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guidelines

Keeping paths of communication open in a fiber optic world

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The Revolution

Beginning at the birth of optical fiber

TO BEGIN A REVOLUTION//BRING IT ON//TEXAS WIRED//LIGHTSPEED IN NEW YORK

CORNING
Discovering Beyond Imagination

editor's note



Welcome to *GuideLines*! Our feature article this issue recognizes the 30th anniversary of the invention of low-loss optical fiber by spotlighting one of the inventors, Corning's very own Dr. Donald Keck.

GuideLines has a new format, too! Each issue will include a carrier profile article, and this quarter we focus on LightSpeed Fiber Network, an exciting new company that is deploying a ring of MetroCor™ fiber around New York City.

We have included articles specifically highlighting recent technology developments in the realm of telecommunications. This edition includes articles on LEAF® fiber upgradeability, restricted mode launch (RML) bandwidth measurement for InfiniCor® fiber, and the implementation of fiber-to-the-home by ClearWorks, a Houston-based company. Photonic technologies are also featured in an article on amplifying 40 Gbps systems.

I want to introduce myself as the new editor for *GuideLines*, and encourage you to provide me with comments, questions and story ideas. You can reach me via e-mail at wrighte@corning.com. Also, please feel free to offer the free subscription card insert to a colleague.

Be sure to watch your mailbox in March for the Spring 2001 issue of *GuideLines*.

sincerely,

Elizabeth Wright

editor

WINTER/00

gl guidelines

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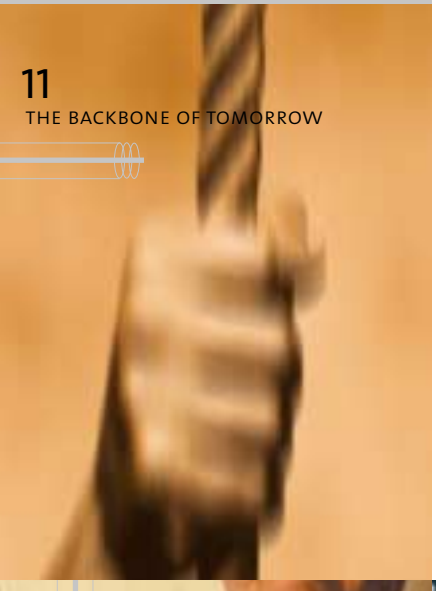
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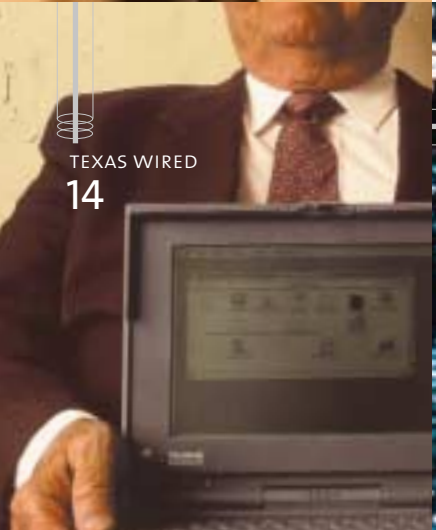
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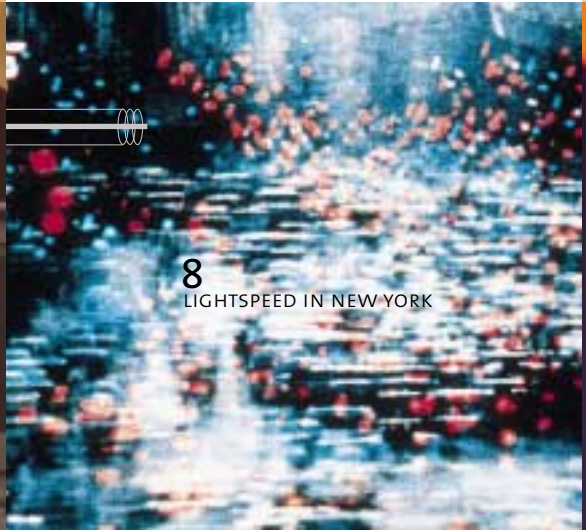
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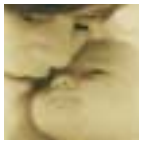




Elizabeth Wright // Editor for Guidelines // Corning Incorporated

to begin a revolution





the birth of optical fiber

Growing up with a physicist father in a home filled with prisms and lenses, it is no surprise that Don Keck grew up to be one of the founding fathers of low-loss optical fiber. The first time Keck saw an optical fiber, he was a second-year graduate student at Michigan State University studying infrared spectroscopy. It was a very short, preliminary specimen; but it certainly intrigued Keck. After completing graduate school in 1967, Keck visited Corning Incorporated and met Dr. Bob Maurer, who elaborated on Corning's optical fiber development project. He told Keck all he had been learning about the possibilities of optical fiber communications, particularly through trips to visit British Telecom. Attracted by the opportunity to work for Maurer on a fiber development project, Keck soon after accepted Corning's offer to be a senior research scientist on this project, and began work in Corning, New York, in January 1968.

Upon arriving at Corning, Maurer instructed Keck and Dr. Peter Schultz, a research chemist who had come aboard only a few months earlier, that the objective of their research, dubbed the Optical WaveGuide Project, would be to fabricate a 20 dB/km waveguide. Many leaders of other telecommunications companies had already abandoned this effort, citing that it was an impossible task. Therefore, it was definitely advantageous to have two young and inexperienced scientists like Schultz and Keck involved with the project; they didn't know what they didn't know.

Initially, Maurer was able to provide guidance and answer many of the fundamental questions, as he had been working on light-scattering measurements since the early 1950s. He had already discovered that fused silica was one of the lowest scattering-loss glasses that existed, and Corning had already developed the ability to work with fused silica glasses. One of the first conclusions they drew was to eliminate the rod-and-tube process as the best method for accomplishing their objective. The rod-and-tube process, a popular method for making early fiber, involved placing a core glass inside the cladding tubing, then heating and drawing it into fiber. However, this technique tended to result in significant amounts of scattering at the core-clad interface, which severely limits the optical transmission properties of fiber. Keck and Schultz instead focused on developing a new method, which came to be known as the inside vapor deposition (IVD) process. The two would first select a high-purity fused silica tube and use that as the foundation material for the cladding. Next, they concentrated on selecting the appropriate mix of doped silica materials and deposited thin layers of glass on the inside of the tube to manufacture the optical fiber preform. This was followed by drawing the fiber, and finally, performing the measurements.

This process was unique for making fiber and was considered a risk since Keck and Schultz had no indication the direction they had chosen would succeed. Yet the



Donald Keck

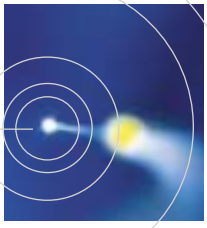
Low-loss optical fiber founder
Corning Incorporated

team made a number of discoveries from their trial-and-error approach. For instance, during the early stages of their research they were experimenting with titania-doped silica in the core. Titania dioxide was added to minimally raise the refractive index of the core. However, they soon discovered that with these materials the extreme environment of the draw caused the fiber to come out of the draw essentially opaque. To correct this, they had to heat-treat the fiber in an oxygen atmosphere. (Later, when the process was being refined for optical fiber manufacturing, germania was ultimately found to be a more appropriate dopant.) It was Keck's job to experiment with these heat treatments to find the optimum time-temperature trade-off for improved transmission. Says Keck, "When you heat-treat silica and oxygen, crystals grow on the surface, which are break sources. The fiber would be so fragile that if you looked at it crossways it would break. Therefore, we obviously had considerable angst in making and measuring the fiber, but, of course, that is part of research." After each experimental phase, Maurer, Schultz and Keck would gather to discuss where they had failed and where they had succeeded in order to plan a new course of action. After two years of this, the team had their "whoopee!" day.

