NP Photonics

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Erbium Micro Fiber Amplifiers (EMFAs)

Novel highly doped fibers are enabling high gain, inexpensive, small amplifiers that are ideal for the metro and access markets. Using erbium micro fibers in amplifiers provides the simplicity, low noise and reliability of Erbium Doped Fiber Amplifier (EDFA) technology, coupled with the advanced attributes of new Semiconductor Optical Amplifier (SOA), Linear Optical Amplifier (LOA) and Erbium Doped Waveguide Amplifier (EDWA) technology, such as the ability to integrate and to array.

EDFA Evolution

Conventional EDFAs have enabled the optical Internet by expanding the reach of optical telecommunication links. EDFAs do this by amplifying light signals in the optical domain without requiring regeneration of the signal in the electrical domain.

However, technology migrates toward smaller, better and lower cost as new methods and products come along to challenge the status quo. Erbium Micro Fiber Amplifier (EMFA) technology is doing just that.

The Metro Market

The next generation of optical networks is transitioning from static networks toward more dynamic networks. The emerging ringed/mesh metro architecture has some very different requirements for optical amplification than the entrenched point-to-point architecture of the long haul system. For example, since signals must travel shorter distances in a metro area, they require less optical gain than in a long haul system. Conversely, the greater number of components required to switch, mux-demux or add-drop within the metro architecture cause a larger amount of signal loss. Also, an increased number of connectors and splices add to signal loss at each metro processing node. Thus, total node loss is the dominant contributor to total network loss in the metro network, as opposed to transmission span loss due to distance in long haul systems.

More nodes in the metro architecture mean more optical amplifiers will be required to overcome signal losses in these new dynamic, re-configurable, scalable networks. Current EDFAs are too bulky and expensive to do the job. However, within an Erbium Micro Fiber Amplifier (EMFA), the meters of coiled erbium doped fiber found in a conventional EDFA are replaced with ultra-short, high-gain micro fibers of multi-component glass just a few centimeters in length. This results in an amplifier that is more compact, inexpensive and provides an exciting alternative to current EDFA technology.

EMFA Technology

Glass

Erbium micro fiber technology starts at the glass level. The enabling technology behind an EMFA is a special Er^{3+}-doped glass fiber that exhibits both extremely high gain per unit length and extremely low cost—less than 1 percent of today's cost for commercial Er^{3+}-doped silica fiber.

The multi-component glasses found in an EMFA support doping concentrations of the rare-earth erbium ions far in excess of levels believed possible with conventional glasses. Using this new Er^{3+}-doped fiber a gain per unit length of greater than 5dB/cm has been demonstrated. This gain per unit length is more than 100 times larger than the gain displayed by a typical commercial silica fiber amplifier. And, in fact, the novel Er^{3+}-doped fiber exhibits the highest gain per unit length of any glass known today. Moreover, the erbium micro fibers are chemically stable, durable and reliable.

Because of this breakthrough, a compact, low-cost, rugged, and highly integrated optical amplifier, or EMFA, can be constructed employing just a few centimeters of innovative Er^{3+}-doped fiber.

Fiber

Er^{3+}-doped core glasses and cladding glasses with matched refractive index and thermal performance have been designed and fabricated based upon an extensive glass composition search. The resulting glasses enable the production of a special single-mode, double-clad fiber.

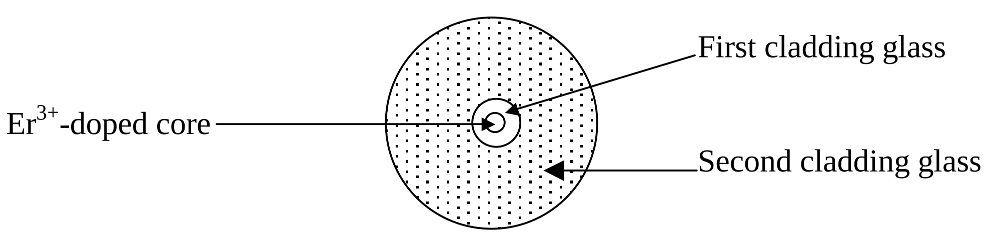

Figure 1. Double Clad Fiber

Pumping
The novel single-mode, double-clad fiber can then be coupled to a highly reliable Broad Area Laser Diode (BALD) pump using a low-cost proprietary device that exhibits greater than 90% pump coupling efficiency and nearly 100% signal coupling efficiency. Single-mode pumped EMFAs have been demonstrated as well.

