Configurable Er-Doped Core-Pumped Multi-Element-Fiber Amplifier

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Paper Summary

We demonstrated an Erbium-doped multi-element-fiber amplifier extending the bandwidth at shorter wavelengths in C-band. Each fiber-element provides a maximum gain of 36dB and NF <4dB. The fiber-elements were cascaded to obtain >20dB gain in 1520-1570nm.

Introduction

The potential data capacity crunch has generated considerable interest to increase the data carrying capacity of an optical fiber in a cost-effective manner [1]. Various methods such as space-division multiplexing (SDM), mode-division multiplexing (MDM), and orbital angular momentum (OAM) multiplexing [1-3] are currently being investigated. The amplification bandwidth offered by the Erbium(Er)-doped fiber is still not used to its full capacity, and mostly 1535 – 1560 nm in the C-band is currently being used in telecommunications. Er can amplify a much wider window of about 100nm, covering from 1520nm to 1620nm.

In this paper, we demonstrate the flexibility offered by multi-element fiber (MEF) geometry in tuning the gain profile of the amplifier. An Er-doped 3-element MEF (3-MEF) was fabricated, which comprised of 3 fiber-elements that are drawn and coated together in a common polymer coating [4]. The core preform used for the 3-MEF was doped with Al and Er ions, producing a measured refractive index step (Δn) of 0.005. Preform was then stretched, cut and stacked to obtain the MEF assembly. Each fiber-element of the 3-MEF have a clad diameter of 125µm and a core diameter of 11µm with overall coated diameter of 310µm.

Results and Discussion

Fig. 1 shows the schematic diagram of the experimental setup used for Er-doped MEF characterization. The setup comprised of a tunable laser source (TLS) as an input signal, 976nm pump laser diodes(LD), isolators (ISO), and 980/1550 nm wavelength division multiplexers (WDM) at the input/output to combine/separate the signal and the pump. The input and output signals for different wavelengths were measured by the optical spectrum analyzer (OSA). The spectra obtained were then used to calculate the gain and noise figure (NF) of each fiber element of the 3-MEF.A 3meter length of fiber was used for gain and NF measurements. The fiber-elements were indexed as S1, S2, and S3 for identification at both ends of the MEF as shown in fig. 1.

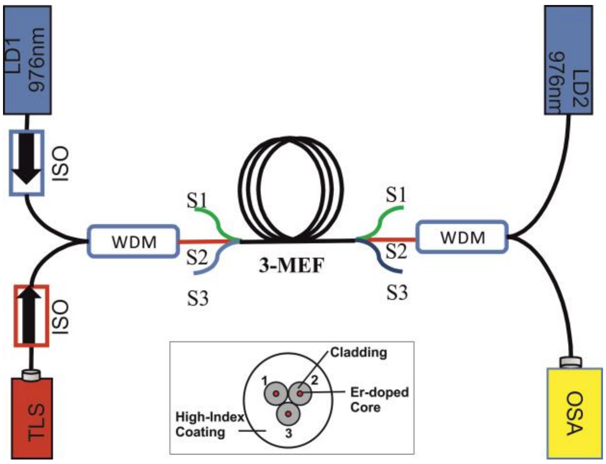


Fig. 1 Schematic of experimental setup used for 3-MEF characterization. Inset shows the schematic cross-sectional view of Er-doped 3-MEF.

Input signals of −10 dBm, and −23 dBm were used for the characterization. The characteristics of all three fiber-elements were found to be similar. Fig. 2 shows the gain and NF characteristics of S3 with pump powers of 112mW, 208mW and 250mW respectively. A maximum gain of 36dB was observed in the C-band for an input signal of -23dBm and a pump power of 250mW.Also, the NF was <4.5dB in the 1520-1570nm wavelength region.

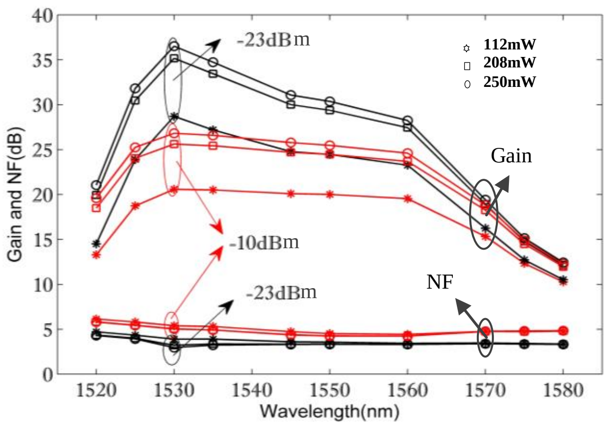


Fig. 2 Gain and NF variation in one of the fiber-elements for different input signal and pump powers.

