Building Bandwidth

With the need for faster, bigger, and cheaper bandwidth, companies are rushing to convert their wavelength-division-multiplexing technology to meet demands.

By Kristin Lewotsky

"You can't be too rich or too thin," the Duchess of Windsor once said. The fiber-optic communications twist on that phrase would be, "Your network can't be too cheap or have too much capacity." Mere wavelength division multiplexing (WDM) is no longer enough.

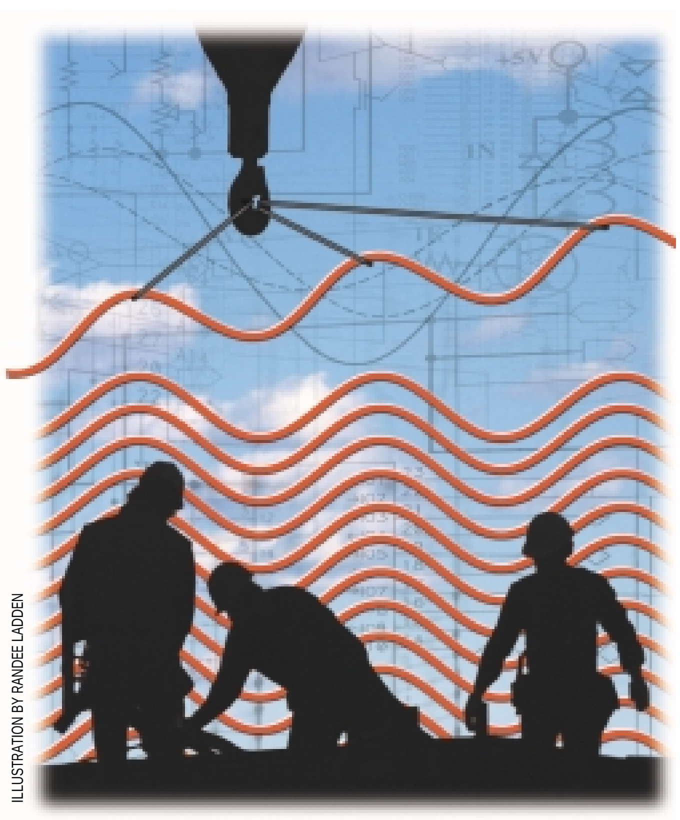

ILLUSTRATION BY RANDEE LADDEN

Bandwidth at a bargain is the primary driver of the fiber-optics industry, and component vendors are feverishly striving for the cutting-edge technology to meet the goal.

The technology surge of the past five years has catapulted the industry past the once-impressive bit rate of 622 Mb/s. Long-haul WDM networks operating at 10 Gb/s are de rigueur now with the technology beginning to migrate into the metropolitan area loop.

Never one to rest on its laurels, the industry has now begun to focus on the challenges of 40 Gb/s transmission. A bevy of companies are hard at work refining indium-phosphide-based electronics and developing compensation schemes for polarization-mode dispersion (PMD) and chromatic dispersion, laying the groundwork for the high-speed Internet of the future (see page 21).

Meanwhile, ultralong-haul technology developers hope to reduce the need for optical amplifiers and repeaters in terrestrial networks with soliton transmission schemes and other techniques (see page 24), which would cut costs significantly. In all of this work, fiber Bragg gratings continue to be a critical component of WDM networks (see page 38).

As the technology growth curve in optical communications shoots upward, the market sector continues to captivate the attention—and the funds—of venture capitalists and Wall Street traders alike. At the start of the twenty-first century, photonics is firmly in the lead as the enabling technology that is changing the face of telecommunications, even as the lucrative fiber-optic market sector changes the face of the photonics industry. **oe**

WDM provides modular capacity increase

Wavelength division multiplexing (WDM) offers a tremendously powerful means to increase network capacity by modularly raising transmission volume 32 or more times via spectral multiplexing. Instead of sending one optical data stream down a fiber at 10 Gb/s, a network operator can simultaneously send, for example, four different data streams at four specific wavelengths (channels) all operating at 10 Gb/s for an aggregate capacity four times that of the single-channel type.

In a typical WDM system, diode-laser-based transmitters generate pulsed signals, and external modulators impress the high-bit-rate data stream on this optical carrier signal. Multiplexers based on thin film or grating technology combine the modulated data streams into a single data stream that gets launched into the transmission fiber. After detection at the far end of the link, a demultiplexer reverses the process, separating the data back into individual channels for subsequent routing.

Erbium-doped fiber amplifiers (EDFAs), which generate gain across a relatively broad wavelength band centered at 1550 nm, provide the multichannel power boost to send WDM signals across long-haul networks. The gain band of erbium effectively defines the telecommunications wavelength ranges: conventional band (C-band) at 1530 to 1565 nm and long-wavelength band (L-band) at 1565 nm to 1625 nm.

Early systems featured four channels spaced at intervals of 200 GHz (1.6 nm) on the International Telecommunications Union (ITU) frequency grid. More recently, channel spacings have decreased to 100 GHz (0.8 nm). Interleaver technology allows network vendors to achieve channel spacings as tight as 50 GHz (0.4 nm) by meshing together separate data streams of even and odd channels spaced at 100 GHz each. Other equipment vendors have used fiber Bragg grating technology (see Tutorial, page 38) to directly multiplex a signal at 50 Hz.

Although tight channel spacings increase capacity, they involve performance tradeoffs. Optical fiber has a small nonlinearity. Because the cross-sectional area of a fiber is so small, the optical flux in a data signal becomes appreciable. In the case of tightly spaced channels, these nonlinearities trigger four-wave mixing, which degrades transmission performance.

According to Tom Mock, product marketing director at Ciena Communications, Inc. (Linthicum, MD), four-wave mixing can be minimized by reducing the amount of power launched in each channel. "You have a certain amount of optical power to spend," he says. "If you double the number of channels, you're launching each channel with half power." Corning, Inc. (Corning, NY) also has developed a fiber designed with a large effective area to minimize nonlinear effects. *—K. L.*