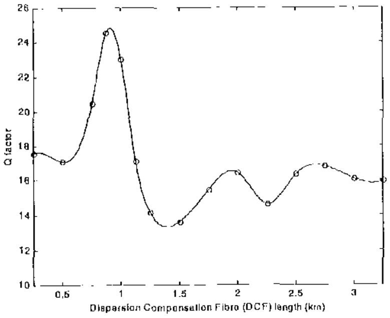
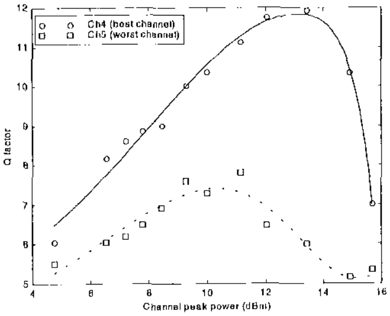


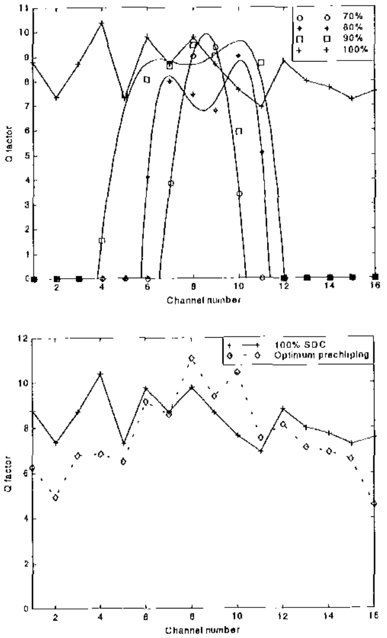
CTuG4 Fig. 2. Optimum single-channel launch position.



CTuG4 Fig. 3. Q factor evolution with 100% DSC.

polynomials to the simulated data using least-squares error minimisation.

The best results for a 16 × 40 Gbit/s WDM transmission can be obtained with a symmetrical allocation of the channels respect to λ_0. If we also consider a perfect (100%) DSC at λ_0, as we report in Fig. 3, an error free transmission (BER $<10^{-9}$) distance of 1000 km can be achieved for at least 7 dB power variations. In this figure the evolution of the Q factor versus the input peak power is shown for the worst and best channel.



CTuG4 Fig. 4. (a) Q factor per channel for different DSC percentages; (b) evolution of the Q factor per channel.

A lower percentage of DSC reduces the spectral range available for WDM transmission and therefore the number of channels with error-free transmission at the reception. This can be observed in Fig. 4(a) for the 16 × 40 Gbit/s system with 10-dBm peak power per channel, where the evolution of the Q factor per channel is shown for different percentages of DSC provided by the DCF.

To compensate the different dispersion accumulated per channel at the receiver because of the non-perfect SDC, we have investigated the effect of introducing an appropriate pre-chirp per channel at the transmission end using commercial SF or DCF. In Fig. 4(b), in a similar way to Fig. 4(a), we show the similarity in the Q factor per channel when using perfect 100% DSC and 75% DSC with the optimum pre-chirp per channel.

We have analyzed the use of channel-dependent pre-chirp in dispersion-compensated, standard fibre 16 × 40 Gbit/s WDM systems with non-ideal DSC, and obtained similar performance over 1000 km to systems with ideal DSC.

