Experimental demonstration of step-like dispersion profiling in optical fibre for soliton pulse generation and compression

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Generation of 100GHz trains of 500-1500 ps pulses using dual-frequency beat conversion in a step-like dispersion profiled fibre is reported.

Optical fibres with a profiled dispersion along the fibre length are very attractive for effective control of soliton pulse propagation. The use of continuous dispersion decreasing fibres (CDDF) was proposed for compensation of soliton broadening due to optical loss [1] and for soliton pulse compression [2-5], because propagating in such a fibre gives rise to an "effective amplification". The effect of dual-frequency beat conversion into a soliton pulse train in a dispersion decreasing fibre was discovered [6] and used for pulse-train generation at repetition rates in the range from tens to hundreds of gigahertz [7, 8]. Dispersion profiling along the length was achieved experimentally using spatial optical fibres [9]. However, the fabrication of dispersion decreasing fibres with predetermined and controlled dispersion properties requires special facilities and meets a number of existing manufacturing problems. An alternative approach to is profiling the fibre dispersion using segments of conventional fibres with different dispersions which can successfully replace continuous dispersion profiling in many applications. For soliton train generation through beat signal conversion, we have recently demonstrated a comb-like dispersion profiled fibre designed by splicing alternating segments of standard telecommunication fibres and dispersion-shifted fibres [10]. In turn, a dispersion-decreasing characteristic can be approximated by a simple step-like dispersion-profile fibre (SDPF), and it can also be employed for soliton pulse generation and compression as theoretically predicted in [8]. In the present Letter, we describe the experimental realisation of a step-like dispersion-profiled fibre and the generation of 10GHz trains of femtosecond soliton pulses using a dual-frequency beat-conversion technique.

![Fig. 1 Schematic diagram of experimental setup and dispersion-length profile of step-dispersion profile fibre (SDPF) used in experiment.](image)

The step-like dispersion profiled fibre (SDPF) used in the experiment was designed for generation of solitons at a ~10GHz repetition rate, which was dependent on the available dispersion-shifted fibres and accessible amplified power. Fig. 2 demonstrates the autocorrelation trace and spectrum for a 104 GHz train of 660fs solitons obtained by adiabatic beat signal reshaping in the SDFP at 40kW of input power. Owing to a large ratio between the input and output dispersions of the SDPF, the pulse train exhibited a mark-space ratio (MSR) as high as 1:14. The pulses had no pedestal within the accuracy of our measurements, and background was not discerned on the autocorrelation trace. In the spectrum, the maxima of equally separated spectra can be well fitted by a sech² shape with a 3.2fs FWHM (broken line in Fig. 2). The corresponding time-bandwidth product is 0.31, Repetition rate tuning within ~10GHz was achieved keeping the same high quality of pulses and MSR value.

As demonstrated, adiabatic compression of the ~10GHz beat signal took place in the step-like dispersion profiled fibre for an input power of ~400mW. However, using the maximum available 600mW pump power, use can be made of other nonlinear processes for ultrashort pulse generation, namely Raman self-scattering or the soliton self-frequency shift [11, 12].

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of the generated soliton train was shifted towards the Stokes region (as would be expected) and separated from the residual background radiation at the input, wavelength. A 'multi-soliton-
type' compensation of the half-periods of the beat signal in the first stage of propagation resulted in generation of short femtosecond pulses which were then separated spectrally and temporally from the background radiation due to Raman self-scattering, facilitating recording of the pulses. The stepped dispersion decreasing along the length provided an increase in the soliton number (i.e., an 'effective amplification'), and hence enhanced the compensation ratio. A similar mechanism of pulse train generation was previously observed [13] using a dispersion-decreasing fibre; however, a CW train was not obtained in that case.

![Fig. 3 Autocorrelation trace and spectrum of 95 GHz train of 0.3 fs pulses.](image)

Inset: demonstration of center peak of autocorrelation measured at a higher resolution.

Note that a small R.F. modulation of the current supplied to the DFB laser diodes was required in these experiments for suppression of stimulated Brillouin scattering (SBS) [7]. However, SBS can be intrinsically suppressed in the step dispersion profiled fibre similar to that which has been reported in the case of comb-like dispersion profiling [10].

In conclusion, we have demonstrated, for what we believe is the first time, the generation and compression of soliton pulses using step-like dispersion-profiled fibre. The fabrication of such fibre assemblies does not require any special facilities and relies only on conventional optical fibre technology. We believe that the use of profiling the fibre dispersion by fibre segments instead of continuously dispersion-decreasing fibre is not only possible but preferable in many applications.

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