

Gosse Wedzinga  
Editor

## Metro Amplifiers Provide Gain Without the Pain

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It is fair to say that erbium-doped fiber amplifiers not only defined the operating parameters (e.g., the C-band) of long-haul optical networks, they also helped drive the success of dense wavelength division multiplexing (DWDM) technology.

The point-to-point optical backbone that evolved from these technologies did an excellent job of meeting and exceeding bandwidth requirements for long-haul transmissions. So well, in fact, that carriers have shifted emphasis to delivering Internet traffic across metro markets, which pose very different challenges—and opportunities—for conventional amplifier technology.

The most notable difference between long-haul and metro markets is measured in dollar signs. The hey-day of network build-outs is past and, compared to long-haul vendors, metro engineers came late to the party. But even if they enjoyed the same spending climate as the late nineties afforded, metro architects would have to stretch their funding to cover denser componentry, amortize costs from a smaller base of end users, and compete in a more populated market than long-haul engineers. Consequently, metro operators want to upgrade their networks with a very low first investment and to be able to add on inexpensively as market demand dictates. That requires more flexible and less costly amplifiers.

Amplifiers also encounter new technical issues as they move downtown: growth in metro traffic necessitates greater degrees of flexibility in the network, which translates into added components at each node. So, although metro signals travel shorter distances than those on long-haul networks, these signals often traverse more switching, multiplexing, and add/drop components as well as more connectors and splices before they reach their destination. Each of these components can introduce between 4 and 9 dB of loss of the signal, for which amplifiers must compensate. That leaves, for metro networks, two potential solutions: increase the frequency of discrete optical amplification or reduce the loss of node components.

### Profit and Loss

Engineers, in general, and cash-strapped network architects in particular recognize that simpler is better—as long as it gets the job done. This unwritten law favors amplified or zero-loss components, which not only help simplify network design, but also its operation, its flexibility, and its ability to be upgraded. The component-level integration implied by this approach would also provide potential cost savings to network engineers, both in the near- and the long-term. Right now, adding an amplifier to a metro network node generally means adding another card, which means adding to the footprint, power draw, training, inventory, and cost of the node. Integration is the easiest way to avoid this and reduce operational costs.

Integrated amplification, however, also implies compact technologies such as semiconductor optical amplifiers (SOAs) or linear optical amplifiers (LOAs). Both are compact and inexpensive enough to be incorporated onto the cards of other network components. In fact, the shift in focus to metro markets helped to boost flagging demand for semiconductor amplifier technologies, which now find frequent application as preamplifiers at metro access points. There, the noise that SOAs and LOAs introduce to the signal can be compensated for. However, when integrated into components these amplifiers produce a sort of cascaded configuration along a network route, introducing an unmanageable level to noise.

This is precisely the problem that high-gain, low-noise, erbium-doped fiber amplifiers addressed in long-haul optical networks, which suggests that loss-less components for the metro are possible only if a small gain element can be developed with the noise characteristics of erbium-based technology. Erbium-doped waveguides offer this along with a small form factor, but they fall short on gain and do not include electronics in the small form factor package.

Conventional EDFAs designed for long-haul systems are too bulky, power hungry, and expensive to be integrated into metro components or applied in such high volume. In response, some vendors have begun to offer stripped-down EDFAs, but even streamlined, these amplifiers still require an erbium-doped fiber component measuring meters in length in order to convert 980 or 1480 nm pump light into signal gain.

The complex problem of introducing low-cost flexibility into growing metro networks without introducing signal noise, therefore, finds its root in the much simpler challenge of reducing the length of erbium-doped fiber required to provide sufficient gain in integrated amplifiers.

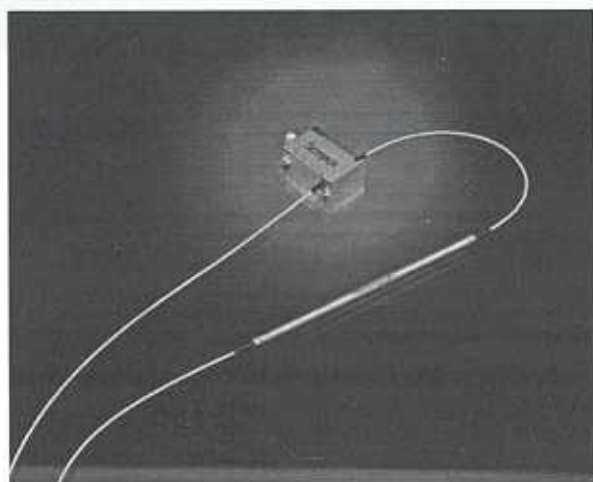
One solution that has emerged is erbium microfiber (EMF) technology, which increases the concentration of erbium atoms rendering comparable gain in a shorter span of fiber. These microfibers have already begun to replace conventional erbium-doped fiber components with high-gain, low-noise, multi-component glass strands just a few centimeters in length.

