All-fibre DFB lasers as highly reliable transmitter sources for high speed WDM systems

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Introduction:

WDM transmission systems have received growing attention over the last few years because of their obvious advantages when upgrading existing systems to operate at higher data-rates. Operating at bit-rates of 10 Gbit/s and above requires compensation of the chromatic dispersion suffered in the existing fibres. Dispersion compensation with single channel chirped fibre gratings has been demonstrated on numerous occations [1,2]. Transmitting multiple WDM-channels the relative channel spacings are of great importance. The periodic spectral response and identical multiple channel characteristics of the recently developed sinc-sampled grating [3] makes it a very attractive WDM device. DFB fibre lasers exhibit ideal source characteristics being an inherently fibre compatible device. The operating wavelengths [4] can readily be manufactured with high accuracy to achieve a constant frequency separation using current grating writing techniques [5]. They can also be designed to lase in a single polarisation whilst single-sided lasing output by offsetting the phase-shift from the centre position [6,7] increases the potential further.

In this paper we combine the devices and demonstrate an all-fibre WDM transmission [8] system comprising 4 high power DFB fibre lasers operating with single sided and single polarisation outputs. The lasers are demonstrated to be reliable signal sources in a 4x10 Gbit/s, 100 GHz channel specing WDM transmission experiment over 200 km of standard fibre with robust dispersion compensation performed by a single 4 channel 100 GHz spacing chirped sinc-sampled fibre Bragg grating.

Experiment:

The experimental setup (Fig. 1) consists of 4 single polarisation asymmetric DFB-fibre lasers of length 5 cm separated in frequency by 100 GHz. The lasers have [4,7] phaseshifts offcentret by 4 mm. Each is pumped at 980 nm with 60 mW power from a pump diode, resulting in single sided output powers of 7.1 dBm, 7.7 dBm, 7.0 dBm, and 7.7 dBm, and operating wavelengths of 1547.6 nm, 1548.4 nm, 1549.2 nm and 1550.0 nm respectively. The signal to noise ratio between the 4 DFB signal channels is in excess of 50 dB (0.08 nm resolution) and the linewidth of the devices has been measured to be ~10 kHz. Polarisation purities in excess of 40 dB has been measured [7] together with RIN values larger than -160 dB/Hz (f>10 MHz).

The polarisation states of the lasers are individually aligned using polarisation controllers to allow modulation in a single modulator. The excess power of the lasers allows their output to be combined in an all-fibre multiplexer consisting of three 1550 nm 3 dB splitters, before each channel is modulated using a lithium niobate ($LiNbO_3$) modulator. Fig. 2a shows the output spectra of the 4 DFB fibre lasers measured directly after the modulator. The WDM channels are amplified and then transmitted over a 200 km standard telecommunication fibre (D=16 ps/nm/km @ 1.55μm) link. Ultimately the high power of the fibre DFB's will obviate the requirements for amplification prior to transmission. After transmission the channels are simultaneuosly dispersion compensated with a 4 channel sinc-sampled fibre grating [3], which is wavelength

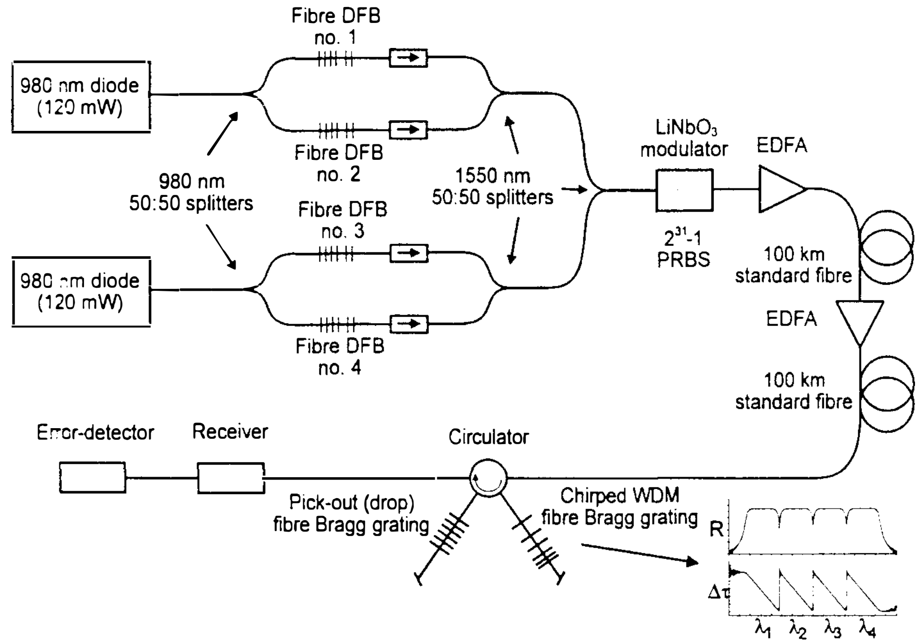

Fig.1. *Schematic diagram of the experiment setup employing all-fibre DFB lasers as transmitter sources.*