It was late on a Friday evening in August 1970, and the majority of Keck's Corning colleagues had already gone home for the weekend. Nevertheless, he felt compelled to do one more measurement. Earlier that evening the team had run an experiment, heat-treated the newest batch, and made fiber. "As I scanned the laser spot on the end of the fiber, all of a sudden there was a bright flash of light in my eye. It was completely different than anything that I had experienced in the past," says Keck. "I knew something was dramatically different with this fiber." Keck quickly realized that the light was traveling all the way down to the other end of the fiber, reflecting off the end and hitting him directly in the eye. The fiber was short, so measuring it wasn't easy, but as best as Keck could determine, the loss was 17 dB/km. Keck promptly recorded the measurement in his lab book, and noted a single word after the entry: "Whoopee!" After more than two years, they had finally achieved Maurer's objective of less than 20 dB/km.

Keck explains, "I repeated the measurement half a dozen times to be certain. My first inclination was to rush out and tell somebody, but it was after 6 o'clock on a Friday night, and most of my colleagues had already left for the evening." Yet, Keck heard the elevator open, and he rushed out into the main hallway to find the laboratory chief technology officer, Bill Armistead, standing there. Seeing how excited Keck was, Armistead accompanied him back into the laboratory, and Keck ran the measurement to show him. At the time, Armistead probably didn't even know who Keck was or understand the significance of what the young scientist was showing him. But later, he certainly did.

Keck says of this event, "In many respects, the game was just beginning. But obviously we were elated." At that time, other labs working on similar projects, including AT&T, Nippon Sheet Glass and British Telecom, had only gotten as close as 200 dB/km, so Corning was without question leading the race. It was over 10 years before the team saw their invention embraced by the telecommunications industry. The measurements had to be repeated on significantly longer pieces of fiber and several facets of the process had to be improved and refined. "Any time you begin a revolution," says Keck, "you



cannot understand the full scope of it until you are well into it. Even today, 30 years later, I believe that we are not entirely aware of how much the future holds for the optical fiber industry."

Since Keck and his team invented low-loss optical fiber in 1970, there have been a number of milestones as the optical fiber industry has developed. Early on, scientists began working with multimode fiber, but within a decade, most were back concentrating on single-mode fiber, which was the basis of the first low-loss fiber. Along the way, Corning developed the technology to design more complex core glass for a single-mode fiber. In 1985 Corning introduced dispersion-shifted fibers. These were fibers designed to operate at longer wavelengths of light than their predecessors. Now fiber could have the low-loss of the longer wavelength as well as the minimization of dispersion. Today, this concept is illustrated in Corning® LEAF® and MetroCor™ fibers, which are changing the complexion of the entire telecommunications network worldwide.

Certainly integral to optical fiber evolution over the past 30 years was development of efficient manufacturing processes. After Keck and Schultz met their initial goal of less than 20 dB/km, Corning expanded the research team and proceeded to focus on mass production of optical fiber. It was eventually realized that the IVD process could not readily support large preforms, and therefore, would not ultimately be a cost-effective production method. Instead, Corning introduced and implemented the outside vapor deposition (OVD) process, which is embraced today by all five Corning manufacturing facilities. Though at the time Corning was only selling a few thousand kilometers of fiber, long before it actually evolved into an industry, Corning had bet that it would become one. By 1979 Corning's first commercial manufacturing facility was operating in Wilmington, North Carolina, and finally, in 1982, Corning and optical fiber had a major breakthrough: MCI ordered 100,000 km of single-mode fiber. Shortly thereafter, GTE also initiated substantial deployment of fiber, and the revolution was launched.

Thirty years later, Dr. Keck, vice president and technology director of optical physics, describes the optical fiber industry as young and as vast as ever. Looking to the next 30 years, the possibilities are endless. A few trends have already become apparent: Over the next three years there will certainly be significant optical switching and routing deployment. Also, look for ultra long-haul terrestrial lengths based on some of the fibers that Corning has already introduced, like LEAF fiber. Additionally, Raman amplification will make the process more cost-effective by expanding distances to 1500-2000 km or longer. Looking further ahead, it is likely that we will start to see significant fiber-to-the-home deployment over the next five years. Within 10 years, the significant deployment of an all-optical network is almost certain. Thirty years ago this industry didn't even exist. Today, the global optical information industry is a $1.5 trillion business. The possibilities over the *next* 30 years are certainly endless.

Peter Pondillo // Senior Market Development Engineer // Corning Incorporated



Setting New Standards

Consistent performance from high-speed, laser-based, multimode fiber networks

Economical high-speed data transmission came to local area networking with the advent of Gigabit Ethernet, which allows for the use of inexpensive vertical-cavity surface-emitting lasers (VCSELs) operating at 850 nm and low-cost multimode fiber optimized for use with lasers. In response to this new requirement, Corning Incorporated has introduced two lines of high performance InfiniCor® multimode fiber, the first multimode *laser-optimized fiber*® with guaranteed transmission distances ranging from 300 to 2000 meters in Gigabit Ethernet compliant systems.

Yet even with these and other breakthroughs, in order to achieve optimum system performance using multimode fiber with lasers, technical obstacles had to be overcome. Research has revealed that restrictions on laser launch conditions and on multimode fiber bandwidth measurements were required if networks were to be assured of system bandwidth sufficient for multi-gigabit transmission. Consequently, a Telecommunication Industry Association (TIA) FO-2.2.1 Task Group has completed much of the work to establish source and multimode fiber selection criteria to ensure successful high-speed operation of laser-based networks.

Restricted mode launch key to system performance reliability

Studies have consistently shown that VCSELs, and other short-wavelength sources that create a small spot of light, known as a restricted mode launch, produce increased bandwidth in multimode fiber. In essence, the bandwidth of optical fiber is largely dependent on modal dispersion, which is the spreading of light pulses as they travel down the length of a fiber. Using a restricted mode launch (RML) stimulates fewer modes, which significantly reduces modal dispersion and, therefore, increases bandwidth.

The trouble is that short-wavelength sources produced by different manufacturers have exhibited a variety of launch conditions. So to guarantee consistent link performance, the laser launch condition must be specified using a reliable measure of restricted mode launch.

Next, fiber bandwidth must be measured and specified for laser performance with a restricted mode launch. Although some fiber manufacturers have characterized multimode fibers for use with lasers, until recently fiber's information-carrying capacity was only measured using over-filled launch conditions. Over-filled launch bandwidth (OFL BW) is a good measure of relative fiber performance capability when used with LEDs, which distribute optical power in 100 percent of the fiber core

and use hundreds of modes. With lasers, however, optical power is concentrated in the fiber's center and distributed in less than five percent of the inner modes. Even small perturbations in the index profile at or near the fiber's center can dramatically reduce laser performance, resulting in bandwidth-limiting effects. Therefore, fiber must be specified for laser bandwidth under RML conditions.

