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PASSIVE, ALL-FIBRE SOURCE OF FUNDAMENTAL, FEMTOSECOND SOLITONS

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We report for the first time the generation of 50 fs solitons from an all-fibre circuit comprising a passively mode-locked erbium-doped fibre laser, an erbium-doped fibre amplifier and a short section of dispersion-shifted fibre.

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Advances in erbium-doped fibre fabrication and the generation and amplification of ultra-short pulses [1-5] make the development of sub-100 fs pulse sources based on erbium-doped fibre a very attractive proposition.

Recently, a source of 320 fs pulses from a passively mode-locked fibre laser has been reported [4,5]. Despite the very broad gain-bandwidth of erbium ions in silica, the effect of soliton self-frequency shift (SSFS) restricts the minimum possible pulse duration to around 300 fs. One possible way to make shorter pulses is to exploit the pulse compression effects which occur during soliton amplification in a fibre amplifier [3]. In this paper we report the results of an experimental study of both the temporal and spectral characteristics of pulses generated within an all-fibre unit containing a passive erbium-doped fibre laser, an erbium doped amplifier and a short section of undoped dispersion-shifted fibre.

The experimental configuration is shown in Fig.1. The performance of the passively mode-locked laser has been described elsewhere [4]. With just 20 mW of launched pump power at 980 nm, a power easily obtainable from a laser diode, the laser produces bandwidth-limited soliton pulses with a duration of 500 fs or less. The average output power in this instance was 120 μW. The external amplifier consisted of 5.5 m of erbium-doped fibre (NA= 0.15, λ_{co} = 1230 nm) with an Er^{3+}-doping level of 800 ppm. With an amplifier pump power of 200 mW a gain of 25 dB was obtained and pulse compression down to 90 fs was observed at the fibre output (see Fig.2). In addition to the compression, note the spectral shift due to the Soliton Self Frequency Shift (SSFS)[6] in the spectra in Fig.2. The time-bandwidth product for these pulses is 0.3, in reasonable agreement with that expected for a $sech^2x$ pulse shape. Thus, during soliton amplification and propagation we have transformed 500 fs fundamental solitons at 1.56 μm into 90 fs fundamental solitons at 1.59 μm. At higher amplifier gains, high-order soliton break-up into coloured solitons due to SSFS was observed, the individual pulse widths being of the order 100 fsec.

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The amplifier length was reduced to 4.5 m in order to reduce the SSFS at the amplifier output and the amplifier pump adjusted slightly to enable us to obtain the shortest possible, single, high-order soliton pulse, as shown in Fig.3. A 1.2 m length of dispersion-shifted fibre was then spliced to the amplifier output in order to obtain further pulsewidth reduction by high-order soliton compression.
The dispersion of the fibre was 1.5 ps/nm/km within the 1.55-1.61 μm wavelength range. At the propagation "focal point" within the undoped fibre, the pulse duration is comparable to the Raman response time. We therefore expect SSRS to have a great influence on the pulse evolution. The SSRS results in both temporal and spectral separation of the short central spike from the rest of the pulse, yielding compressed pulses at the output of the dispersion-shifted fibre. Using this technique we have obtained fundamental solitons as short as 50 fs at 1.59 μm (Fig.4a). With increased amplifier pump power we observed coloured soliton generation as shown in Fig.4. At 270 mW pump input we observed the appearance of a second pulse (Fig.4b) and at 320 mw and 350 mW additional soliton pulses became apparent (Fig.4c,d).

In conclusion, we have demonstrated for the first time an all-fibre module capable of generating 50 fs fundamental solitons within the 1.6 μm region with repetition rates as high as 1GHz. We envisage being able to generate pulses as short as 20 fs. Results of further investigations into the properties of such a pulse source, including detailed measurements of coloured soliton generation, will be presented at the conference.

