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Performance of an Erbium-Doped Fiber Amplifier in a 16-Channel Coherent Broadcast Network Experiment

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Abstract

An erbium-doped fiber amplifier was used in a 16-channel coherent broadcast network experiment operating in the wavelength range of 1538.8 to 1540.0 nm. The fiber-to-fiber gain was 22dB and the amplifier dynamic range was 15dB for the entire transmission spectrum. This enabled the distribution of sixteen 155Mb/s signals to one of 256 end-users at a distance of 102 km.

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INTRODUCTION: Recently, there have been several experimental demonstrations of multichannel coherent broadcast networks for possible use in single-mode-fiber subscriber systems /1,2/. Optical amplifiers have high potential for use in such networks /3/ because the number of end-users can be increased significantly. Erbium-doped amplifiers /4,5/ are especially attractive for this purpose as they are efficient /6/, low-noise, high fiber-to-fiber gain amplifiers operating around 1.5 μm. In addition, channel crosstalk penalties due to gain saturation are expected to be smaller than in conventional semiconductor amplifiers /7/. In this paper we analyze the performance of an erbium-doped fiber amplifier in a 16 channel distribution experiment /1/.

EXPERIMENT: The experimental system configuration is shown in Fig.1. The transmitter station comprised 16 DFB lasers which were stabilized at wavelengths between 1538.8 and 1540 nm with an optical frequency spacing of 10GHz. One of the lasers was modulated at 155Mb/s with a pseudorandom signal of length (2^{23}-1), while the other lasers were modulated with digitized video signals at 155Mb/s. The outputs of the 16 lasers were combined in a 16x16 star coupler. One output of the star coupler was connected to 42 km of fiber, an erbium-doped amplifier, another 60 km of fiber and a 1x16 splitter at the end of the link. Couplers before and after the amplifier were used to monitor the amplifier power levels. The amplifier consisted of 1.5m of an alumino-silicate erbium-doped single-mode fiber (~500ppm Er^{3+}) with a spot size of 8.3μm and a cutoff wavelength of 1250 nm. It was optically pumped with 200mW of power at 528 nm using a dichroic fiber coupler.

The experimental arrangement simulated a network providing 256 end-users with sixteen 155Mb/s channels over a distance of 102 km. This corresponds to a simulated network capacity of 65Tb/s*km*user. Satisfactory transmission system performance was obtained for error-ratios of 10^{-9}.

RESULTS: Fig.2 shows the optical spectrum at the output of the amplifier when the signal input power was -12dBm. The emission from the 16 transmitted channels appears as a single unresolved peak in the center of the measured spectrum. This falls substantially outside the peak gain region, near 1531 nm, where the spontaneous emission level is maximum. Nevertheless, when operating in this near-constant gain region between 1538 and 1560 nm, a fiber-to-fiber gain of 22 dB was achieved. This indicates the possibility of operating erbium-doped fiber amplifiers over a spectral bandwidth of 30 nm or more.

In order to determine the dynamic range of the amplifier /8/, the fiber before the amplifier was replaced with an optical isolator and an attenuator; the fiber and the 1x16 splitter following the amplifier were replaced with a second attenuator. We then measured the system error ratio as a function of amplifier input power under the condition of constant span loss by suitably adjusting the two attenuators. Fig.3 shows the bit-error-ratio for a constant total span loss of 50 dB (curve a) and for a span loss of 47 dB (curve b). The bit-error-ratio measured in this fashion defines the optimum position of the amplifier in the link and is characterized 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 gain saturation. We define dynamic range as the range of amplifier input power within which the amplifier causes a degradation of less than 1 dB, corresponding to a bit-error-ratio increase of about two orders of magnitude. With this criterion, the dynamic range is 15 dB. The dynamic range would be 12 dB larger if only one channel were present, since degradations at saturation depend on the total power of the 16 channels.

CONCLUSIONS: We report the use of an erbium-doped fiber amplifier in an experimental coherent multichannel broadcast network. With a fiber-to-fiber 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 /9/.