Their small size coupled and multifunctional amplification echoes the core EDFA technology that helped drive the rise of long-haul networks. Also, their application extends beyond signal amplification to include signal generation in the form of fiber lasers.

### Core Technology: Erbium Microfibers

Erbium microfibers comprise multi-component glass that allow doping concentrations of rare-earth erbium ions far above levels previously believed possible with conventional silica glasses. Their structure encloses a single-mode  $Er^{3+}$ -doped glass core within two cladding layers with matched refractive index and thermal expansion performance. The result is gain per unit length greater than 5 dB/cm, which when pumped by a laser diode, translates into more than 20 dB of signal gain across the C-band. Significantly, this gain comes with the same low 5.5 noise figure that conventional EDFAs deliver.

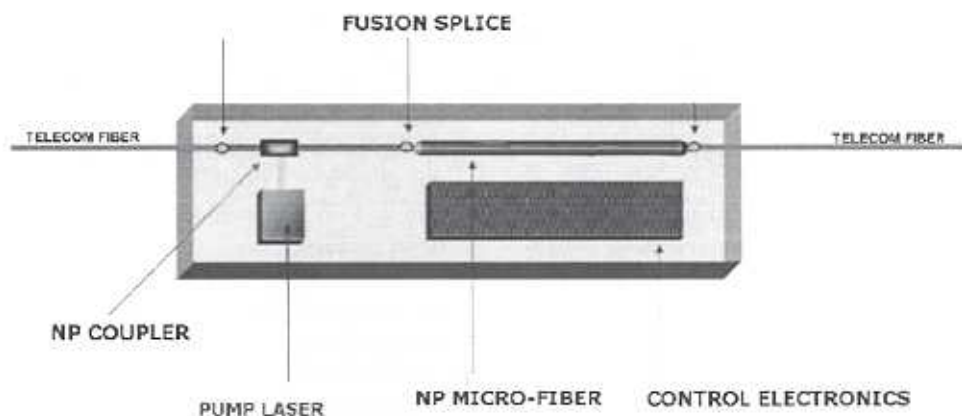
But compact gain is only one virtue of microfiber technology. In order to be integrated, metro amplifiers will also require low-cost packaging that maximizes coupling efficiency. Conventional photonic packaging of electro-optical components contributes anywhere from 50 to 75 percent of a subsystem's cost and this cost scales proportionally with the volume of the packaged product. Ampli-



**Figure 1:** Erbium micro fiber technology relies on multicomponent glass that allows much higher concentration of erbium atoms, delivering gain comparable to conventional EDFAs from fibers that measure centimeters in length.

fiers based on EMF technology can fit a considerably smaller envelope and cost profile than traditional EDFAs because they require no fiber spooling. Their small form factor facilitates integration into devices designed for loss compensation. For example, active erbium microfibers could replace passive fibers in switches, add/drop multiplexers, or arrayed waveguides. In such configurations, the pump diode and its electronics would be integrated directly onto the component's card.

What's most important, perhaps, is that this is not theoretical or lab-bound technology for tomorrow's networks. It has already begun to find commercial application, most recently in the form of a gain block consisting of an EMF efficiently coupled to a semiconductor pump laser. This so-called gainlet provides 10 dB of gain for either channel or band amplification and enables integrated loss compensation for metro DWDM components.



**Figure 2:** Active erbium microfibers can replace passive fibers in switches, add/drop multiplexers or arrayed waveguides to enable loss-less components. Or they may be configured as discrete compact gain blocks as shown. Such pump/coupler modules have demonstrated 10 dB of gain in a package measuring  $26 \times 34 \times 12$  mm.