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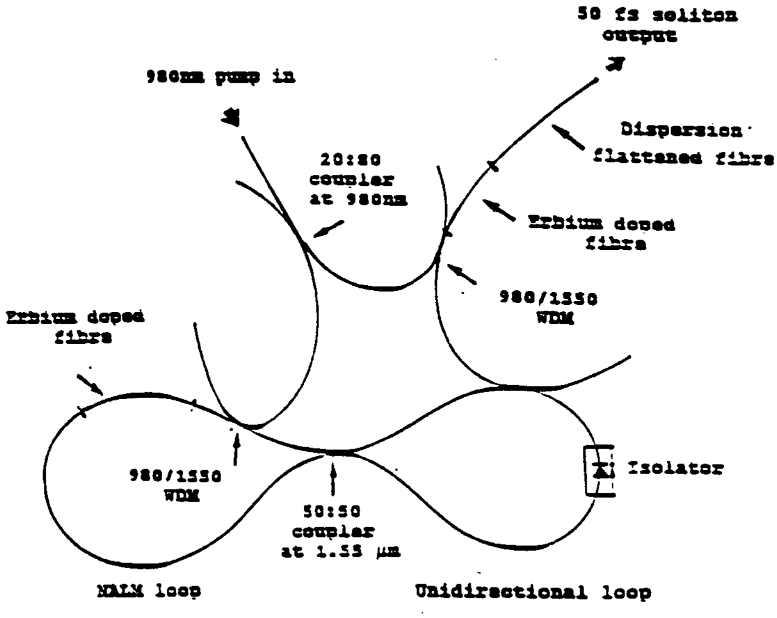

Fig.1 All-fiber circuit

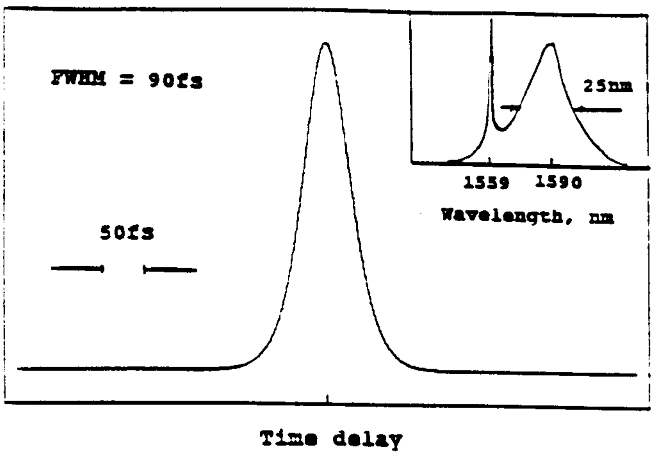

Fig.2 Background free autocorrelation trace and spectrum of 90fs pulses at output of 5.5m fibre amplifier. Amplifier pump power - 200mW

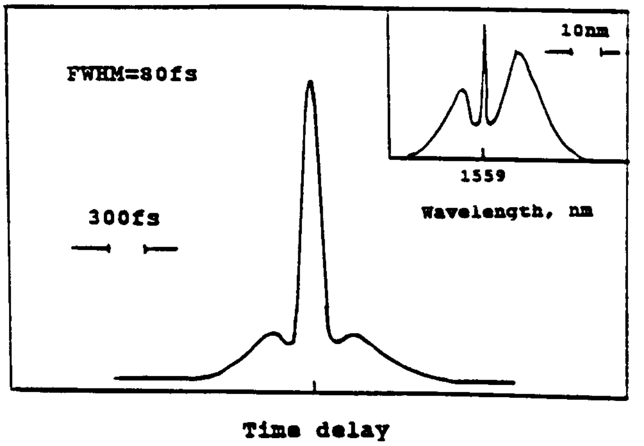

Fig.3 Background free autocorrelation trace and spectrum of 80fs pulses at output of 4.5m fiber amplifier. Amplifier pump power - 200mW

