MICROWAVE SIGNAL DISTRIBUTION USING AN OPTICAL AMPLIFIER

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ABSTRACT

It has been shown that up to 15 GHz, erbium doped fiber amplifiers (EDFAs) do not modify the S_{21} of an optical link. Here, we demonstrate that EDFAs do not alter the linearity either and can provide enough gain and power to split the microwave signal to 64 detectors with a 145 dB/Hz signal to noise ratio.

INTRODUCTION

Due to their small size, light weight, low loss and high bandwidth, optical fibers are an interesting medium for microwave signals transmission. Optical links working up to the Ku-band are now available.

The optical distribution of a microwave signal to a large number of detectors requires optical power before splitting to keep a good signal to noise ratio. Optical amplification can provide it. The erbium doped optical fiber amplifier (EDFA), which has been developped for telecommunication systems working at 1.5 μm can be a suitable candidate: it has high gain, high output power and low noise. Moreover it has been shown that, up to 15 GHz, the EDFA does not modify the electrical bandwidth of the optical link [1].

THE OPTICAL AMPLIFIER

The scheme of the EDFA is shown in figure 1: an optical source delivers the pump power, the pump and the signal to be amplified are mixed and injected in the doped fiber. Pump photons excite the erbium ions into a higher energy level thus causing a population inversion. The incoming photons (signal) stimulate the emission of photons with the same frequency and phase resulting in an amplification. The remaining pump power is opticaly filtered to avoid extra noise on the photodetector. The doped fiber can be forward or backward pumped (or both to increase the optical gain and the output signal power). Optical isolators are needed in order to cancel oscillations and thus suppress any lasing effect.

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The doped fiber amplifier is inherently well suited for fiber transmission (splicing losses as low as 0.1 dB) and polarisation independant. It is efficient (more than 10 dB of gain per mW of pump power was obtained) and low noise [2]. It provides high

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fiber to fiber gain (more than 50 dB was measured) and high optical output power (500 mW is attainable) [3]. It has a broad optical bandwidth, especially when operated in a saturation mode. Moreover, due to the low relaxation time constant of the erbium ions (~ 10 ms), the amplifying medium is transparent to signal variations whose frequency is higher than a few tens of kHz [3]. So the EDFA does not degrade high−speed signals, even if it works deeply into saturation.

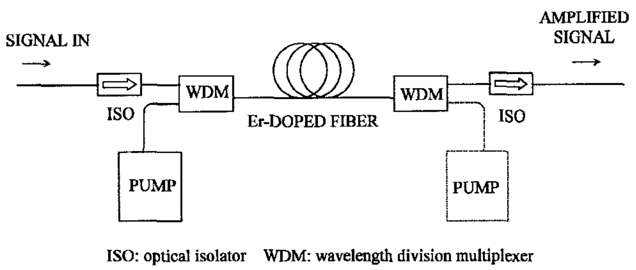

Figure 1: Scheme of the EDFA

The EDFA used in the experiment was provided by AMOCO LASER COMPANY model 1.5−AMP−017 with a +21 dBm output power. Figure 2 shows the optical bandwidth measured for different input optical powers: it reaches 28 nm. Figure 3 shows the output optical power versus the input optical power for different signal wavelengths. The amplifier gain saturates (−3 dB point) for −20 dBm of input power. A +2 dBm input power leads to a 20 dB decrease in gain.

