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Erbium-doped Fibre Amplifier in a 16-Channel Coherent Broadcast Network

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ABSTRACT

In this paper, we describe the use of an erbium-doped fibre amplifier in a 16-channel coherent broadcast network experiment operating in the wavelength range of 1538.8 to 1540nm. The fibre-to-fibre gain was 22dB and the amplifier dynamic range was 15dB for the entire transmission spectrum. The amplifier was used to amplify sixteen 155Mb/s signals on one output of a 16-by-16 star coupler, allowing a total span loss of 47dB between transmitted and received signals. Satisfactory transmission system performance is obtained for error rations of 10^{-9}.

INTRODUCTION

Recently there have been several demonstrations of multichannel coherent broadcast networks[1,2] for use in single-mode fibre subscriber systems. The number of end-users and the transmission distance can be increased by the incorporation of an optical amplifier[3,4]. The erbium-doped fibre amplifier[5,6] (EDFA) is extremely attractive for this purpose as it is an efficient[5,6], low-noise, high-gain, polarisation-insensitive amplifier which has been demonstrated to operate between 1.53 and 1.55μm[4-8]. In addition, EDFA's are likely to show lower channel crosstalk than their semiconductor counterparts[8].

Here we describe a 16-channel wavelength-division-multiplexed coherent distribution network with integral EDFA. The amplifier provides a fibre-to-fibre gain of 22dB with no detriment to receiver sensitivity and a dynamic range of 15dB for the entire transmission spectrum. Further, we demonstrate the feasibility of transmitting sixteen 155Mb/s channels to a cluster of 256 end users at a distance of 102km. This is a total network capacity of 65Tb/s*km*user.

EXPERIMENT

The experimental configuration is shown in Figure 1. The 16 transmitter lasers were locked, with 10GHz separation, in the wavelength range 1538.8 to 1540nm and each frequency modulated at 155Mb/s. Data for the 9th channel were produced by error rate test equipment, with a pseudorandom pattern length of $2^{23}-1$. The laser outputs were multiplexed via a 16x16 star coupler such that the total power from each output port was ~1dBm. One output was transmitted via an attenuator and 3dB monitor coupler to the amplifier. The amplified output was transmitted via ~14km of fibre

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and another attenuator to the wavelength-tuned balanced polarisation diversity heterodyne receiver. The amplifier consisted of a dichroic coupler and 1.5m of alumino-silicate erbium-doped (~500ppm Er^{3+}) fibre, characterised by an NA of 0.15 and λ_{cutoff} at 1250nm. It was optically pumped with ~200mW of power at 528nm. Figure 2 shows a spectrum of the amplifier output for total signal input power of ~-12dBm. It can be seen from the ASE spectrum that the 16 lasers were not operating at the amplifier gain peak (1531nm) but over the reduced, relatively constant gain region between 1540 and 1560nm; however a fibre-to-fibre gain of 22dB was still obtained. This indicates the possibility of operating erbium-doped fibre amplifiers over a spectral bandwidth of 30nm or more.

To characterise the performance of the amplifier in the network we measured its dynamic range[9]. This was determined by adjusting the attenuators such that the total link attenuation remained constant whilst the amplifier input power was varied. Fig.3 shows the error ratio for a constant total span loss of 50dB (curve a) and for a span loss of 47 dB (curve b). The error ratio measured in this fashion defines the optimum position of the amplifier in the link and is characterised by a degraded response at low amplifier input power, a flat central part and a degraded response at high amplifier input power. The degradations at low input power are due to the amplifier noise and the degradations at high input power are due to amplifier gain saturation, which results in a reduced signal level at the receiver. We define the dynamic range as the range of amplifier input power within which the amplifier causes a degradation of less than 1 dB, corresponding to an error ratio increase of about two orders of magnitude. With this criterion, the dynamic range is 15dB. The dynamic range would be 12dB larger if only one channel were present, since degradations at saturation depend on the total power of the 16 channels[8].

To simulate a network, 42km of fibre replaced the attenuator prior to the amplifier (Fig. 1), 60km of fibre and a 1x16 splitter were inserted in addition to the attenuator after the amplifier to give a total repeatered link of 102km. Figure 4 shows the receiver sensitivity measured both directly through 60km of fibre and via the amplifier. It is clear that there is no detriment in receiver sensitivity and thus the full advantage of the amplifiers 22dB gain can be used.

CONCLUSIONS

We report the use of an erbium-doped fibre amplifier in an experimental coherent multichannel broadcast network. With a fibre-to-fibre amplifier gain of 22dB and a dynamic range of 15dB, we achieved a network capacity of 65TBit/s*km*user, which corresponds to distribution of sixteen 155Mb/s signals to a cluster of 256 end-users at a distance of 102km. This is more than twice the capacity of any previously reported network[10].

ACKNOWLEDGEMENTS

The authors would like to acknowledge H. Kodera and Y. Koga of Hitachi Ltd. for the specially packaged DFB lasers, D.N. Payne, A. Von Lehman, L. Curtis, R.E. Spicer, K. Nanduri and J.R. Barry for important contributions to the experiment.