The task of solving these technical problems was assigned to the TIA FO-2.2.1 Task Group on Modal Dependence of Bandwidth, which is chaired by Mike Hackert, measurement project engineer at Corning Incorporated. When asked to verify a recommendation for a laser-based system that transmits 1 Gbps up to 500 meters using 62.5 micron multimode fiber and 850 nm sources, the task group concluded that without appropriate source and fiber selection criteria, fiber link lengths for local area networks must be set ultra-conservatively to minimize risk of link failure. With proper specifications, however, those same networks can be assured of system bandwidth sufficient for 1 Gbps transmission.

New standards for RML and multimode fiber bandwidth

Again, to ensure optimum multimode fiber performance in laser-based systems, where laser launch conditions are restricted such that fewer modes are used, the fiber must be specified for laser bandwidth, not OFL BW, under these RML conditions. TIA FO-2.2.1 developed standards for each of these restrictions:

- FOTP-203, Launched Power Distribution Measurement Procedure for Graded-Index Multimode Fiber Transmitters.
- FOTP-204, Measurement of Bandwidth on Multimode Fiber.

FOTP-203 provides a standard procedure for measuring launched power distribution for multimode fiber transmitters. Described simply, the procedure involves shining light through a short length of multimode fiber and measuring near-field intensity at the receiver end. The data collected is used to calculate the encircled flux, which is the percentage of power within a given radius when light is launched by a transmitter into a multimode fiber. For Gigabit Ethernet systems, the recommended encircled flux is >75 percent within a 15 micron radius and >25 percent within a 4.5 micron radius.

The encircled flux transmitter launch measurement is employed to characterize the launch spot size carried by a multimode fiber, to specify transmitter launch conditions and to ensure a restricted mode launch, or a reduced spot size, which is necessary to limit the number of modes stimulated. As noted earlier, restricted mode launch results in increased bandwidth in multimode fiber. Calculations based on encircled flux measurements characterize fiber optic laser sources for use in mathematical models to predict minimum guaranteed link length.

With the laser launch condition appropriately characterized, the next step is to ensure that the optical fiber, using methods described in FOTP-204, meets bandwidth requirements of >385 MHz-km under RML conditions. In the test, the restricted mode launch is created by filtering an over-filled launch condition with a mode-conditioning patch cord consisting of a special fiber, which is a graded-index multimode fiber with a 23.5 micron core. After testing a variety of fibers for RML, the task group determined that 23.5 micron fiber was the best choice because it produces a launch condition most like that of a VCSEL.

Finally, TIA FO-2.2.1 validated its specifications by measuring system Effective Modal Bandwidth (EMB). EMB is the information-carrying capacity of a system, accounting for both fiber modal delays and transmitter launch condition. EMB measures effects of the interaction of an optical fiber meeting the bandwidth requirements under RML conditions and a transceiver meeting the launched power distribution requirements to accurately evaluate overall system performance.

The Telecommunication Industry Association recently adopted restricted mode launch bandwidth as the standard measurement of laser bandwidth for 62.5 micron multimode fiber operating at 850 nm. In conjunction with this, Corning has announced that, using the RML bandwidth measurement, it will specify laser bandwidth for InfiniCor® 300 and InfiniCor® CL™ 1000 fiber, its 62.5 micron laser-optimized fibers. These minimum RML bandwidth values for both fibers at the 850 nm operating wavelength will give end-users confidence in their fiber's performance in laser-based systems.

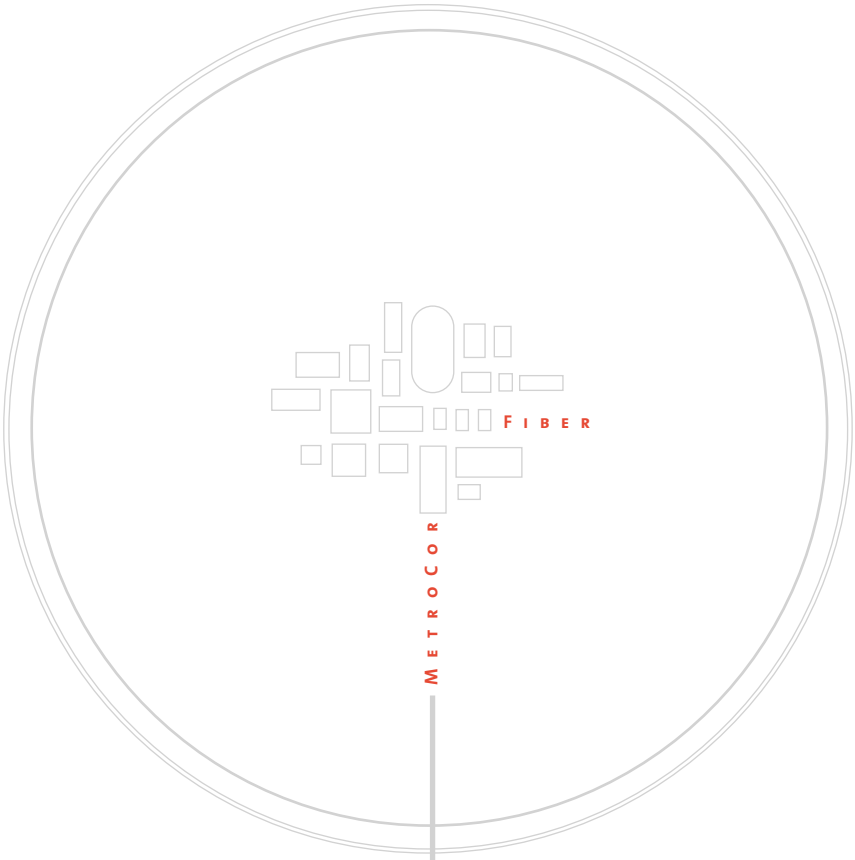
Corning is leading the effort to establish comparable measurement standards for 50 micron fiber and for operation at 1300 nm. Finalizing these criteria is now the focus of the Task Group on Modal Dependence of Bandwidth, whose work on 62.5 micron multimode fiber is complete. Soon, the means will be available to guarantee optimum performance in low-cost, laser-based, high-speed network systems using either 50 micron or 62.5 micron multimode fiber. ■

To learn more about multimode fiber and restricted mode launch, call the Corning Optical Fiber Information Center at 1.800.525.2524/ext. 4256.

JANE LI // METRO APPLICATIONS MARKETING & SALES DIRECTOR // Corning Incorporated



LightSpeed



in New York

Rob Tannor, President of S.N. Tannor, Inc., a well-known and established New York construction company, is certainly an opportunist. With years of metro New York construction work under his belt, Tannor has jumped at the chance to apply his experience to metropolitan access networks. In 1999, S.N. Tannor, Inc. joined with Thalle Construction Company, Inc. to create a new company, LightSpeed Fiber Network (LightSpeed), which acquires rights-of-way, engineers and constructs metropolitan area fiber networks, and leases fiber optic bandwidth capacity to customers on a non-metered fixed cost basis.