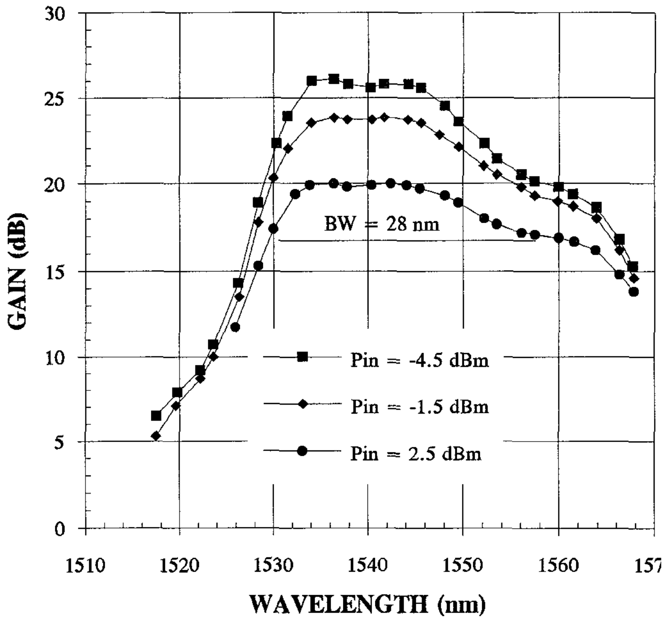

Figure 2: Optical bandwidth of the AMOCO EDFA

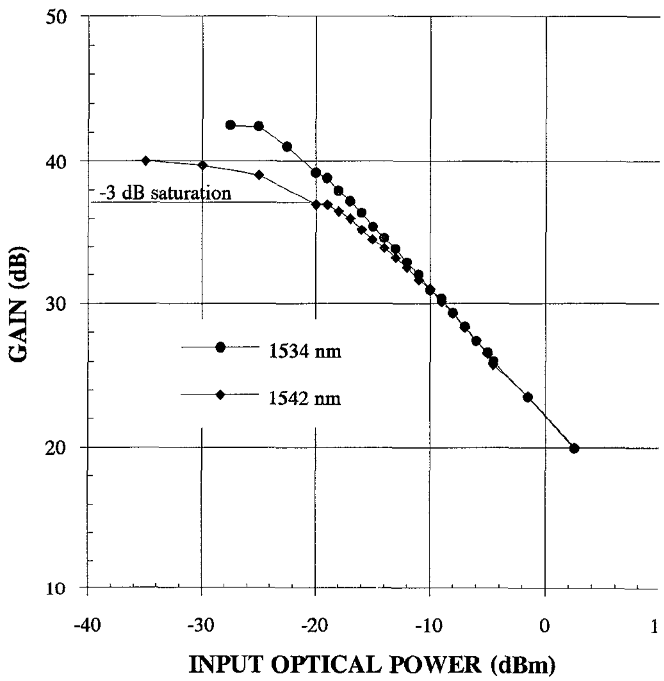

Figure 3: Optical gain of the AMOCO EDFA

THE MICROWAVE OPTICAL LINK

The frequency response (AM) of the EDFA was measured using a high-speed DFB laser followed by a 60 dB isolator and a high-speed PIN photodetector. An optical attenuator followed the optical amplifier in order to compensate for the optical gain. Figure 4 shows the experimental curves obtained for the link with and without the optical amplifier (the optical attenuation was set to 3 dB less than the optical gain so that the two curves can be distinghished). The two curves are parallel, showing that the optical amplifier has no effect on the electrical bandwidth of the link. Here the laser limits the bandwidth but EDFAs can theoritically be used to amplify millimeterwave optical signals.

To evaluate the linearity of the optical amplifier, the level of the third intermodulation product (IMP3) was measured at 3 GHz using two tones 100 MHz apart. The optical modulation index varied from 1% to 100%. Measurements were made for the optical link with and without the amplifier. The input optical power of the amplifier was set to 0 dBm (corresponding to ~20 dB into saturation) and the optical attenuation was set to 20 dB. It can be seen, from the experimental curves of figures 5 and 6, that the IMP3 level remains the same for the link with and without the optical amplifier.

At 3 GHz, the signal and noise levels, measured at the output of the optical link with the amplifier, were -27 dBm and -172 dBm/Hz, respectively. The optical attenuation was set to 20 dB and can be replaced by 64 way optical power splitter to distribute the microwave signal from one source to 64 detectors with a 145 dB/Hz signal to noise ratio. As a matter of fact such a splitter has a 18 dB splitting loss and roughly 3 dB excess loss.

CONCLUSION

We measured the performances of an optical link with an erbium doped fiber amplifier. We found that EDFAs can be used in the saturation regime to transmit high power optical microwave signals without noticeable linearity degradations. Finally the distribution of a microwave signal from 1 source to 64 detectors was shown with a signal to noise ratio of 145 dB/Hz.

REFERENCES

[1] R. I. Laming, "0.1-15 GHz AM and FM response of erbium-doped fibre amplifier", Elect. Lett., vol. 25, n° 17, p. 1129 (1989).

