LOW COST MULTI-PORT RECONFIGURABLE ERBIUM DOPED CLADDING PUMPED FIBER AMPLIFIER

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Abstract: We present a new erbium-doped fiber amplifier, which is effectively eight separate amplifiers. A single multi-diode source cladding pumps all eight Er/Yb fibers. We demonstrate cross-talk free WDM application, as one of many possible areas.

Erbium-doped fiber amplifiers (EDFAs) have revolutionized optical telecommunications over the last ten years. The increasing need for capacity drives not only amplification requirements, e.g., output power and gain flatness for WDM, but also the required number of EDFAs in a system. Still, EDFAs by and large have remained "stand-alone" devices, with individual amplifiers individually pumped and separately packaged. Component count as well as cost then holds back penetration of optical amplifiers into different application areas that require a large number of amplifiers at a low cost. Instead, the drive has been towards purpose-built EDFAs with high specifications (bandwidth, output power) for use in applications that can tolerate a high cost.

In this paper, we present a new approach in design of adaptive EDFA with drastically increased amplification capacity in a compact, low-cost configuration. The EDFA has eight independent ports that provide independent amplification. Thus, it can replace eight single-port EDFAs, and bring down the amplifier count by nearly an order of magnitude. Furthermore, thanks to the abundance of amplifier capacity, the EDFA can be configured in different ways to fulfill different roles. Here, we demonstrate cascading of ports to increase output power and bandwidth, as well as independent amplification of eight different wavelength channels.

Our approach is based on a further development of the coiled cladding-pumped structure [1]. In this case the fiber assembly comprises eight Er/Yb co-doped fibers for signal amplification and two pump fibers coiled together in such a way that pump power launched into one of the pump fibers penetrates into all eight doped fibers via evanescent field coupling.

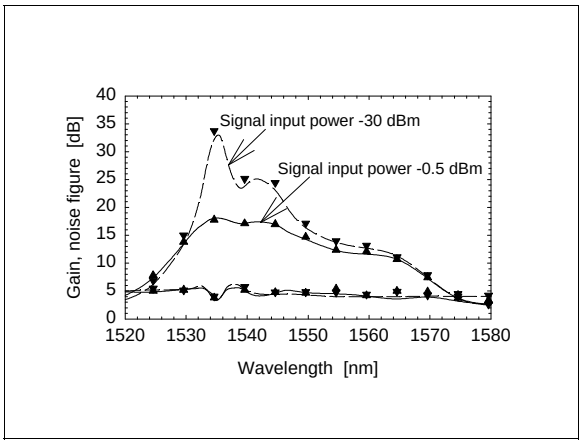


Fig. 1. Spectral dependence of gain and noise figure. Single channel amplifier: symbols and curves are related to two different channels and demonstrate nearly identical performance of two independent amplifiers;

Each amplifier fiber had a 100 mm cladding and a 10 mm core. The pump fibers had a diameter of 125 mm. Fibers coming out of the assembly were coated with UV curable secondary coating. Each of the amplifier fibers was then spliced to optical isolators so that the entire fiber assembly may be considered as a set of eight independent fiber amplifiers.

The pump was provided by a module comprising six broad stripe 915 nm laser diodes coupled into a single 100 mm core, 0.22 NA multimode optical fiber. The pump unit had built-in laser diode driver and control electronics in a compact package. The amplifier was pumped through a single pump port, leaving three other pump ports available for another pumps.

The current for the pump laser diodes was set at approximately 70% of its maximum value. This protected the amplifier against diode failure: One or even two failed diodes can be compensated for by a larger pump current to restore the pre-set output power of the system.

We first evaluated the performance of individual amplifier fibers. Figure 1 shows the spectral dependence of signal gain for two arbitrary channels. The gain curves for the other six channels were similar.

However, the saturation output power from each of the eight amplifiers varied from 15 – 18 dBm. The variation is caused by non-uniform pump power distribution between individual amplifier fibers. The uniformity can be improved by further developments of the system. Figure 1 further shows that the EDFAs offer a 1530 - 1570 nm gain bandwidth with noise figure below 5 dB. This is very close to data for conventional, core-pumped amplifiers while the total output power from this type of amplifiers is almost an order of magnitude higher.

The amplifier configuration allows two or more fiber amplifiers to be cascaded to increase the gain or saturated output power, while at the same time retaining the low noise figure. Figure 2 shows gain and noise figure for three cascaded amplifiers.