Initially, one might wonder how you move from construction to fiber, but in reality, it is a natural progression from construction services delivery to fiber optic bandwidth development for a company like S.N. Tannor. Traditionally, Tannor's work has involved electrical work on wastewater treatment plants, data and telecommunications cabling, highway construction, and maintaining the streetlights of New York City. LightSpeed's core competence in fiber networks emerges from a strong background in municipal and city public works construction, which has equipped the emerging company with the appropriate skill set necessary to

quickly negotiate and acquire the city and state rights-of-way. In short, LightSpeed is primed to acquire access to city streets and highways quickly, which in turn allows them to deploy and lease dark fiber less expensively than their competitors.

LightSpeed kicked off work in June 2000, when it concluded an agreement with the city of New York to deploy high-capacity telecommunication bandwidth throughout the metropolitan area. Once LightSpeed had the agreement, the next task at hand was to choose an optical fiber type. Rob Tannor, now chairman and COO of LightSpeed, says, "We had investigated a whole host of fiber technologies for use in our network, and Pirelli Cables & Systems suggested that we consider Corning® MetroCor™ fiber, as our business plan is to lease dense dark fiber in metropolitan areas to Incumbent Carriers, CLECs, ASPs, ISPs, Storage Area Network providers, business and government customers." After much research and due diligence, LightSpeed announced its strategy to bring value and cost savings to their customers by deploying their network with Corning's MetroCor and SMF-28™ fiber products, which are being wrapped in an 864-fiber ribbon in loose tube (RILT) Pirelli cable design. The first delivery of fiber for the 150-mile New York City deployment was rolled out early in the fourth quarter 2000, and the availability of dark fiber to the customers is anticipated at year-end.

Released by Corning Incorporated in March 2000, MetroCor fiber is a single-mode non-zero dispersion-shifted optical fiber that operates across the entire usable bandwidth from 1280 nanometers (nm) to 1625 nm. It eliminates the need for dispersion compensation, reduces amplification along the network path, and facilitates the use of less expensive lasers. From a carrier standpoint, obtaining the ability to utilize the whole bandwidth at lower operating costs is certainly a benefit. Tannor states, "As our formula for success, LightSpeed is driving the cost down for our customers by deploying the most advanced metropolitan fiber on the market, which will enable customers to reduce their costs and allow applications and content to flourish." LightSpeed's strategy includes acquiring metropolitan area rights-of-way to facilitate the engineering and construction of dark fiber networks, which will enable the fiber optic bandwidth capacity to then be leased to customers on a non-metered fixed cost basis.

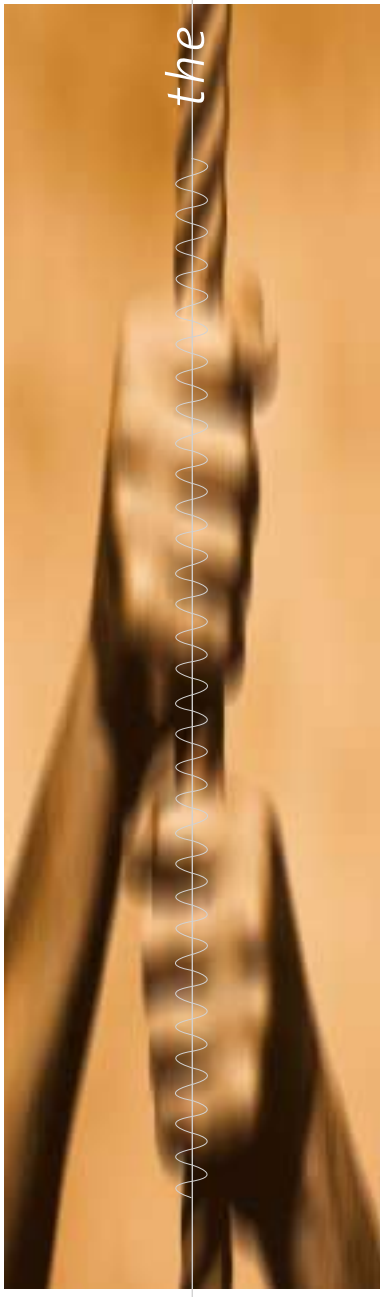
Besides driving the cost of bandwidth down, LightSpeed is transforming the Bell business model of monthly cost per megabit per second into a long-term fixed cost asset for its customers. In other words, companies seeking to acquire bandwidth before sought a connection from the Regional Bell Operating Company (RBOC) at a monthly dollars per megabit per second connection charge. LightSpeed, on the other hand, allows the customer to lease dark fiber over a long period of time at a fixed cost. This empowers the bandwidth customer by providing flexibility, upgradeability and durability. As the customer's needs grow, high-speed telecommunications transmission equipment can simply be upgraded or supplemented, and the marginal cost per megabit per second is virtually zero. Additionally, LightSpeed's dark fiber network provides a value proposition for carriers and customers since it allows for much longer transmission distances than traditional fiber networks, and this is key as metropolitan area networks expand beyond the dense metropolitan downtown areas into suburbs.

MetroCor fiber is a critical part of the mix, as it enables LightSpeed to provide its customers with true flexibility and upgradeability. Today MetroCor fiber can be used with commercially available 1300 nm band equipment and newer dense wavelength division multiplexer (DWDM) equipment with lasers in the 1500 nm band range. Tomorrow, MetroCor fiber, which was designed for the entire usable optical spectrum, will also allow LightSpeed customers to upgrade to future optical network technology. As network traffic increases and the customer's needs adjust, rather than being entirely replaced, the equipment is simply upgraded. In essence, LightSpeed and MetroCor fiber future-proof the network for the customer.

LightSpeed's overall business strategy is not limited to New York City, but is applicable to almost any metropolitan area. In fact, presently, LightSpeed is in various stages of investigations and negotiations with a number of cities, from Atlanta to Seattle. Tannor anticipates a continued relationship with Corning as well: "Clearly, our deployment of MetroCor and SMF-28 fibers is not just limited to New York. We plan to install these fibers across the board. Anywhere we go, we are going to bring the product with us." And according to many industry predictions on the continued bandwidth explosion, anywhere could be everywhere. Leading telecommunications industry consultant RHK calculates that data traffic on public networks will swell by nearly 2200 percent between 1998 and 2002. This is definitely good news for LightSpeed. As music, video and voice propel demand, and bandwidth continues to be a force to be reckoned with, look for this construction spin-off to build a solid foundation in the fiber business. ■

For more information on LightSpeed and the advanced fiber optic technology deployed, please contact Rob Tannor at 718.977.9083/EXT. 301, *e-mail: rtannor@tannor.com. For more information on MetroCor fiber, please call the Corning Optical Fiber Information Center at* 1.800.525.2524/EXT. 5063.

the Backbone of Tomorrow



Future-proof your long-haul network

Perhaps it is fitting that the very technology that transmits data through optical pulses is advancing at the speed of light.