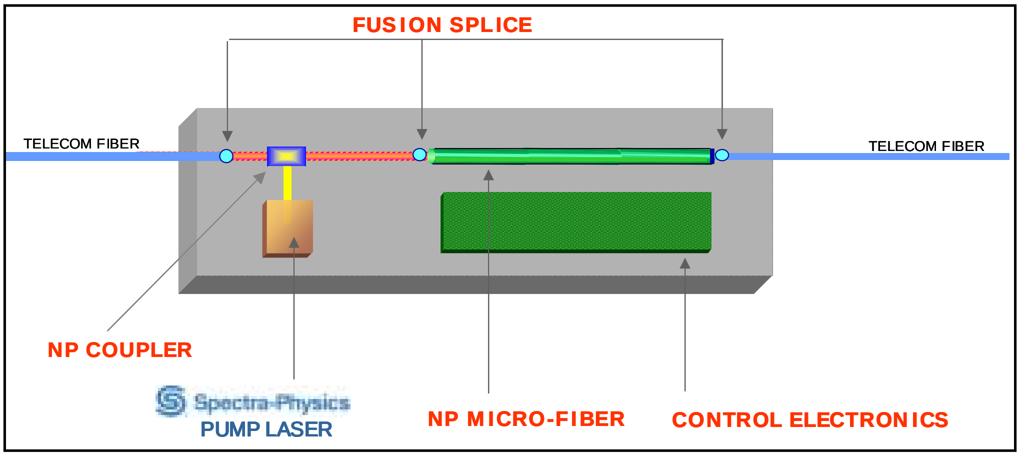

Figure 2. Amplifier Schematic

Because of the small size and simplicity of the EMFA design, the overall packaging is much smaller than that of a conventional EDFA. Further, without a need for fiber management, EMFAs are easier to integrate.

EMFA Performance

EMFAs' performance characteristics for noise and other parameters are similar to what is found in conventional EDFAs.

Performance metrics are shown in Figure 3 for the NP Photonics EMFA technology. The first figure is a single channel gain sweep, without gain flattening, showing more than 20 dB small signal gain across the C-band.

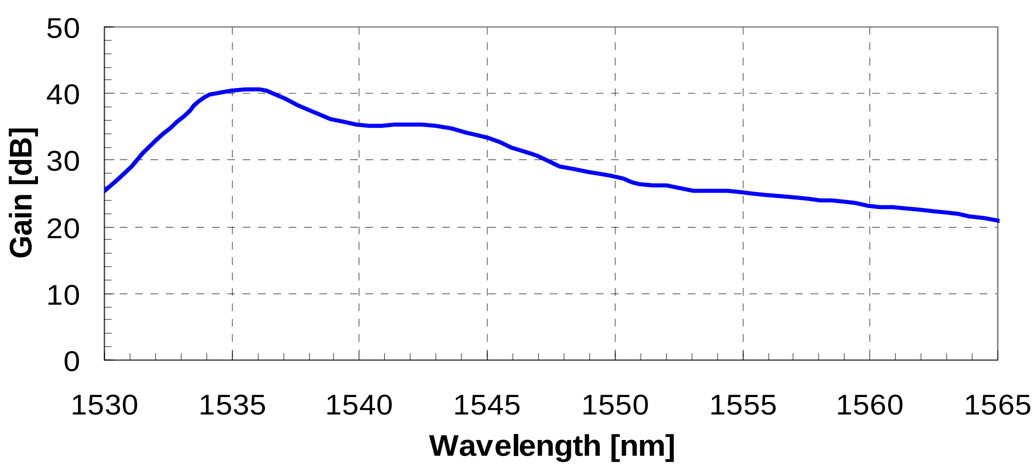

Figure 3. Very high peak gain performance

Figure 4 shows a plot of the saturated gain spectrum without any gain flattening filter. The EMFA shows a low noise figure of 5.5 dB across all wavelengths.

