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Whether stripping fibers or machining photonic chips, lasers are providing new methods to build fiber-optic components.

telecom's cutting EDGE

The telecommunications industry is facing tough times. Despite the profit warnings and large job losses, however, a central dilemma remains:

How does the industry pull itself out of the current gloom to meet the demands for increased bandwidth and large numbers of components? On a purely technical front, the answer may lie in improved production methods and the use of innovative laser manufacturing systems.

Modern telecommunications networks contain thousands of components that have to provide high degrees of functionality in often inaccessible environments, and they need to work faultlessly for many years. Meeting such stringent demands requires extremely high levels of manufacturing control to provide the necessary product functions while delivering high yields. Automated laser production tools are now not only meeting these criteria but also providing the scope to develop next-generation devices. The range of products that have benefited from laser processing include modulators, fiber Bragg gratings (FBGs), bulk waveguides, and MEMS structures.

In addition, the presence of optical fiber in virtually all photonic devices means that their machining demands cannot be neglected, either. Even though FBGs have received a lot of attention in the past few years in their role as dense-wavelength-division-multiplexing (DWDM) filters, pump stabilizers, dispersion compensators, and gain flatteners, the vast majority of fiber deployed in networks is non-FBG fiber. Hence, laser processing solutions to fiber preparation tasks such as cutting, buffer stripping, cleaving, and machining offer an enormous benefit to the telecommunications industry.

better, cleaner stripping

Every telecommunications network device has to interface with an optical fiber at some stage. This means that lengths of optical fiber have to be cut, their outer protective layer removed, and the ends of the fiber cleaved at some specific angle to allow the core of the fiber to be interfaced with another structure. Although the cutting of fibers to set lengths using mechanical tools is quick and simple, the buffer layer stripping and cleaving operations are more time consuming and require some degree of operator skill. In the case of the buffer stripping, the two most commonly used methods of chemical/thermo-chemical stripping or acid stripping both suffer from associated environmental and safety issues. Manufacturers would benefit from removing wet processing steps—especially those involving hot acids—from production lines. Whichever stripping method is used, however, has to leave the fiber clean and undamaged.

Various laser routes for buffer stripping have been developed over the past few years using infrared and UV lasers. Laser stripping is attractive because it is a single-stage dry process, it can strip ends or windows in fibers, and it produces clean, debris-free fibers whose tensile strength has not been degraded. Carbon-dioxide, solid-state, and excimer lasers have all been successfully used for buffer stripping (see figure 1 on page 24). The choice of which laser to use is largely determined by the specific application. For example, the presence of photosensitive fiber may prohibit the use of UV lasers, or an inappropriate buffer layer material may limit the choice of laser types. Other factors affect the choice of laser type; for example, the cost of ownership of excimer lasers is higher than that of solid-state or CO₂ lasers.

The use of high-repetition-rate CO₂ or solid-state lasers is becoming increasingly attractive for buffer stripping because it is conducive to very rapid and efficient processing. Properly designed optical systems can control focal spot sizes and beam shapes to optimize strip speed. Ribbon fibers also can be stripped by using a line focus beam, for example, and moving the entire ribbon assembly under the beam. Typical processing rates for acrylate buffer layers can be hundreds of microns per second, and the cleanliness and reproducibility of such processing means that preprogrammed lengths of fiber can be stripped with guaranteed results.

It seems clear that laser preparation of fibers is set to become an increasingly important factor in the automated manufacturing of telecommunications devices, given that it offers a simple, clean method of achieving high quality and consistent results.

the future in chips

Certain developments in the photonics field are mirroring what happened to the microelectronics sector in the 1970s, and the parallels are striking—just as in the case of integrated electronic circuits (ICs), there is now a big drive to make photonics components smaller and pack them densely onto single chips. The immense increase in speed and functionality that occurred for ICs is sure to be replicated in photonics devices as miniaturization and integration become more advanced. Part of these developments are being made possible by new laser machining methods allowing on-chip processing and the ability to manufacture structures in a variety of materials that were otherwise difficult to machine.