Fiber optic technology is developing at a rate unseen since Corning invented the world's first low-loss optical fiber in 1970 and revolutionized the way the world communicates. Within the last 18 months, there have been tremendous strides in technological development that will allow long-haul systems to transmit data further and faster than ever before. Equipment designed to increase system reach, bandwidth or data rate has excited network designers with its potential, but left many of them with a looming question: Does my network have the backbone — the optical backbone, that is — to make the most of it?

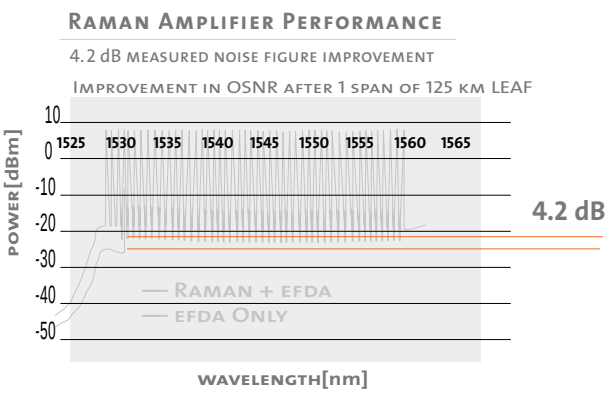
For advanced networks deploying Corning® LEAF® optical fiber, the year 2000 has been an exciting one. Corning Incorporated has demonstrated time and again the future-proof flexibility to maximize network performance on emerging technology.

Revolutionizing fiber technology in 1998 by demonstrating the muscle of effective area on fiber performance, LEAF fiber is the world's most advanced, non-zero dispersion-shifted fiber. LEAF fiber's design increases the effective area of the optical fiber significantly, improving system performance by reducing non-linear effects. Data can be delivered through the fiber, pumped by more power, with a higher signal-to-noise ratio and lower bit-error rates (BERs). All told, it adds up to a fiber that provides more power and better performance at the lowest cost-per-bit for dozens of carriers worldwide who have selected LEAF fiber for their advanced long-haul networks.

There are many promising technologies surfacing in the telecommunications industry today, some of the most

In the ever-changing world of high-data-rate transmission, the race will not go solely to the swiftest, strongest network, but to the one that can offer the greatest flexibility.

figure 1



significant lie in the ultra long-haul arena. This is just one window in the optical layer where Corning has developed not only the fiber but also the components to make the most of this emerging technology.

Raman Amplification

It seems that you can't go anywhere in the telecommunications field anymore without hearing about Raman amplification. This technology has been used in submarine systems for years, and now it is migrating to terrestrial long-haul applications as well. This new application allows for "gentler" amplification of an optical signal down the fiber, offering longer reach, higher bit rates or tighter channel spacing within a network.

Put simply, Raman amplification pumps backward along the fiber — against the optical signal — transferring its energy to the signal and thereby "boosting" it. Because Raman amplification occurs down the length of the fiber, rather than at isolated locations outside of the fiber, as with a traditional amplifier, it is a very efficient method of amplification and significantly lowers the noise figure of the signal.

This technology has been of considerable interest to network designers, who recognized that Raman amplification would allow for higher transmission rates, longer reach, tighter channel spacing or longer spans without regeneration — all of which add up to cost savings. The concern was how this amplification technique would operate on the fibers they designed into their networks.

At OFC 2000 in Baltimore, Corning's LEAF fiber proved that its customers would have fewer concerns in this area. In a demonstration within Corning's show booth, light was transmitted along two recirculating loops of LEAF fiber. Recirculating loops are just as they sound: loops of fiber in which the light is transmitted through the loop at least twice in a row, thereby expanding the distance you can simulate within a finite quantity of fiber. One loop, containing three 125-kilometer spans of LEAF fiber, was amplified with traditional EDFA amplifiers; the other loop, also containing three 125-kilometer spans of LEAF fiber, was amplified with a Raman-assisted EDFA, a product that Corning announced at OFC. (*Figure 1*)

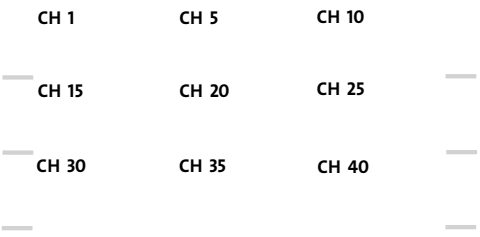
LEAF fiber demonstrated a 4.2 dB noise figure improvement with Raman amplification, an improvement that can mean significant cost savings for network designers. The demo, which effectively doubled the distance that LEAF fiber had ever demonstrated before at an exhibition, illustrated that longer reach is attainable through Raman amplification, and furthermore, over an installed base of LEAF fiber. Networks deploying LEAF fiber will be able to realize the benefits of Raman amplification while still enjoying the performance and cost-per-bit economic advantages of LEAF fiber.

Performance in the Long Band

Clearly, network designers also hope to maximize the bandwidth potential of their existing fiber plant by taking advantage of new operating bands in which to place channels. While most long-haul networks operate now in the conventional (or C-) band, which ranges from 1530 to 1565 nm, for a few years now, there has been substantial interest in the long band (L-band), which offers additional bandwidth

figure 2

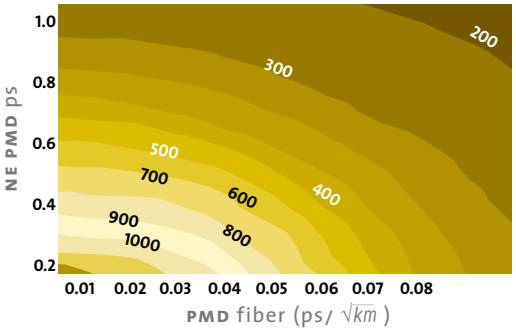
Eye Diagrams and PRBS



eye diagram of selected channels at the output of the system
all channels have clean and wide eye aperture

figure 3

40Gbps: $\delta\tau_{dc}$ =0.2ps/$\sqrt{}$km



potential in the 1565 to 1625 nm range. With amplifiers optimized for the L-band on the horizon, performance in the L-band has become a tantalizing new option for network designers hoping to maximize bandwidth.

At NFOEC 2000 in Denver, Corning released new data from one of Corning's state-of-the-art testing facilities, further verifying LEAF fiber's L-band performance. In an L-band testbed, 40 channels at 100 GHz spacing were transmitted across five 100-kilometer spans of LEAF fiber with an average launch power per channel of 3 dB. All channels were successfully transmitted with a BER below 1.0 x 10^{-12} dB, the highest acceptable BER for long-haul transmission, and with dispersion compensation at the terminals only (*Figure 2*). This data further demonstrates LEAF fiber's network design flexibility, now and in the future.

Polarization Mode Dispersion

Polarization mode dispersion (PMD) will be an on-going challenge for ultra long-haul systems, in particular those systems at data rates higher than 10 Gbps, which is yet another emerging technology within the optical layer. In essence, an optical pulse exists on more than one "plane" or mode — it is not a two-dimensional creation, but a three-dimensional one — which can cause a problematic phenomenon in optical transmission. Slight asymmetry in any optical fiber causes the different modes of the optical pulse to travel at slightly different speeds, distorting or spreading out the signal. It is an important factor in 40 Gbps transmission, the performance benchmark for tomorrow's long-haul systems.

