studies and for application in future communications and photonic switching schemes.

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Figure 1 Optical fibre circuit

Figure 2 Compressed pulse at amplifier output and associated spectrum

Figure 3 Pulse at output of pulse compressor and associated spectrum