The fiber-elements were then cascaded one-by-one by splicing the output of one fiber-element to the input of another fiber-element to observe the effect on gain profile. It can be seen from fig. 3 that the gain at short wavelengths decreased, whereas the gain at longer wavelengths increased after cascading of two fiber elements. The cascaded amplifier provided a flat gain of 33±1dB in the wavelength region of 1530-1560nm for an input signal of -23dBm. A split band amplifier can be designed in which one of the fiber-element (S1) is used for short wavelength amplification and the other two fiber-elements are cascaded (S2 + S3) for long wavelength amplification. This would provide >20dB gain in the wavelength range of 1520-1570nm (50nm).

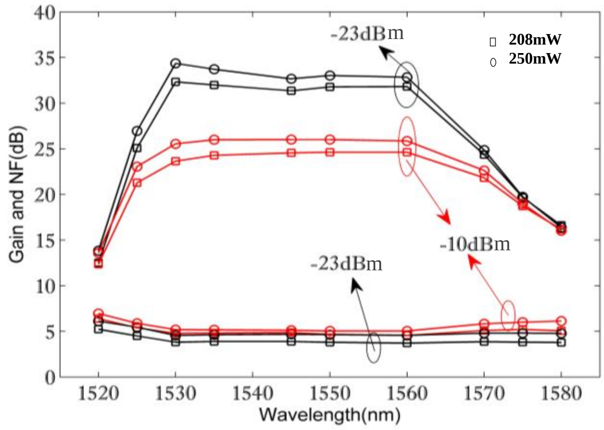
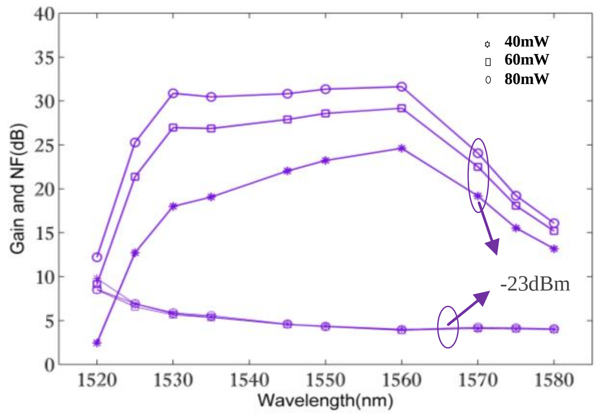
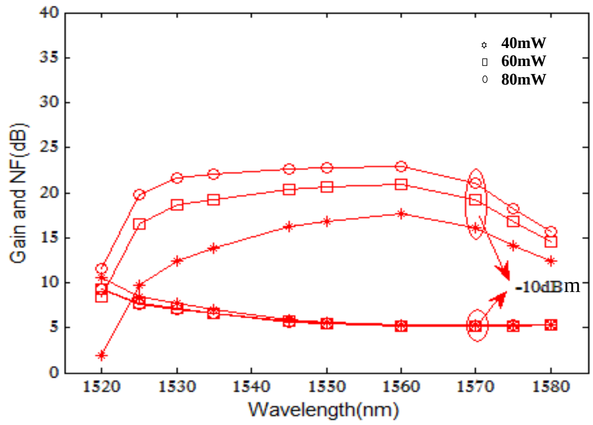


Fig. 3 Gain and NF variation of 2-cascaded fiber-elements for different input signal and pump powers.

The pump power requirement in a cascaded amplifier can be further reduced by bi-directional pumping. To demonstrate this effect, the two cascaded fiber elements were bi-directionally pumped from two 976nm LDs each providing 60mW of pump power. The gain profile of the amplifier was tuned by changing the pump power to vary the pumping ratio in bi-directional amplifier as shown in fig. 4a and fig. 4b.



(a)



(b)

Fig. 4 Gain and NF for cascaded two fiber-elements with bi-directional pumping for an input signal of (a) -23 dBm and (b)-10dBm. Pump power of one of the laser diode was varied while the other laser diode was maintained at a fixed power of 60mW.

For the total pump power of 140mW, the gain is >30 dB in the wavelength region of 1530-1560nm and ≥ 20 dB in the wavelength region of 1525 – 1570nm for input signals of -23dBm and -10dBm respectively.

Conclusion

We demonstrated a flexible Er-doped 3-MEF amplifier which provides a gain of >20 dB and NF≤4.5 dB in the wavelength region of 1520-1570nm. In case of cascaded amplifier, it was shown that through bi-directional pumping the overall pump power required was significantly reduced as compared to co-pumping while maintaining the similar gain characteristics. Work is in progress to extend the operating bandwidth of the amplifier, covering both C and L bands, by increasing the number of Er-doped fiber-elements in the MEF.

Acknowledgement

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References

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