Corning recently announced that it was introducing a third generation of LEAF fiber, one with a 100 percent improvement in its PMD specification, an improvement that can translate into significant cost savings for networks. This latest generation of LEAF fiber lowers the PMD link value to ≤ 0.04 ps/√km with a 0.1 ps/√km for maximum fiber PMD. No other commercially available NZ-DSF has matched this low fiber PMD value.

By reducing the fiber PMD specification to half of its previous amount before cabling, this latest generation of LEAF fiber can enable network designers to increase the distance of their networks without signal regeneration or PMD compensation (*Figure 3*). This new generation of LEAF fiber will better support emerging 40 Gbps transport systems at substantially less cost than existing transport systems.

You Need Backbone

In today's fast-paced world of high-data-rate transmission, the race will not go solely to the swiftest, strongest network, but to the one that can offer the greatest future flexibility. You need an optical backbone that will meet your business needs today *and* tomorrow. The world's most technologically advanced long-haul networks, providing telecommunications on six of the seven continents of the globe, have recognized that market leader LEAF fiber gives them that flexibility. Find out what LEAF fiber can do for your network plans. ■

For further details on LEAF fiber and the flexibility it provides networks, call the Corning Optical Fiber Information Center at 1.800.525.2524 / EXT. 7572.



Bringing fiber optic technology home

Texas wired



In the suburbs around Houston, pastures are giving way to upscale neighborhoods with names like North Pointe, Stone Gate and Rock Creek. Fueled by high-tech prosperity, the new developments are springing up fast. Employees of Houston-based companies like Compaq Computer and Texas Instruments are now in a position to build new, state-of-the-art houses, and they want their houses wired. For these homeowners, high-speed Internet access, video on-demand and multiple telephone lines are on the list of must-haves.

Priming the demand is ClearWorks.net, Inc., a provider of voice, data and video services via fiber optic residential networks. ClearWorks, founded in Houston in 1998, is determined to solve the "last mile" problem by installing fiber-to-the-home and is offering high-speed digital connections to homeowners in the new developments. Homeowners are going for it in a big way.

Within two years of operation, ClearWorks had 60,000 homes in 15 developments under contract and had begun to expand their operations to other cities. "Consumers want the service," said John Diaz, ClearWorks president. "They're always calling us, asking 'Where are you going next?'" Diaz's biggest problem now is implementing the network construction, and his crews are working at breakneck speed to get fiber in the ground and into the walls of under-construction homes.

The vision

Michael T. McClere, ClearWorks' CEO, is a man with a vision. "Voice, video and data are all converging," he said. "We're starting to see telephone companies and cable TV companies becoming ISPs. We think we know where the market's headed, so we've elected to provide all services in a convergent model to our consumers." Thanks to the Telecommunications Act of 1996, deregulation of the industry has facilitated market entry for players like ClearWorks.

According to McClere, the idea was to devise a sole method for delivering dial tone, cable TV, high-speed Internet connectivity and other services. "We designed a fiber-to-the-home network to deliver all these services in a convergent model," he said. "That means we've got much less infrastructure to deal with because we're doing everything on one 100 percent fiber optics-based



system. We're running fiber up to and inside homes for the delivery of all services, unlike anybody else in the market right now. We're part telephone company, part ISP, part video rental store, part cable TV company — all rolled together."

One of the reasons ClearWorks chose fiber, McClere said, is that fiber has almost unlimited bandwidth. "We wanted to take advantage of that to deliver a multitude of services. We've heard a lot of industry talk — 'Oh, fiber-to-the-home is not a viable technology, it's too expensive, etc.' We don't believe any of that talk is true. We're delivering more than dial tone. When you start delivering cable TV, video on-demand and high-speed Internet connectivity, fiber becomes feasible very quickly. We think it's the only thing we can invest in that has a long-term return on our dollar."

ClearWorks has a massive task ahead — to rebuild the nation's infrastructure with fiber all the way to the home. The company's strategy for meeting this challenge is to go after new residential development that does not have any infrastructure built yet. "When we build the initial infrastructure as the community is built," McClere said, "we're putting in state-of-the-art technology, i.e., fiber-to-the-home. We're concentrating on that end of the market because that's where we can begin. What we're talking about doing is rebuilding the nation's infrastructure with a 100 percent fiber solution. That's pretty exciting, because the limiting factor in getting bandwidth to the consumer is that last mile of old copper infrastructure."

How do they do it?

ClearWorks is providing 100 Mbps switched service with up to six drops per home. John Diaz makes a point: "That's not shared service. It's 100 Meg for each home." This is particularly advantageous to homeowners who use the Internet at peak usage times. According to Diaz, heaviest usage occurs on Saturday at 11:30 a.m. With switched 100 Mbps service, consumers who have a "bandwidth hog" in the neighborhood don't have to wait while he downloads a movie.

The physical plant consists of Corning Cable Systems (formerly Siecor) optical cable, carrying Corning single-mode fiber. The wiring scheme calls for four fibers terminating in a box that functions as a node located inside the master bedroom closet of each home. Two of the fibers are dedicated to Internet use and one for both video and voice. The fourth fiber is held in reserve. From the box, copper wiring goes to data ports in each room: coax for TV, cat 5 for voice and data, cat 3 for the security system. The data ports have four outlets where homeowners can plug in their computers, telephones and TVs, and move them around from room to room as they wish. Connecting the home back to the ClearWorks distribution point is a 144-fiber count cable. The high fiber count, according to Diaz, is dictated by Internet use. "Of 72 fibers," he said, "70 are for the Internet." Typically, ClearWorks installs 1,500 homes per distribution point. For the homeowner, the cost is affordable, usually about $1,000, which is added to the price of the home and incorporated into the mortgage.

"One of the keys to our solution," McClere says, "is that we're using Internet technology for the deployment of all services." That makes it easy for consumers to use. By using Internet mechanisms to deliver video on-demand, for example, ClearWorks can provide the consumer at home a menu for selecting from a library of video titles.

Video on-demand is sometimes regarded as a demand driver of the future, but McClere feels the only thing preventing it now is bandwidth. "Right now, there's not very much bandwidth," he said. "Ninety-six percent of the

population is still behind a 56K modem, which is not very fast or user friendly. By providing a large amount of bandwidth, we can deliver real-time video-demand. There's a whole video distribution network set up already. The infrastructure already exists for supplying movies in digital format. With our use of Internet technology, you can launch any of these videos to your television."

New world

As ClearWorks gains new subscribers, they are introducing them to a whole new world, according to McClere. "Bandwidth really enables a lot of new services that you couldn't consume unless you had it," he said. "For example, videoconferencing from the desktop has been pretty limited because of bandwidth constraints. With a 56k modem, you don't get a very good signal. But with high bandwidth, we can real-time videoconference. That's going to be an enabler for telecommuting."

Builders and developers seem to be waking up to the fact that there is something new to consider about their communities: technology. Anticipating the need or desire for technology and building it right into the home is a priority in today's market, according to McClere. "Some builders out there are still developing on a 1940s standard for wiring and technology. They need to understand how technology integrates into what they do. I think it will continue to ripple through the entire industry and cause major changes. Gone are the days when you can fail to consider technology in the home."