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CTuG5 3:30 pm

Noise in sliced self-phase modulation broadened spectrum

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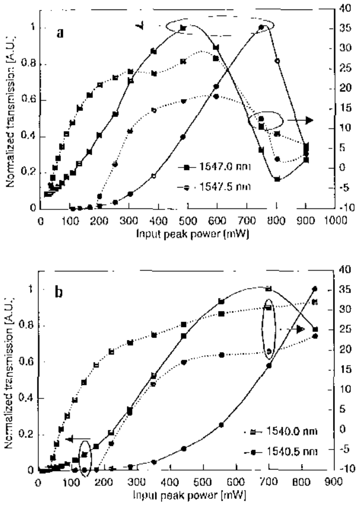
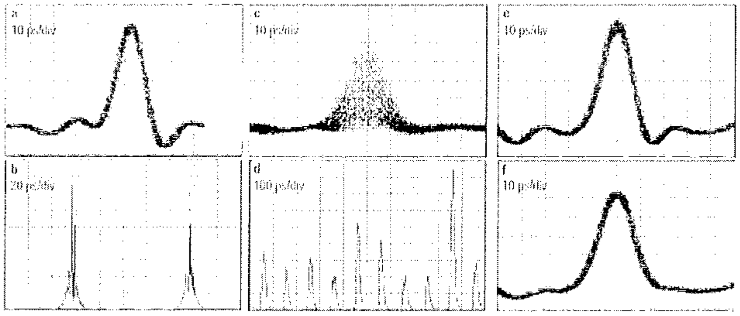
Recently there has been a great interest in applications where a slice of a broad optical spectrum generated by nonlinear effects in a fiber is filtered out by selecting a narrow part of the spectrum with an optical filter. Such applications are e.g., the generation of super continuum with subsequent multi-wavelength filtering to accomplish a wavelength division multiplexing (WDM) source,[1] or narrow filtering of a self-phase modulation (SPM) broadened signal to achieve data reshaping.[2] Spectral slicing can also be utilized in a cross-phase modulation (XPM) broadened spectrum to achieve e.g., wavelength conversion.[3] Under ideal circumstances, slicing of an e.g., SPM broadened spectrum should give a clean high quality pulse, where the pulse width and pulse shape are determined by the filter function of the filter used. However, when operating in anomalous dispersion regime in the fiber, the filtered pulses become noisy if the input pulses are not extremely stable in amplitude and the signal to noise ration (SNR) is very high. This is due to unstable excitation of higher order solitons either due to amplitude fluctuations in the input pulse itself or due to beating between the pulse and optical noise, e.g., from an Erbium-Doped Fiber Amplifier (EDFA). This phenomenon has been shown to become a severe limitation in the generation of super continuum[4-5] where the input peak power has to be extremely high compared to the generation of a fundamental soliton. In this communication we show that this effect also has severe noise implications even at the much lower input power required for moderate SPM broadening of the spectrum. Here, the growth of noise is characterized by measuring the SNR versus input power for a sliced SPM broadened spectrum. Random generation of higher order solitons, when pumping the fiber in the anomalous dispersion regime, may also impair other all optical fiber devices, like the nonlinear optical loop mirror and devices relying on four wave mixing.



CTuG5 Fig. 1. Transmission and SNR vs. input peak power in the anomalous (a) and normal dispersion regime (b).

An 8 ps soliton-like pulse train with a repetition rate of 10 GHz from an actively mode-locked fiber ring laser was amplified in an EDFA and injected into a 5 km dispersion-shifted fiber with a zero dispersion wavelength of 1543 nm. The spectrum was broadened due to SPM in the fiber, and at the output a tunable 0.2 nm band-pass grating filter was used to slice out a part of the spectrum. To estimate the SNR, the output signal was analyzed with an electrical spectrum analyzer and the noise power was integrated from 50 MHz to 9.9 GHz and compared with the power in the fundamental 10 GHz tone. Figure 1(a) shows the transmission from input to output and SNR variation when pumping the fiber in the anomalous dispersion regime at 1546.5 nm. The measurements were carried out with the filter set at 1547.0 nm (■) and 1547.5 nm (●). The transmission functions have the same principal behavior, but the peak power re-



CTuG5 Fig. 2. Measured and simulated optical pulses. a-d show pulses in the anomalous dispersion regime and e-f show pulses in the normal dispersion regime, without (a, b, e) and with (c, d, f) a 0.2-nm filter.

quired for maximum transmission increases as the filter is positioned away from the input wavelength. The output SNR for low input power is low due to the noise from the detector and spectrum analyzer and thus increases as the transmission goes up. At a certain power level the SNR begins to decrease due to the generation of random higher order solitons. The net effect in this region is that noise at the input signal is amplified due to modulation instability (MI) on the pulse[5] and results in a random pulse evolution in both the temporal and spectral domain. When looking at the SPM pulse without the filter in the temporal domain using an oscilloscope, the pulses do not look noisy because the integrated energies within the time resolution of the oscilloscope are constant, see Fig. 2(a). Figure 2(b) shows simulated output pulses with a high resolution, where all pulses look different even though the integrated pulse energy may still be the same. Figure 2(c) and 2(d) show measured and simulated pulses, respectively, after the 0.2-nm band-pass filter. The pulses are now extremely noisy, i.e., all pulses have different amplitude due to the random energy distribution in the spectrum. Figure 1(b) shows the transmission and SNR measurements when the fiber was pumped in the normal dispersion regime at 1539.5 nm and the filter positioned at 1540.0 nm and 1540.5 nm. The transmission function looks somewhat different and more input peak power is required for maximum transmission. On the other hand there is no decrease in SNR for high input powers since no solitons are generated in the normal dispersion regime and MI cannot occur. Figures 2(e) and 2(f) show a measured output pulse at 1539.5 nm without filtering and sliced output pulse at 1540 nm, respectively. Here no addition of noise is observed after filtering. The results above have also direct implication on randomness of XPM of another signal,[3] because the pump required for XPM always suffers SPM. However, the interplay between SPM and XPM in the presence of dispersion is complex and subject to further investigation.

