IMPROVED OPTICAL FIBER AMPLIFIER FOR 1.3 µm AM-VSB SYSTEMS.

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We present an innovative, compact, powerful fiber amplifier operating at 1.3 µm and dedicated to CATV transmission. Its output power is +20 dBm and its noise figure is 6 dB. Supertrunk transmission of 30 channels over 94 km is reported.

INTRODUCTION

Most CATV systems throughout the world use the hybrid fiber-coax architecture, with SubCarrier Multiplexing (SCM) in the Amplitude Modulation-Vestigial Side Band (AM-VSB) format. The fiber backbone of these networks operate at the wavelength of 1.3 µm with laser diodes using direct modulation.

An optical amplifier compatible with the demands of AM-VSB, i.e. high output power, low noise and high linearity, offers an increase of loss budget which opens new possibilities of network architectures, in terms both of geographical extent and connectivity.

We present an innovative Praseodymium Doped Fiber Amplifier, which combines optimized ZBLAN fiber with advanced splicing technology, pumped with a compact fiber laser. +20 dBm output power is obtained, and full CNR, CSO and CTB degradations are measured, for a 94 km straight-line supertrunk transmission.

DESCRIPTION OF THE PDFA

PDFA's have been studied for sometime now[1], [2] , and they use a fluoride ZBLAN fiber doped with Praseodymium. The ZBLAN host, (compared to silica), reduces non-radiative transition of the Praseodymium ion, which is a key feature for the amplification.

The amplifier uses a contra-propagating configuration, with a simple pass of the signal. The ZBLAN doped fiber has a 1000 ppm weight Praseodymium concentration, a 12 meter length, a 1.8 µm core diameter, a 0.35 N.A. and a 0.05 dB/meter scattering loss. The angle-cleaved ends of the ZBLAN fiber are butt-coupled to a high-N.A. silica fiber, which is then fusion-spliced to a low N.A. silica fiber. All fiber splices are of low reflection. The pumping source is an Ytterbium-doped cladding pumped fiber laser emitting 600 mW at 1030 nm. The very strong confinement of the ZBLAN fiber is required because of the unfavourable spectroscopy of Praseodymium, (at least compared to that of erbium), namely short metastable level lifetime and low cross-sections. The choice of the 1030 nm pumping wavelength is a compromise between the best pumping wavelength of Praseodymium (1020 nm) and the peak emission wavelength of Ytterbium (1060 nm). The detailed theoretical and experimental investigation of the structure of the amplifier has been discussed in [3]. The scheme of the PDFA is given on Figure 1.

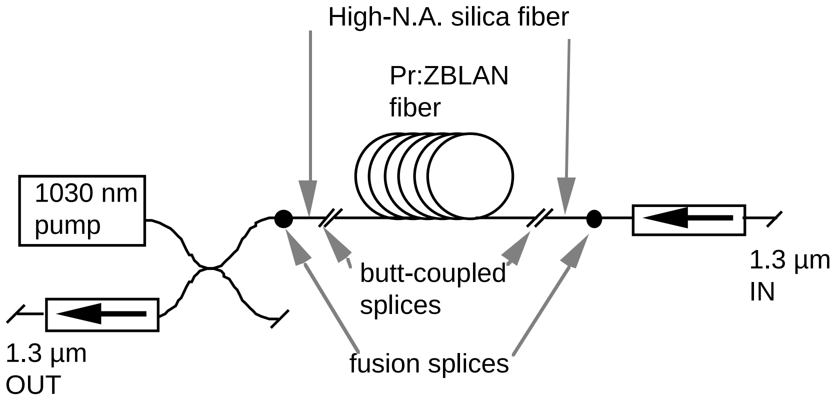

Figure 1
Scheme of the amplifier

GAIN CHARACTERISTICS

The output versus input power is shown on Figure 2, for the peak gain wavelength of 1300 nm, and input powers ranging from -10 to +10 dBm.

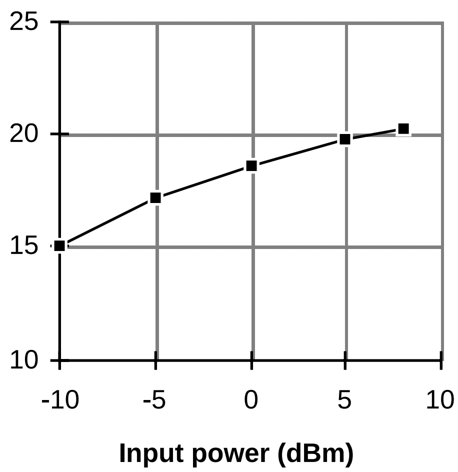

Figure 2
Output versus input power
Wavelength: 1300 nm
Pump power: 600 mW

The input power range around 0 dBm corresponds to the values compatible with the high CNR required for CATV systems. Although the output power increases with input, there is a significant saturation of the gain of the amplifier, since the 18 dB change in input signal results in only 5 dB increase in outptut. Taking into account the losses to and from the doped fiber, the internal quantum efficiency at maximum input power is higher than 30 %. The noise figure, measured with the optical spectrum analyzer method, is 6.2 dB for 0 dBm input signal at 1300 nm.

TRANSMISSION OVER 94 km

We have recently reported the application of this type PDFA's to distribution networks, and have shown that less than 2 dB CSO and CTB degradation were obtained with a high-quality link[4] . This asseses the use of PDFA's with AM-VSB signals, contrary to the results reported in [5]. However, application to long fiber spans remains to be confirmed, because of possible effects of fiber scatterings or non-linearities.