Some builders are calling ClearWorks "fiber-to-the-home pioneers." Developers are seeing how high-bandwidth services are pumping up home sales. Johnnie Staggs, construction manager for Village Builders, is busy in the construction office trailer at the new 3,000-home Stone Gate development, located in Houston's suburban northwest sector. Stone Gate is another ClearWorks project. Staggs said, "They're smart homes. It's really where technology's going now — it's almost a necessity. People think it's a good value, and that's a selling point. They want media rooms and home offices. Many of our buyers have their own company and work out of the home."

Presently, Staggs reports that the builder is selling 15 new homes per month, with another two years of construction anticipated. ClearWorks residential wiring crews are on the scene, pulling fiber into the homes and wiring each room as construction progresses. They are in a hurry because they are responsible for providing fiber to the home, a feature that many new homeowners desire. In fact, in the glossy Stone Gate marketing brochure, fiber optic connectivity and high-capacity Internet access are advertised three pages before the on-site 18-hole golf course. ■



When Nathan and Pam Berlin started looking for a new house in the Houston suburbs, their search led them to North Pointe, a new development wired with optical fiber. The Berlins bought one of the first 300 homes to be occupied in the 3,000-home neighborhood, which includes homes ranging in price from $90,000-$350,000. For the Berlins, one of the convincing factors was the communications service. "We liked this deal," Nathan said. "Cable TV, Internet, telephone, security — all in one package."

The Berlins are customers of ClearWorks Communications, and they are enthusiastic about the 100 Mbps service that connects their home to the world. "We moved here from Waller, Texas, 20 miles away," Nathan said. "We had no Internet connection. We didn't even want a computer at home. Now we're on it all the time."

Nathan, a Fluor Daniel employee, likes to use the Internet to participate in stock chat lines and view his portfolio via an Ameritrade account. Ten-year-old daughter Ashley has not had much computer experience at school yet, but she has quickly learned to navigate the Internet to access video games and music. For Pam, the most impressive benefit of their fiber optic connection is the telephone service. "It's fabulous," she said. "Our phone bill alone used to be $100 a month, cable TV runs at least $40, plus another $35 for the security system — and an Internet provider on top of that. We get all that now for $139.99 per month."

Being among ClearWorks' early customers, the Berlins are on a first-name basis with ClearWorks employees. "They're really good about service," Pam said. "If we call Randy or Marsha — they can do a lot on the phone. They'll come right out if necessary. The service is right on the ball."

Nathan said, "We're shareholders, too. The neighbors really like ClearWorks, and most them have bought stock in the company." Pam and Nathan clearly enjoy being part of a small customer base. At the rate ClearWorks is expanding, that customer base will not be small for long. ■

George Wildeman // Product Line Manager // Corning Incorporated

Bring it on

Amplifying 40 Gbps Systems

Since the late 1990s there has been a steady stream of advances in wavelength-division multiplexing (WDM) technology in the drive for greater bandwidth. While 10 gigabits per second (Gbps) transmission rates are just starting to come online, 40 Gbps systems are expected to be introduced as early as next year.

Despite the seemingly imminent arrival of these ultra high-data-rate systems, there are a number of parameters that need to be managed to make 40 Gbps long-haul systems optimized and ready for the network. One of the key areas is amplification.

Early in development, it was clear that system noise figure was a big limitation for 40 Gbps networks. These networks were incapable of transmitting data across spans of more than about 40 km before needing signal regeneration. To make them economical, it was imperative that the standard 80 to 100 km hut spacings be maintained.

Corning scientists and engineers are researching Raman amplification, an effect which is distributed along the length of the transmission fiber, reducing the gain required of a line amplifier (EDFA). It also provides a dramatic improvement in the noise figure, allowing the signal to travel further along a network before regeneration is required.

About Raman

Raman amplification occurs when higher energy (shorter wavelength) pump photons scatter off the vibrational modes of a material's lattice matrix (optical phonons) and coherently add to lower energy (longer wavelength) signal photons. In distributed Raman amplification, the pump light is launched into the fiber at inline amplifier sites opposite to the signal direction. As such, Raman amplification acts as a low-noise preamplifier to maintain signal integrity. Also important, since the signal power is weak near the output end of the fiber, no additional fiber nonlinearities are incurred.

In many respects, the use of Raman amplifiers in terrestrial long-haul systems mirrors what is done today



in undersea networks. A trans-Atlantic system, for example, does not use regenerators. Instead, optical amplifier repeaters are spaced very closely together, about 35-40 km apart. In a terrestrial long-haul system, the Raman amplifier actually provides amplification in the middle of the span, mimicking the type of amplification that is done undersea. Several system OEMs will introduce Raman EDFA systems to substantially extend the reach of 10 Gbps long-haul systems.

Moving toward a 40 Gbps platform

Corning's world-leading expertise in optical fiber and amplifiers provides unique insight into the development of Raman amplifiers and their potential uses in long-haul networks. At the European Conference of Optical Communications (ECOC) in Germany this fall, Corning and Siemens AG demonstrated several new high-data-rate technologies by running eight 40 Gbps channels over 400 km of Corning® LEAF® optical fiber. The long-haul system demonstration incorporated four spans of 100 km of LEAF fiber with Raman amplifier modules and EDFAs on each span at four repeater sites. In the demonstration the signal was given an initial boost by an EDFA. It then traveled over four 100-km spans with Raman and EDFAs at repeater sites on each span. The Raman amplifier module combined the Raman pumps in the 1400 nm region of the window. It put the pump power out onto the transmission (LEAF) fiber in a counter-propagating direction. The signal, coming into the repeater site, was "pre-amplified" by the Raman gain as it was going down the transmission fiber. An EDFA then provided the booster power to go on to the next span.

The demonstration showed how Raman amplification can be used with LEAF fiber to lower overall network costs by reducing the requirements for electrical regeneration. It also demonstrated how backbone networks that include LEAF fiber are ready for 40 Gbps data rates.

Corning® PureGain™ 5000R Raman amplifier

Corning will begin manufacturing the PureGain 5000R Raman Amplifier with electronic controls by the end of 2000. The new Raman amplifier provides 10 dB Raman gain and optical output power up to 500 mW. It is also the first "intelligent" Raman amplifier on the market, as it includes a microprocessor-driven controller, which can actually detect fiber transmission type and set gain at a specified level. That feature allows network operators to "plug and play" the amplifier into today's gain-flattened, wideband WDM systems.

Raman amplification is not limited to 40 Gbps systems. Enhanced system margin can be applied wherever it is needed — in a single high-loss span, to extend span distances or to improve noise accumulation with the added loss of wavelength switching and routing elements. Within the inline repeater site, discrete Raman amplification can be applied to broaden the transmission bandwidth beyond that defined by erbium. In the end, Raman amplification provides system designers with several ways to lower the cost-per-bit of optical networks.

As carriers implement Raman-EDFA based 10 Gbps technology in their networks in the next year, system and component vendors will continue to unveil 40 Gbps products designed to take these networks to the next level. Raman amplification combined with EDFAs will also provide a solution for regenerating signals at 40 Gbps. Corning's world-class optical amplifier development team is building these next generation modules today. ■

Prashant Ukhade & John Knight of Corning Photonic Technologies were contributing writers for this article.

Answers to your questions

What are the best chemicals/materials/processes to clean fiber after stripping?