[2] P. C. Becker, "Erbium-doped fiber makes promising amplifiers", Laser Focus World, p. 197 (oct. 1990).

[3] S. G. Grubb and al, "+24.6 dBm output power Er/Yb codoped optical amplifier pumped by diode-pumped Nd:YLF laser", Elect. Lett., vol. 28, n° 13, p. 1275 (1992).

[4] R. I. Laming and al., "Multichannel crosstalk and pump noise characterisation of Er^{3+} doped fibre amplifier pumped at 980 nm", Elect. Lett., vol. 25, n° 7, p. 455.

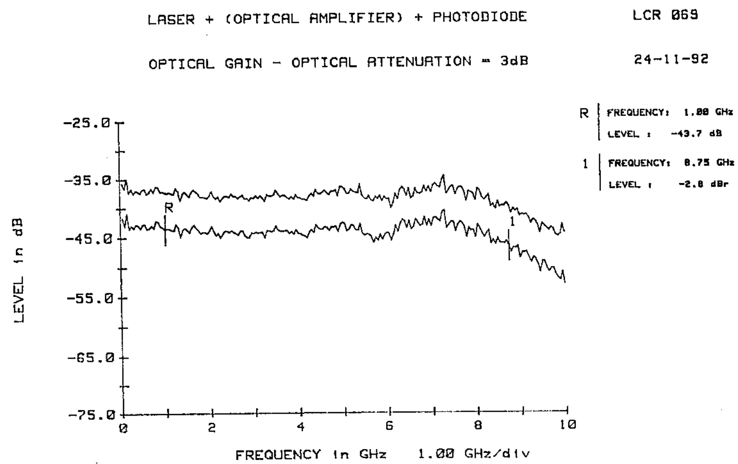

Figure 4: Electrical bandwidth of the optical link with and without the AMOCO EDFA

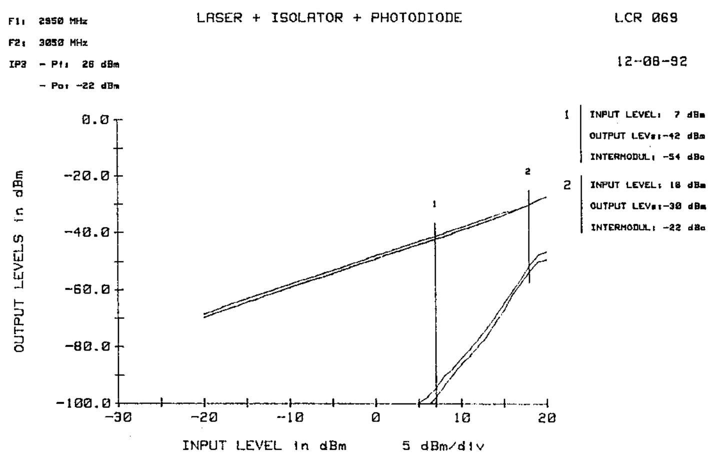

Figure 5: IMP3 levels of the optical link without optical amplifier

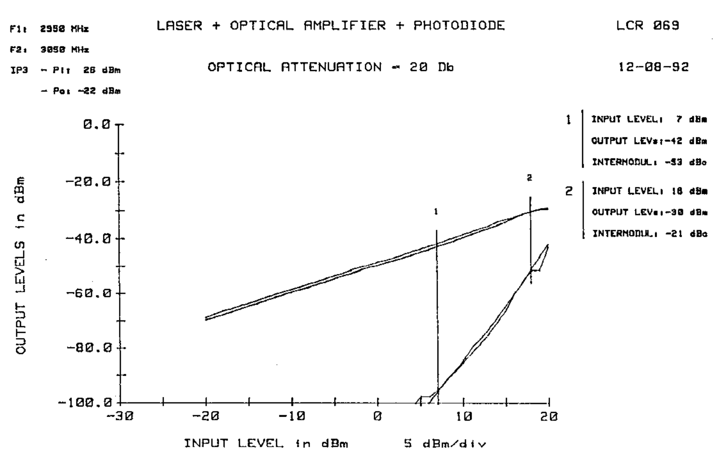

Figure 6: IMP3 levels of the optical link with the AMOCO EDFA