We report transmission over 94 km, with results of CNR, CSO and CTB, for a 30-channel multiplex spanning from 136 to 823 MHz, according to the France-Télécom frequency map. The reference and amplified links are represented on Figure 3

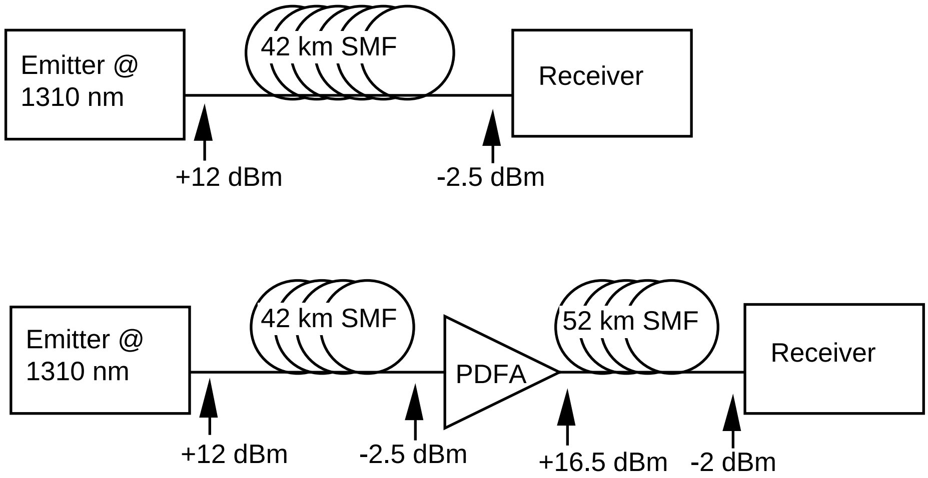

Figure 3
Reference and amplified links.

The average attenuation of the G.652 single-mode fiber (including splices and connectors) is 0.35 dB/km. There are 6 in-line FC-APC type connectors for the amplified link.

The CNR, CSO and CTB versus carrier frequency are given respectively on Figures 4, 5 and 6.

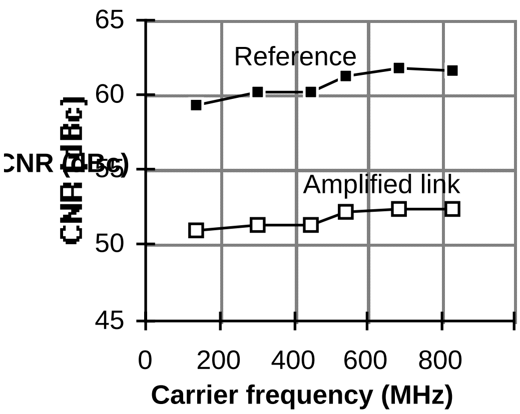

Figure 4
CNR versus carrier frequency

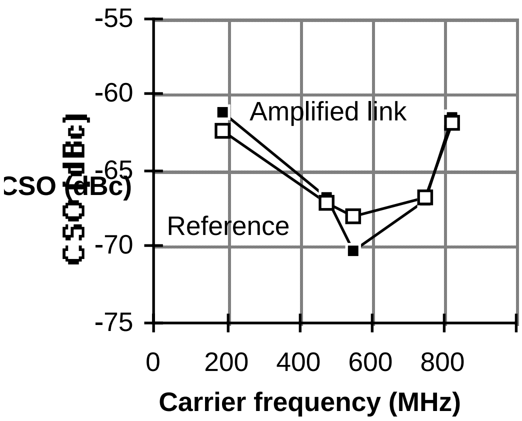

Figure 5
CSO versus carrier frequency

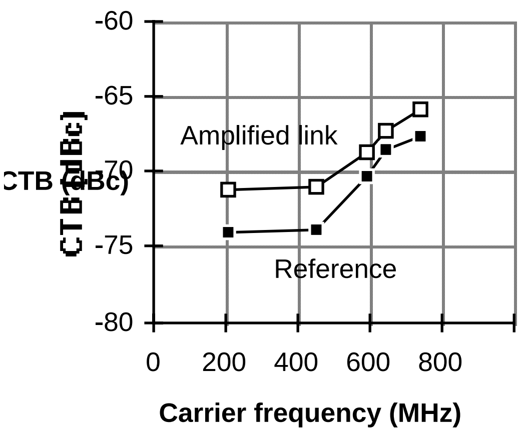

Figure 6
CTB versus carrier frequency

The CNR remains higher than 50 dBc over the whole band and its degradation is 9 dB. There is no measurable CSO degradation; CSO remains lower than -60 dBc and CTB lower than -65 dBc with about 3 dB degradation. Primarly, transmission is limited by the CNR, which in-turn is given by the gain of the amplifier for a given span. It should be noted that these results are obtained with no electronic regeneration, and that the Rayleigh and the possible non-linear scatterings in the fiber are taken in account. Concerning Brillouin scattering, it is estimated that direct modulation of the emitter results in an increased linewidth of the source, (due to the chirp of the laser diode), which lowers the Brillouin scattering efficiency. This is a significant difference with 1.55 µm based systems, where the high dispersion of standard fiber makes external modulation mandatory with a smaller linewidth and thus an increased sensitivity to Brillouin scattering.

CONCLUSION

We have demonstrated supertrunk transmission over 94 km of single-mode fiber, using an innovative Praseodymium Doped Fiber Amplifier. 30 subcarrier multiplexed channels are succesfully transmitted, with CNR's higher than 50 dBc, and CSO and CTB lower than -60 and -65 dBc respectively. This demonstrates that PDFA's are suitable for CATV networks with a large geographical span, or for the extension of already installed systems.

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