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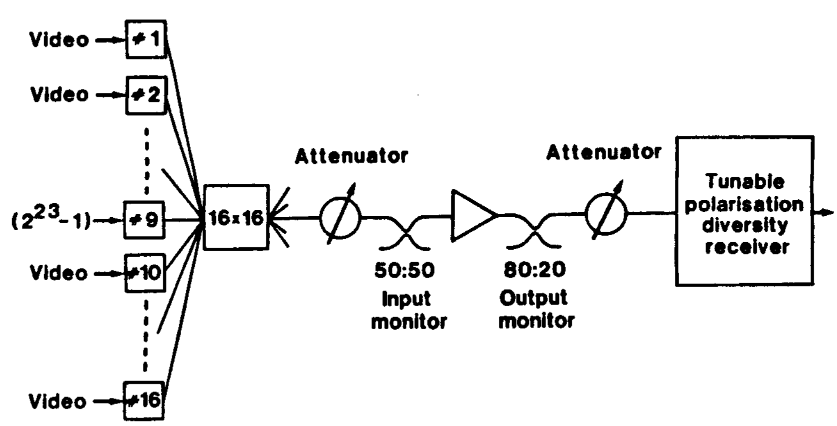

Figure 1. Schematic of multichannel coherent network experiment.

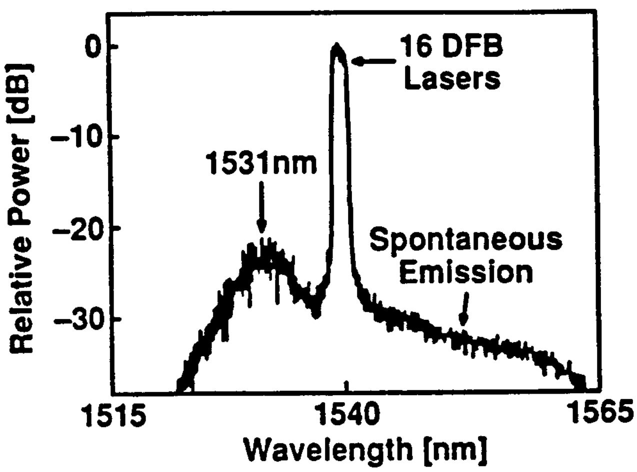

Figure 2. Spectrum of the amplifier output showing amplification of the 16 channels.

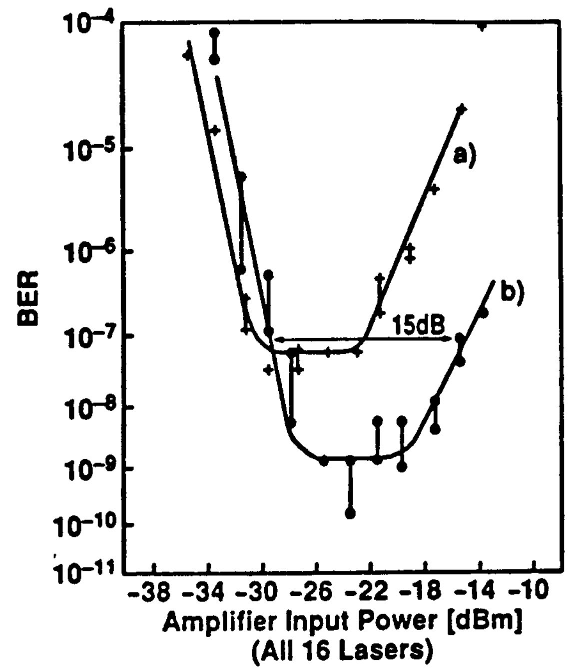

Figure 3. Amplifier dynamic range measurements. Link attenuation (a) 50dB, (b) 47dB.

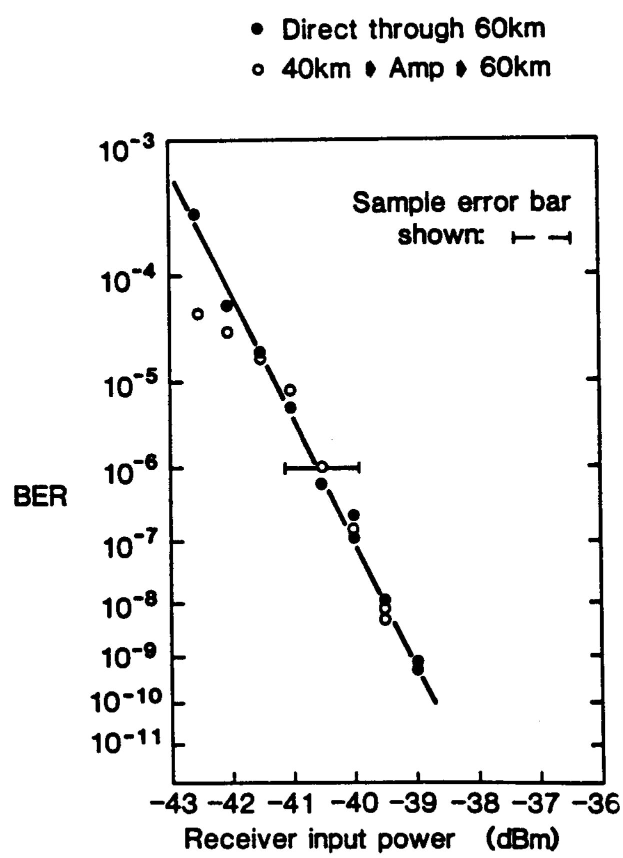

Figure 4. Receiver sensitivity in multichannel coherent network.