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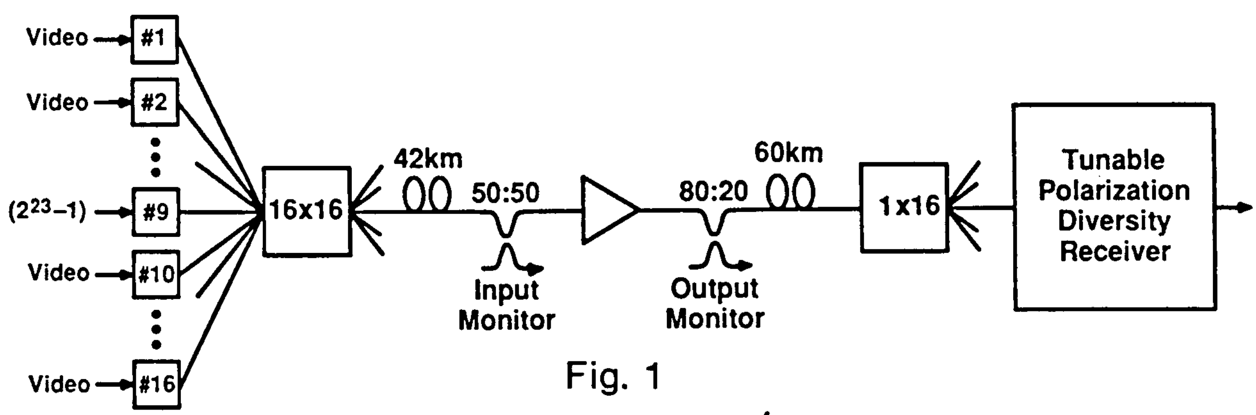

Fig. 1

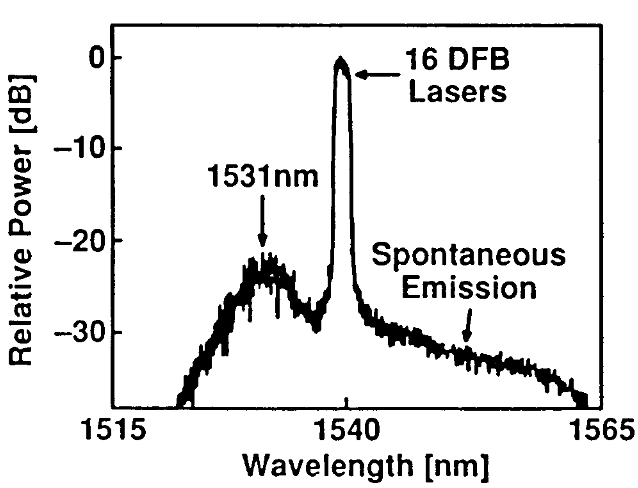

Fig. 2

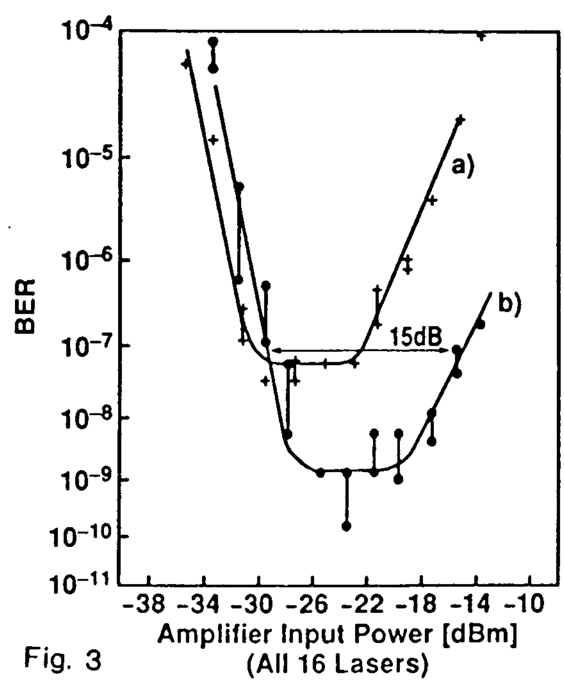

Fig. 3