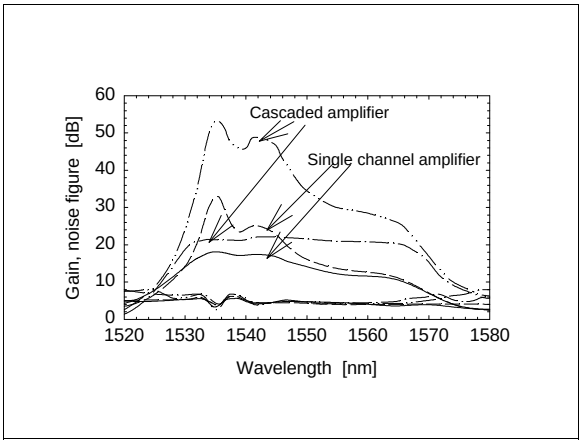


Fig. 2 Comparison between single channel amplifier and cascaded amplifier, when three independent amplifiers are concatenated. Signal input power are the same as in Fig. 1

The small signal gain exceeds 50 dB with a noise figure still below 5 dB. The high gain and flexibility of the amplifier assembly allows, for example, for lossy elements like dispersion compensators or switches to be inserted between individual amplifiers, for added functionality without noise or power penalty.

The performance of the EDFAs was also tested with an array of eight DFB fiber lasers with a 50 GHz signal spacing on the ITU grid [2].

The DFB fiber lasers were individually pumped and the output power was deliberately made unequal with more than 10 dB power variations. Figure 3 shows high contrast output spectra with significant power equalization.
Another way of using the amplifier assembly is for amplification of WDM signals, with the

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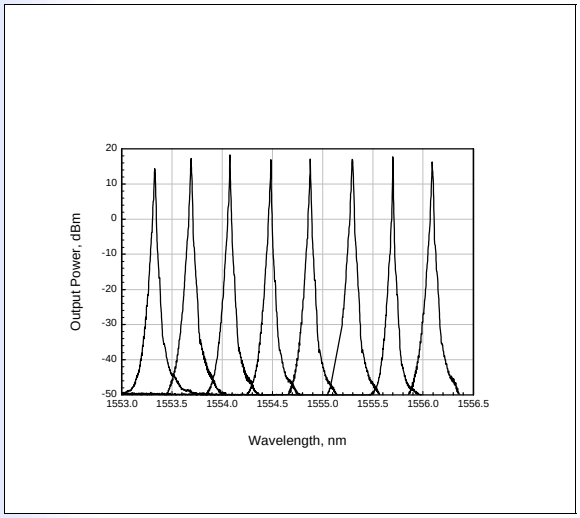


Fig. 3 Output spectra of the amplified DFB fiber laser array.

channels demultiplexed and amplified in separate fibers. The use of a dedicated amplifier fiber for each WDM channel further leads to a very low inter-channel cross talk in the amplifier. Figure 4 shows measurement data on cross-coupling between amplifier fibers.

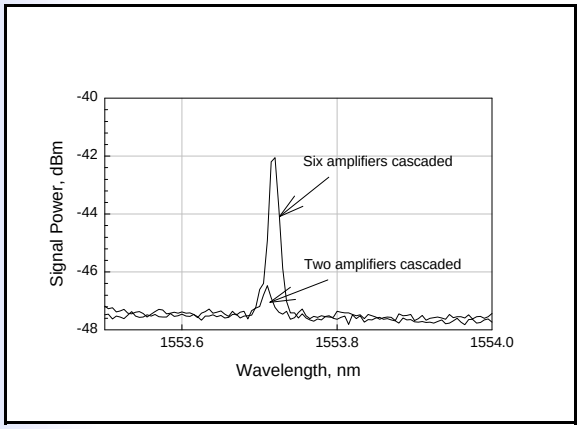


Fig. 4 Inter-channel cross talk measurements: the cross talk in a single channel becomes noticeable only when several other amplifiers are cascaded

The cross coupling is measurable only when amplifier were cascaded and is even then below - 50 dB. The presence of a signal in one fiber did not affect signal in another fiber.

In conclusion, we have developed an erbium fiber amplifier with eight separate amplification channels, each having small signal gain above 30 dB and noise figure below 5 dB. The system comprises eight parallel cladding pumped fiber amplifiers pumped by a compact module with built-in pump redundancy scheme. The amplifiers have a length of 1.5 m, possess low cross talk and small nonlinear signal distortion. We used the amplifier for cross-talk free amplification of WDM signals. To increase gain or saturated power the system can be easily reconfigured by cascading two or more amplifiers, retaining at the same time very low noise figure.

References

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