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Soliton compression in a Nonlinear Amplifying Loop Mirror

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We have experimentally demonstrated the ability of the NALM to compress solitons with a low fraction of non-soliton component. The principle of operation of an all-fibre tunable source of femtosecond pulses has been shown.

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In many applications it is required to compress a soliton with as low a fraction of non-soliton component as possible. Proposed several years ago, the Nonlinear Amplifying Loop Mirror (NALM) [1] possesses both amplification and pulse shaping functions [2-4] and can be very attractive for soliton compression. In this paper we study soliton compression in a NALM and demonstrate the principle of operation of an all-fibre tunable source of femtosecond pulses.

As a source of solitons, we used a passive harmonic mode-locked fibre soliton laser based on Yb^{3+}/Er^{3+} codoped fibre which produced pulses with τ = 2.5ps FWHM at a repetition rate of 50 MHz [5]. The laser output was connected to the NALM through an isolator to prevent feedback into the laser cavity. The NALM was formed between the output ports of a 50/50 coupler and comprised a 3 m long Yb^{3+}/Er^{3+} codoped fibre amplifier and a standard telecom fibre with group velocity dispersion of D = 17ps/nm · km and a length of 50m.

Compression ratio and switching efficiency of the NALM

To characterise the NALM transmission in the soliton regime we studied spectral and temporal characteristics of the output pulses and the switching efficiency for different gain levels. The switching efficiency is taken to be P_{out}/GP_{in} where P_{in} and P_{out} are the powers at the NALM input and output and G is the gain of the amplifier. Fig.1 shows the dependences of the compression ratio K and switching efficiency on gain.

Fig.1

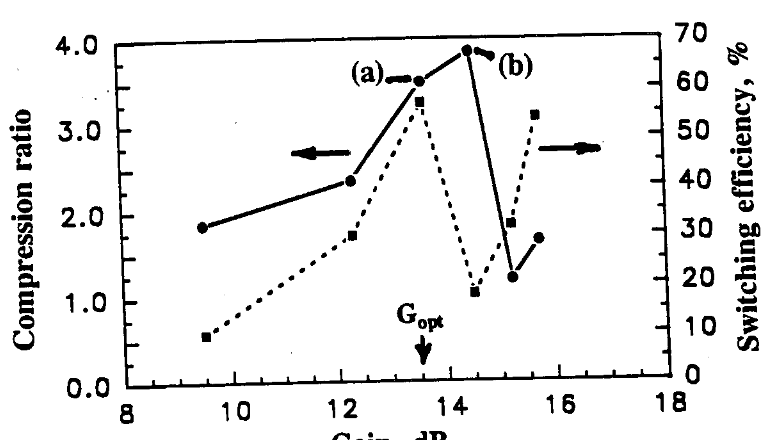

Fig.2(a) demonstrates the autocorrelation and spectrum of the transmitted pulse at a gain of 13.5 dB (point (a) in Fig.1) at which maximum swithing efficiency occurs. Fig.2(b) gives results at a gain of 15 dB (point (b) on Fig.1) where maximum compression ratio K is found.