METRO AMPLIFIER TECHNOLOGIES COMPARED WITH EMFA				
	Compact EDFA	EDWA	SOA/LOA	EMF Amplifiers
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	Very Small
Integrated Intelligence	Yes	No	Yes	Yes
Arrays	No	Yes	Yes	Yes
Integrateable	No	Yes	Yes	Yes

Figure 3

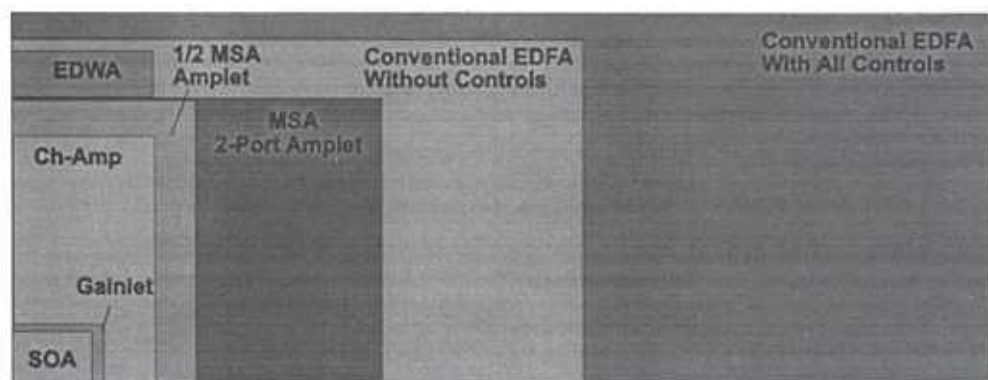


Figure 4: Conventional EDFAs designed for long-haul systems are too bulky to be integrated into metro components. Even stripped-down EDFAs require meter-length fiber components, Erbium-doped microfibers do not require fiber spooling, allowing them to deliver smaller form factors.

## Summary

Long-haul systems pose their own challenges but, like tourists from the sticks, network engineers have found that life gets tougher downtown. The dense component populations of metro networks introduce more potential sources of signal loss. Meanwhile, limited real estate, power budgets, and capital expenditures prohibit frequent additions of amplifier cards to compensate. From an engineering perspective, the simplest solution is loss-less components, which require low-noise integrated amplification. Rather than reinvent the wheel with new amplification schemes, erbium-doped microamplifiers offer a proven technology adapted to deliver compact gain on the same cards that perform switching, multiplexing, and add-drop functions.

## Biographies

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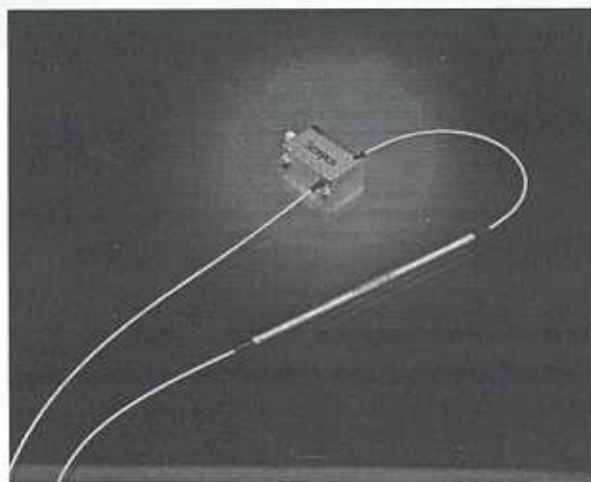
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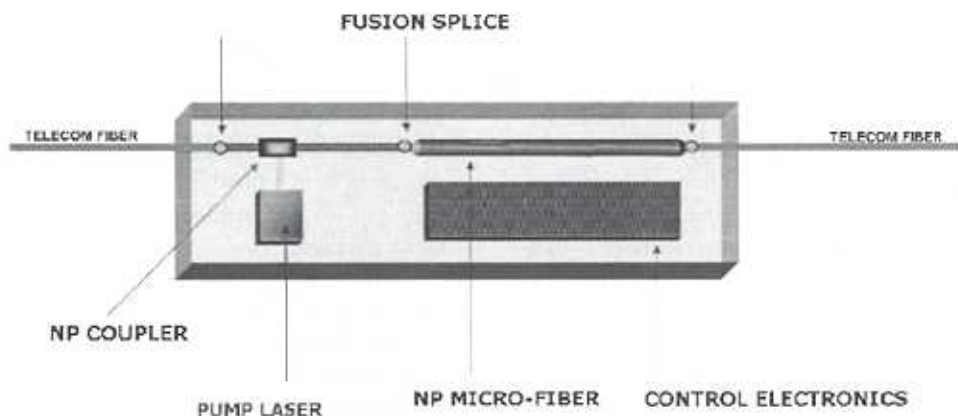
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