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CTuG6 **3:45 pm**

Supercontinuum source based on an electroabsorption modulated laser for long distance DWDM transmission

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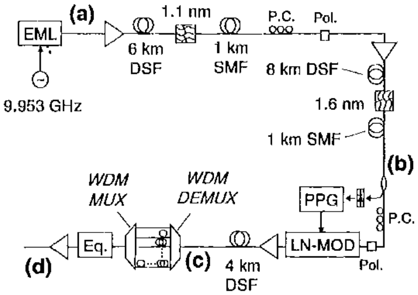
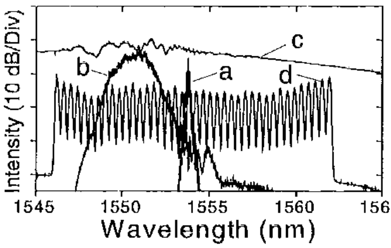
Dense wavelength-division multiplexed (DWDM) transmitters based on spectrum-slicing of supercontinuum (SC) light have attracted renewed interest recently.[1–3] So far, all transmission experiments with SC-DWDM sources have used actively mode-locked lasers to seed the supercontinuum, raising concerns about the stability and the practicality of these systems. Picosecond seed pulses can however also be obtained from a DFB laser using a variety of techniques.[4–10] In this paper, we describe for example a 40-channel 400 · Gbit/s SC-DWDM transmitter where seed pulses are obtained from an electroabsorption-modulated DFB laser (EML). We demonstrate the error-free transmission of all channels over 7 spans (544 km) of standard single-mode fiber. To our knowledge, this is the first system experiment using a mode-locked-laser-free SC-DWDM transmitter.



CTuG6 Fig. 1. 40-channel SC-WDM transmitter based on an EML.



CTuG6 Fig. 2. Optical spectra at four points inside the transmitter.

Figure 1 shows the transmitter layout. A 9.953-GHz train of 21.5-ps pulses at 1553.8 nm was obtained by driving an EML with a sinusoidal RF tone.[9] The pulses were compressed nonlinearly to 6 ps by amplification ($P_{average}$ = 85 mW), propagation through dispersion-shifted (DS) fiber ($D = -2$ ps/nm/km), bandpass filtering, and linear compression in standard fiber (SMF). A second stage of nonlinear compression ($P_{average}$ = 300 mW, $D = -2$ ps/nm/km) produced a train of 2.7-ps seed pulses with a time-bandwidth product of 0.52. Traces a and b in Fig. 2 show the optical spectrum before and after nonlinear compression respectively. Detuning of the bandpass filters in the compression stages allowed rejection of background radiation at 1553.8 nm caused by the finite modulation depth of the EML. A pattern generator synchronized to the pulse train encoded a 2^{31}-1 pseudo-random pattern on the pulses. After amplification to 540 mW, the pulses were launched into 4 km of DS fiber (λ_0 = 1573 nm) for SC generation. Trace c on Fig. 2 shows the SC spectrum. A WDM demux/mux combination was used to slice 40 channels spaced by 50 GHz from the broad spectrum with wavelengths ranging from 1546.2 nm to 1562 nm. Delay lines were used to decorrelate the data patterns of the different channels. Channel power levels were equalized using an integrated dynamic wavelength equalizer.[11] Trace d on Fig. 2 shows the output spectrum of the transmitter.

Figure 3 shows the accumulated dispersion as a function of distance along the transmission line for channels 1 and 40. The transmission link consisted of seven spans of standard fiber with lengths ranging from 76.8 km to 79.3 km. As shown in Fig. 3, dispersion-compensating fiber (DCF) was used before and after transmission, as well as within the in-line amplifiers. The total length of standard