

High output power erbium doped waveguide amplifier for QAM distribution

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Abstract: We report on the first Er^{3+} - Yb^{3+} doped planar waveguide amplifier with +14dBm output power which we use as a post-amplifier for the DWDM transmission of eight wavelengths, each carrying 35 6-MHz 64-QAM channels, over an unrepeated span of 175km.

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1. Introduction

Erbium doped waveguide amplifiers (EDWAs) are now very attractive for use in metro/access applications, due to recent advances in their bandwidth and gain as well as their demonstrated suitability for integration with other devices [1-2]. However, most waveguide amplifiers reported to date do not provide the high output power required to compete with erbium doped fiber amplifiers (EDFAs) as post-amplifiers. Here, we present a compact Er^{3+} - Yb^{3+} doped waveguide amplifier with a saturated output power in excess of +14dBm. We demonstrate its utility as a broadband post-amplifier in an eight wavelength quadrature amplitude modulation (QAM) transmission experiment over 175km, which we believe to be the longest unrepeated QAM span demonstrated to date [3].

2. Device Composition

The 9.6cm long Er^{3+} - Yb^{3+} doped phosphate waveguide is manufactured by Teem Photonics via a two step ion exchange process. 980nm/1550nm fiber wavelength division multiplexers (FWDMs) are attached directly to the waveguide (Fig. 1). The waveguide is dual-pumped by 980nm laser diodes, each delivering 125mW of output power. The total passive device loss is estimated to be 2.5dB, which is separated into 0.15dB/cm of propagation losses through the waveguide, 0.2dB fiber-waveguide coupling losses at each end, 0.2dB of FWDMM losses and 0.5dB isolator loss. In all of the measurements detailed below, the external gains are recorded using a tunable external cavity laser (ECL) and an optical spectrum analyzer (OSA). The external noise figures are measured using an electrical technique [4].

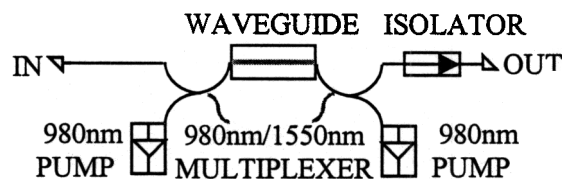


Figure Device configuration

3. Device Characterization

The amplifier's gain profile is shown in Fig. 2. Both pumps were set to 125mW and the input signal power was set to +0dBm. The gain is 14.3dB at the 1535nm peak, while the gain exceeds 9dB over the whole 1530-1560nm range. The associated noise figure profile also is shown in Fig. 2. The noise figure at the 1535nm peak is 5.6dB and is less than 6.0dB in the entire 1530-1560nm band. This combination of high gain and low noise figure throughout the entire conventional erbium band for a +0dBm signal suggests its utility as a broadband post-amplifier.

The output versus input signal power curves are shown in Fig. 3 for four representative wavelengths from the 1535nm peak to the 1556nm shoulder. This waveguide amplifier features the slow output power saturation desired in a post-amplifier. Note also that the associated noise figures remain at a plateau of ~5.5dB for input signal powers up to +0dBm, then increase to a maximum of 8.3dB for +6dBm input signal power. Note that, even for +6dBm input signal power, the signal gain is greater than the noise figure for the wavelengths tested.

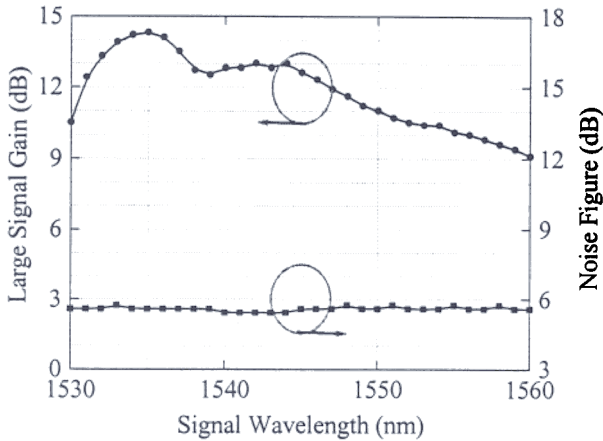


Figure 2. EDWA gain profile for +0dBm input signal.

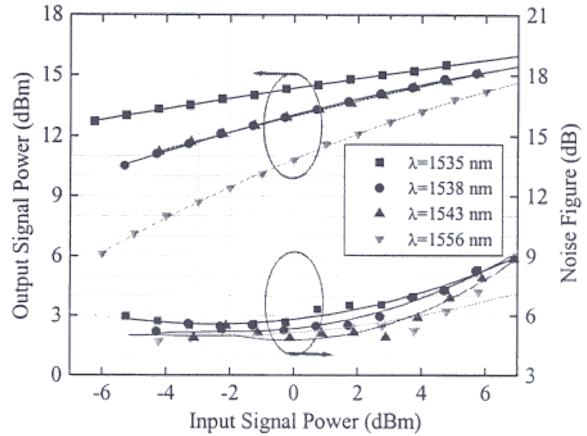


Figure 3. EDWA P_{out} and NF versus P_{in} .