Corning sites use 90% isopropyl alcohol to clean the fiber once it has been stripped. The alcohol is quite effective in removing any coating or material that has been left behind, and it evaporates quickly to minimize any "down time." The alcohol is applied with a cotton mesh fabric, which is approximately 2-4 square inches, and is held between the thumb and forefinger. The fabric is swiped in one direction only, from the beginning of the stripped area to the end of the fiber. To avoid depositing any debris from the fabric back onto the bare fiber, the fiber is only swiped once, and each fabric is only used once as well. ■

We want to use Corning's single-mode fiber in the 1550 nm +/- 50 nm and need to know how the refractive index changes as a function of temperature and wavelength? Does the length change as a function of temperature?

The group refractive index for SMF-28™ fiber at 1550 is 1.4682. Empirical data indicates that the dependence of group refractive index on temperature is 0.000012 /°C. The refractive index varies slightly by wavelength as well, though not more than 0.0006 over the entire spectral range of 1300–1700 nm. The coefficient of thermal expansion for SMF-28 fiber is approximately 5.6×10^{-7} /°C. ■

Are optical fibers completely transparent to infrared light?

Optical fibers are manufactured primarily from very pure silica, which allows efficient transmission of light in the near IR region (700-1700 nm). Outside of this region, the silica tends to absorb too much light to make it a viable transmission media. Even in this range, however, there is some inherent absorption and scattering. Light propagation tends to be the most efficient at 1550 nm, where the effects of absorption and scattering are lowest. Optical systems can also operate effectively at wavelengths less than 1550 nm, but at reduced distances. ■

Do you have any information on the acrylate coating and how it performs with respect to temperature? For example, can the CPC6 coating be subjected to 135°C for an hour without incurring any damage?

Corning does not typically provide data on coating performance at temperatures greater than 85° C, because this is outside the specified operating temperature. Empirical data suggests that the CPC6 can survive an hour at 135° C, but there may be some noticeable effects, such as darkening and stiffening caused by the evaporation of some of the more volatile components. Keep in mind that the coating exists to protect the glass, and exposure to anything that could jeopardize the coating's ability to protect the glass carries with it a potential decrease in mechanical reliability. ■

What is the NA (to 1% power level) for SMF-28 fiber at 1550 nm? What is the NA (to 13.5% power level) for SMF-28 fiber at 1310 nm and 1550 nm?

NA is not a defined parameter for single-mode fibers, so there are no defined criteria for doing the test. However, in order to provide a characterization of the radiation pattern, tests are performed on single-mode fibers. The numerical aperture is not significantly wavelength dependent, so the value is considered the same at either 1310 or 1550 nm. Based on the angle defined by the 1% power level, the NA for SMF-28 fiber is 0.13. Note that the 1% level is somewhat arbitrary. We do not have a value for the 13.5% power level, though one could assume a Gaussian distribution to estimate the NA at other power levels. ■



Michael R. Vastag
Senior Applications Engineer
Corning Incorporated

OPTICAL FIBER QUESTIONS?

If you have technical questions about optical fiber that you would like answered by Mike in future issues of GuideLines, *please e-mail them to the Editor, Elizabeth Wright, at wrighte@corning.com*

News from Corning

Energy Communications Forum Held

On September 26-29, 2000, Corning Optical Fiber hosted the first Energy Communications Forum in Myrtle Beach, South Carolina. Geared toward executives and senior engineers in the utilities market, the objective of the forum was to attract key decision makers in energy communications. Additionally, this provided an excellent medium for networking among utility peers and updating the utility market on Corning's optical fiber, photonics and optical networking technologies.

One hundred seventeen people participated in the event, which kicked off on Tuesday, September 26, with a golf outing at Colonial Charters and an evening reception at Palmetto's Pavilion. Wednesday's sessions opened with remarks from Ed Cook, Market Manager, Utilities, Corning Optical Fiber. The keynote speaker, Corey Ford, Southern California Edison, set the tone for the next few days with his address on utilities working together as a community. Wendell Weeks, Corning Executive Vice President, Optical Communications, gave a presentation on "Building the Optical Layer" and Alan Eusden, Vice President and General Manager, Corning Optical Fiber, spoke on Corning product offerings and the evolution to an all-optical network.

Sessions continued on Thursday and during the mid-day luncheon, Bill Moroney of UTC and Ed Cook, presented the Leo Award to Tony Pini of NEESCom. This award was established to recognize energy communications network executives from electric utilities, pipeline, water and sewer for achievements beyond technology management and network deployment. Besides their leadership in telecommunications, winners of this award are selected for their high standards in citizenship, ethics and integrity. Corning will present the Leo Award at all future Energy Communications Forums.

With presentations on everything from "What's New in Fiber and Photonics Technology" to "Utilities Around the World," participants deemed the event highly successful. Evening events included a Blues Train concert and dinner at the House of Blues and a dinner in the reef tunnel of Ripley's Aquarium surrounded by 10-foot sharks. The event ended on Friday with the choice of touring Corning's Wilmington Plant, golfing at Myrtlewood, or exploring historic Georgetown. Corning looks forward to hosting another Energy Communications Forum within the next 18 months. ■

Corning Announces $50 Million Upgrade and Expansion of Deeside Facility

In late September, Corning announced its plans for a series of investments totaling $50 million to facilitate an expansion of its Deeside, North Wales, fiber manufacturing facility. When complete in 2002, the plant's fiber-making capacity will increase by over 50 percent.

Corning continues to increase its manufacturing capacity to keep pace with worldwide demand for its optical fiber products, while also allowing for new product development and commercialization. This announcement is in addition to the expansion plans released by Corning earlier this year impacting the company's Wilmington and Concord, North Carolina, and Victoria, Australia, fiber manufacturing facilities. ■

First Corning Premises Forum Held

The First Corning Premises Forum, held October 11-13, 2000, at the Holiday Inn SunSpree® Resort in Wrightsville Beach, North Carolina, was a resounding success for both Corning and forum participants. Fifty LAN consultants and system integrators attended this educational, fun-filled event, as well as industry experts, optical fiber equipment and cabler manufacturers and Corning engineers. Presentations covered such topics as fiber, cabling, electronics and network protocols and concluded with a lively round table discussion, allowing for in-depth questions and answers. In addition, attendees witnessed a live demonstration of next generation multimode optical fiber and toured the world's largest optical fiber manufacturing facility.

The forum, however, was not all work and no play. Participants dined on the Royal Winner Princess cruise ship and at the Oceanic, one of the area's finest restaurants. Guests also were treated to golf and golf lessons at Porter's Neck Plantation and Country Club, a championship golf course.

Corning's Premises marketing team is pleased with the forum's success and is looking forward to providing future forums. ■

Corning 2000/2001
Trade Show Appearances

SUPERNet 2001
Santa Clara, California
January 14 – 17, 2001
Booth #119

OFC 2001
Anaheim, California
March 17 – 22, 2001
Booth #2638

Telexpo 2001
Sao Paulo, Brazil
March 20 – 23, 2001
Booth #D18, White Pavilion

CeBit 2001
Hanover, Germany
March 22 – 28, 2001
Booth #D36, Hall 15



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guidelines

Keeping paths of communication open in a fiber optic world

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