matched to the transmitted channels (Fig. 2). The grating has a sampling period of 1 mm and is 25.8 cm long. It is chirped over 0.8 nm and is apodised over 10 % of the total length at either end to reduce the ripples in the dispersion characteristics. Each dispersion-compensating channel of the grating exhibit a reflectivity of ~ 60 % and dispersions of -3263 ps/nm, -3206 ps/nm, -3250 ps/nm and -3238 ps/nm respectively with a maximum in-band time delay ripple of ~50 ps (Fig. 2b&c). A uniform fibre grating used in an add-drop configuration, selects the channel under test and drops it onto the receiver and error detector. All the fibre gratings used in this experiment are manufactured using a continuous grating writing technique [3,9] which allows very complex grating structures to be formed.

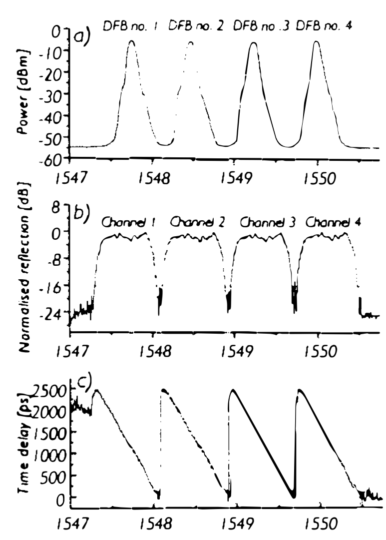

Fig.2. *a) DFB lasing spectra after the modulator. b) Reflection and c) time delay characteristic of the 4 channel chirped sinc-sampled fibre Bragg grating.*

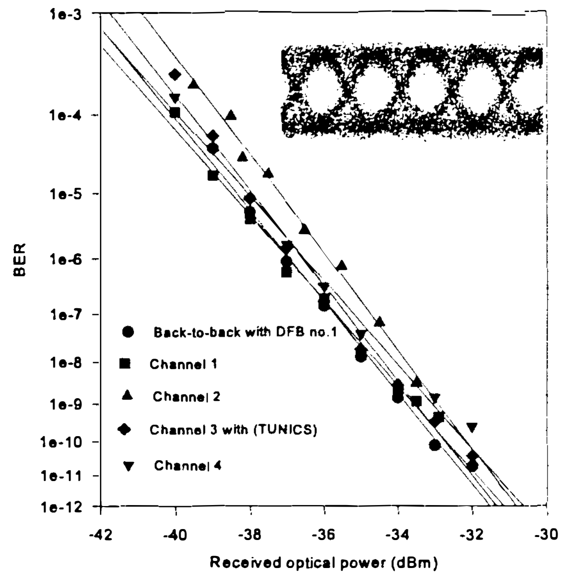

Fig. 3. *Bit-error-rate (BER) performance of simultaneous 4x10 Gbit/s WDM transmission system. (Insert) Dispersion compensated eye of channel 4.*

Results and discussion:

Bit error rate (BER) vs. received power for the 4 dispersion compensated channels and back-to back with DFB laser no.1 are shown in Fig. 3. The figure shows a maximum power penalty of 1 dB for error free operation. This variation could be due to the fact that a different pick-out grating is used for each channel. In order to test the quality of the dispersion compensating grating, a wavelength scan across the bandwidth of channel 2 was made. In this case the received power was kept constant at -34.5 dBm and the BER was recorded. A variation of 2 orders of magnitude in the error rate around 10^{-8} was measured, corresponding to a less than 0.75 dB power penalty. The effect of cross talk between adjacent channels was also evaluated by comparing BER data for the WDM system with data obtained when transmitting only one of the wavelength channels at a time. No degradation in the performance of the system was observed. In order to compare the performance of the fibre DFB laser transmitters with a traditionally used tunable laser source (TUNICS) a single channel BER measurement tuned onto channel 3 using this source was performed. Again no significant difference was observed (Fig. 3).

Conclusions:

We have demonstrated the first 4 channel 40 Gbit/s NRZ WDM transmission experiment over a 200 km standard fibre link employing high power all-fibre DFB lasers as signal sources. Simultaneous dispersion compensation of the 4 channels was performed using a sinc-sampled multichannel fibre grating that exhibits identical dispersion characteristics on a 100 GHz comb of wavelength channels. We believe that this experiment demonstrates that the technology of fibre DFB lasers has matured and that they are an attractive transmitter alternative to semiconductor DFB lasers and are ready to take part in the realisation of all-fibre WDM transmission systems and play an important role herein.

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