4. 100km QAM Distribution Experiment

The EDWA's high output power and broadband operation were verified in a 64-QAM distribution experiment (Figure 4). Eight electroabsorption modulated lasers (EMLs) varying in frequency from 192.3 THz (1559.0nm) to 193.7 THz (1547.7nm) spaced by 0.2THz on the ITU grid were encoded with 35 6-MHz 64-QAM channels ranging in frequency from 543MHz to 747MHz. Each channel carried a payload of 29.7Mbps, excluding a 7.8% Reed-Solomon forward error correction (FEC) overhead. The optical signals from the transmitters passed through different lengths of fibers, each varying by 40m, in order to decorrelate them. Afterward, the signals were combined using a wavelength division multiplexer (WDM) and sent into the EDWA. The input and output combs are shown in Figure 5. The total input power to the EDWA was -0.9dBm and the total output power was +11.5dBm. The gains ranged from 10.7dB for the 192.3 THz signal to 14.2dB for the 193.7THz signal.

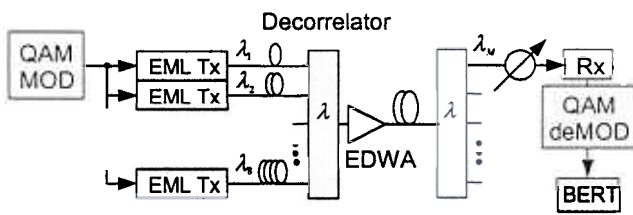


Figure 4. QAM Transmission System

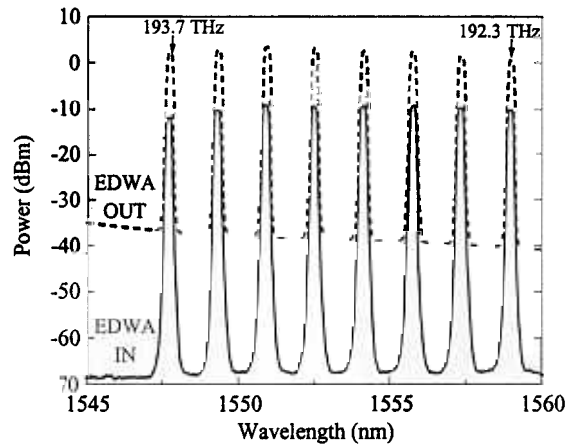


Figure 5. EDWA Input and Output Combs

The EDWA output comb was transmitted through 100km of AllWave™ fiber. The transmitted signals were routed through a fiber demultiplexer and the receiver assembly, which consisted of an attenuator, receiver, QAM demodulator and a BER test set. The post-FEC bit error rate (BER) versus received power was measured for all eight transmitters, for both the lowest (543 MHz) and highest (747 MHz) QAM channels, and is shown in Figure 6. Note that there is just a 1.5dB spread in the received power for 10^{-8} BER.

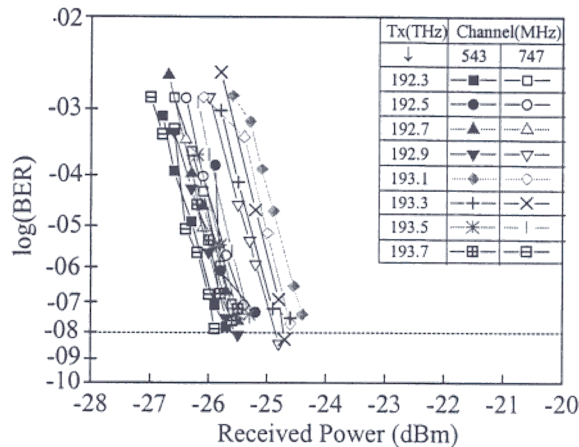
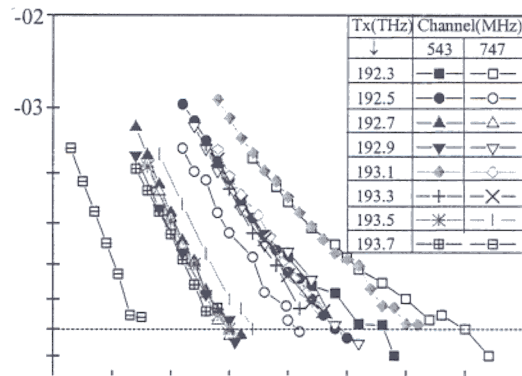


Figure 6. QAM BER through 100km AllWave fiber.

5. 175km QAM Distribution Experiment

An additional 75km of AllWave™ fiber (175km total) was inserted into the previous experiment along with a conventional fiber preamplifier before the demultiplexer. The post-FEC BER curves were recorded for all eight transmitters (Fig. 7). There is a spread of 5.5dB in the received power for 10^{-8} BER, an increase of 4.0dB over the 100km results. We attribute this additional spread, in part, to the influence of the fiber preamplifier performance. Finally, we monitored the stability of the 747MHz channel from the 192.5THz transmitter at $P_{Rx} = -11.5$ dBm, where we measured a post-FEC BER = 9×10^{-14} over three days.



6. Conclusions

We have reported on the first Er^{3+} - Yb^{3+} doped planar waveguide amplifier that delivers +14dBm output power. We have confirmed its suitability as a broadband post-amplifier in an eight wavelength QAM distribution experiment over 175km, which we believe is the longest unrepeated QAM span reported to date. This system architecture may be useful in distribution of QAM channels to several cities from a single headend. The span length could be increased in future systems through integration of the multiplexer with the EDWA.

7. References

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