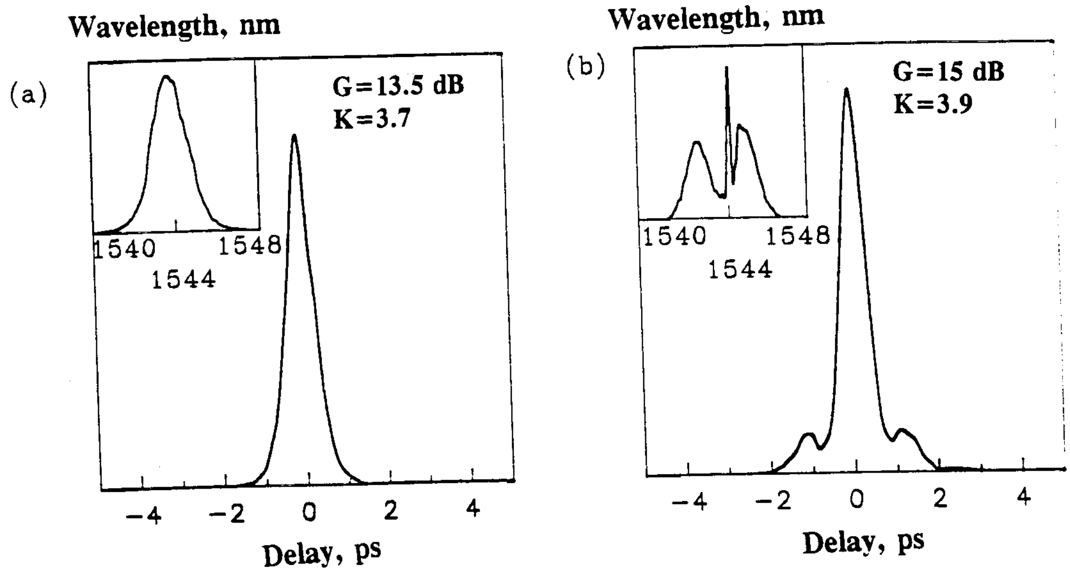

Fig.2

From the results of Fig.1 and 2 one can conclude that there is an optimal gain G_{opt}, corresponding to the maximum switching efficiency, where a clean compressed output pulse occurs. For gain exceeding G_{opt} at the NALM output we observed autocorrelations and spectra corresponding to multisoliton pulses (see Fig.2b). Note also that for $G < G_{opt}$ the time-bandwidth product of the output pulses was close to 0.31, while pulsewidths varied by over a factor of two (Fig.1).

Tunable all-fibre source of femtosecond pulses

The gain dependence of the pulsewidth gives rise to the possibility of developing a convenient tunable source of femtosecond pulses exploiting the effect of the soliton self-frequency shift. It is known that owing to Raman gain the soliton central wavelength λ_0 experiences a Stokes frequency shift, $d\lambda_0/dz(\text{nm/m}) \simeq 2.3 \cdot 10^{-5} D/\tau^{-4}$ where τ is in picoseconds and D in ps/nm · km [6]. Thus using an auxiliary fibre at the NALM output one can translate the pulsewidth variation into a controllable wavelength shift.

To demonstrate such a source we decreased the pulsewidth of the fibre laser output to 1.3 ps by shortening the laser cavity length. The length of the undoped fibre in the NALM was also reduced to 3m. In this configuration by changing the NALM gain in the range of 13.5-15 dB we observed reduction of the pulsewidth from 660 fs to 250 fs, while the time-bandwidth product change was from 0.32 to 0.28. For 250 fs solitons travelling in a lossless fibre with a dispersion of D=17 ps/nm ·km the soliton self-frequency shift is expected to be $\delta\lambda$ = 10nm/100m. Fig.3(a and b) shows the spectra of the pulses after 300 m of the auxiliary fibre and for NALM gains of 14.5 and 15 dB respectively. It can be seen that for small gain change the pulse central wavelength moves from original wavelength of 1544 nm to 1549 nm for 14.5 dB gain and to 1574 nm for 15 dB gain, giving tuning range of 30 nm.

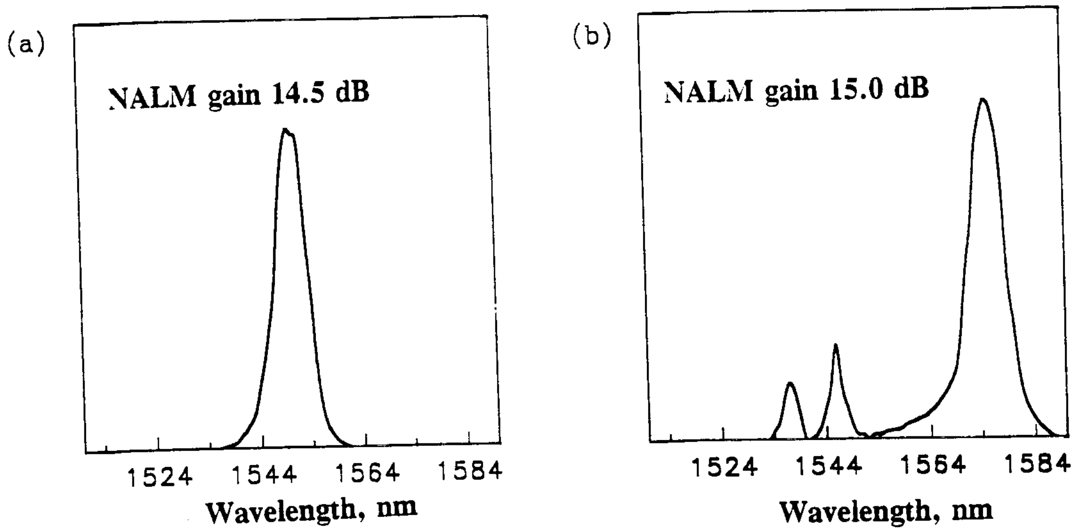

Fig.3

In conclusion, we have experimentally studied soliton propagation through a NALM and demonstrated the ability of the NALM to compress solitons with only an accompanying fraction of non-soliton component of about 10% and a switching efficiency of 60%. In this regime of NALM operation the pulsewidth dependence on gain allows the developmentof an all-fibre tunable source of femtosecond pulses and the principle of operation of such a source has been shown.

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