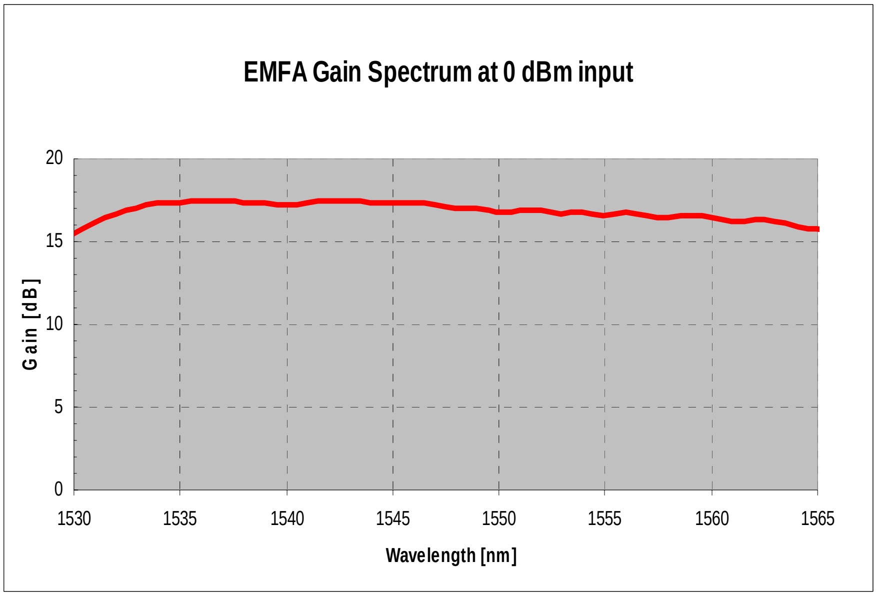

Figure 4. High output power across the C-band

EMFA Technology Comparison

EMFAs can fit a considerably smaller form factor than traditional EDFAs because the fiber within them does not have to be spooled. If smaller gain is required, then the micro fiber can be very short. This small form factor is especially useful for integrating into devices designed for loss compensation. For example, active erbium micro fibers could replace passive fibers in switches and add-drop multiplexers.

EDFAs will have a difficult time penetrating the metro market in their current configurations. The driving factors are size and cost. EMFAs, on the other hand, are well suited to meet metro and access market needs.

The table below lists the key parameters required by the emerging metro optical network.

EMFA MEETS METRO MARKET REQUIREMENTS			
Parameter	**Metro Target**	**EDFA**	**EMFA**
Wavelength Range (nm)	1530-1565	1530-1565	1530-1565
Gain (dB)	15 - 20	15-20	>15
Total Output Power (dBm)	10-15	15	>12.5
Noise Figure (dB)	6	5.5	5.5
PDL/PDG (dB)	0.5	0.3	< 0.3
PMD (ps)			< 0.5
Power Consumption (W)	< 5	3-7	3.5
Size (mm)	As small as possible	90 x 70 x 12	90 x 35 x 12

EMFAs also have some advantages over newer technologies being presented for the metro market, including Semiconductor Optical Amplifiers (SOAs), their close cousin Linear Optical Amplifiers (LOAs) and Erbium Doped Waveguide Amplifiers (EDWAs). SOAs and LOAs, for example, have a very small form factor but a higher noise figure.

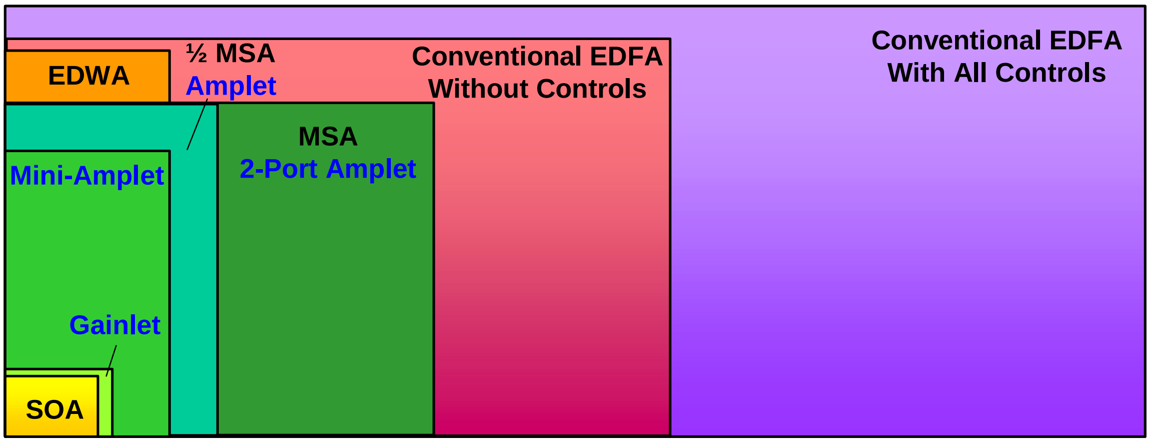

Figure 5. Relative Dimensions (Source: RHK 2001)

EDWAs are small, but currently fall short on gain and do not include electronics in the small form factor package. Although both technologies hold great promise, they have yet to meet the cost targets demanded in the metro market. The table below illustrates comparisons between the different technologies.

METRO AMPLIFIER TECHNOLOGIES COMPARED WITH EMFA				
	Compact EDFA	**EDWA**	**SOA/LOA**	**EMFA**
Power	15 dBm	7 dBm	10 dBm	>12.5 dBm
Gain	10-20 dB	10 dB	10-20 dB	>15 dB
Noise Figure	5.5 dB	5-6 dB	7-9 dB	5.5 dB
Size	Medium	Small	Very Small	Small
Integrated Intelligence	Yes	No	Yes	Yes
Arrays	No	Yes	Yes	Yes
Integratable	No	Yes	Yes	Yes

Summary

When compared with existing and emerging optical amplifier technologies, the EMFA displays the best overall cost, integration and performance characteristics for deployment into the metro optical network.