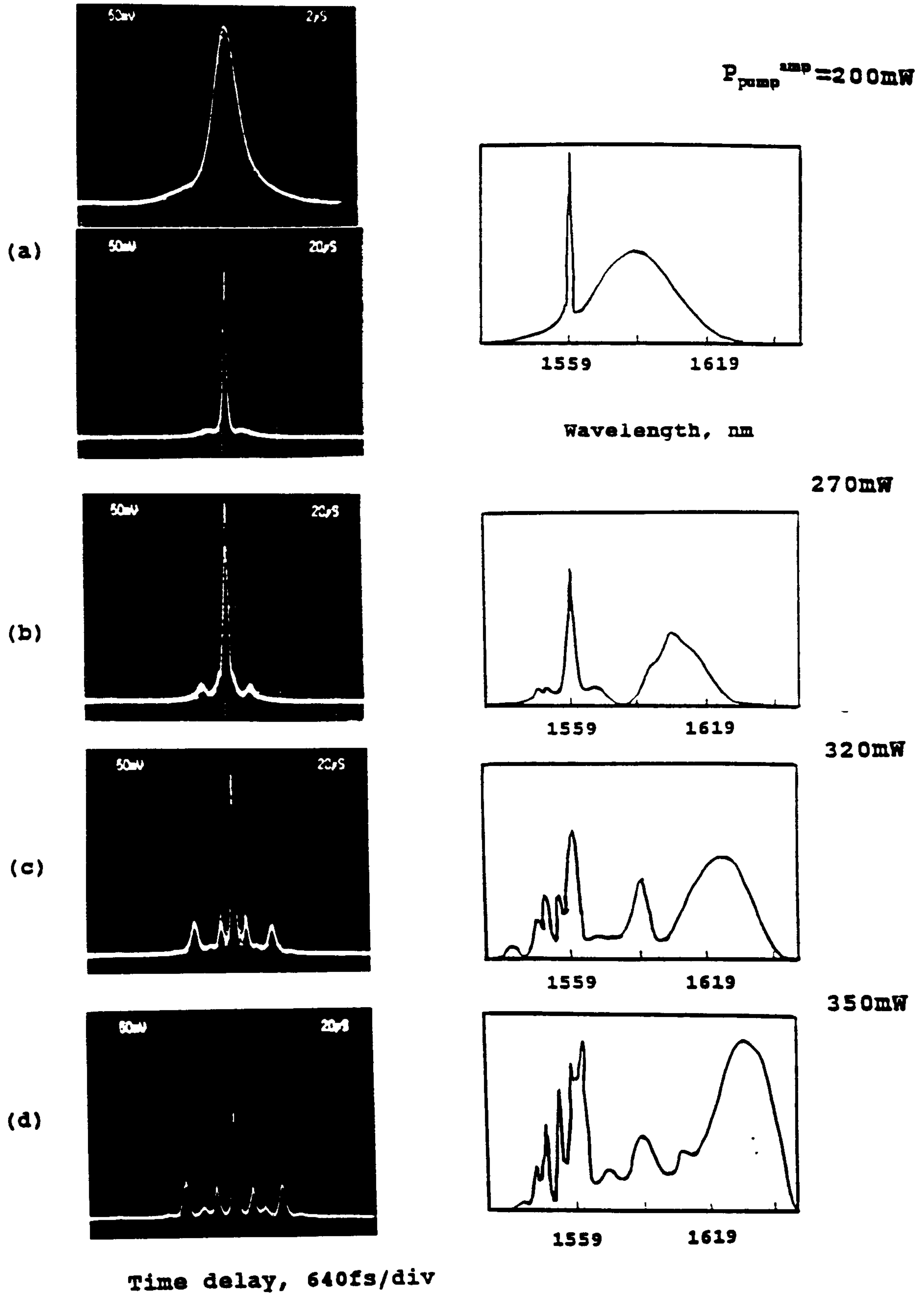

Fig.4 Real-time autocorrelation traces and spectra at the system output for various amplifier pump powers. (a) represents a 50fs fundamental soliton