As in the case of ICs, photonic chips—often called planar lightwave circuits (PLCs)—use a silicon wafer substrate that is then populated with devices performing different functions. These devices can include items such as waveguides, transmitters, receivers, modulators, MEMS structures, filters, attenuators, and amplifiers. The benefits of on-chip integration are obvious in terms of speed, efficiency, and size, but the approach also allows the manufacturing of such chips to be more automated and therefore more economically competitive. Materials commonly used in PLCs include silicon, silica, polymers, silicon oxinitride, lithium niobate, indium phosphide, and glass. Lasers machine all of these materials.

Silicon is part of an extremely mature semiconductor industry, but the processing options are still relatively limited when it comes to machining particular shapes and geometries. Laser micromachining does not suffer from this limitation. The need to dice a larger wafer into individual PLCs is obvious, but manufacturing also may require the production of other structures such as holes, slots, grooves, or recessed areas for the positioning of other devices. All of this microstructuring has to be achieved with high quality and lack of debris. Lasers can meet these requirements.

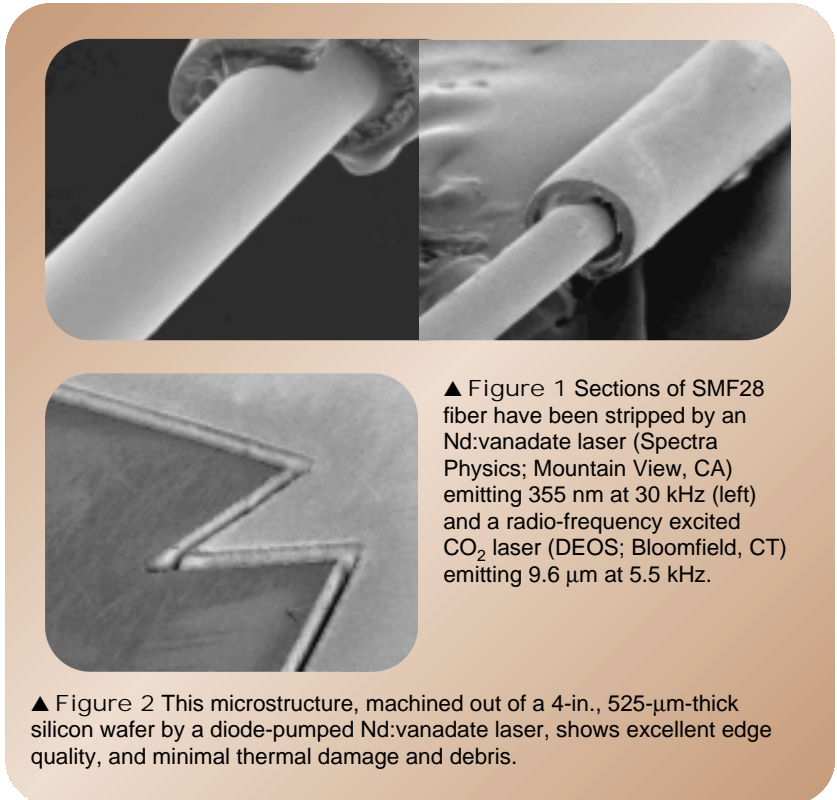
Solid-state lasers can machine cuts in silicon wafers as thick as 525 μm, producing structures with excellent edge quality, minimal thermal damage, and minimal debris (see figure 2). For

example, using a 15-μm focal spot and about 5 W of output power at 30 kHz, a laser can achieve a cutting rate of about 0.2 mm/s for the example shown in figure 2, though far higher speeds are possible depending on the type of cut being produced and the level of quality required. In this example, no post-machining cleaning was performed. Even if debris is an issue, the use of sacrificial layers can provide simple protection for on-chip components.

The direct machining of silica, in particular, has always been very difficult. With the advent of commercially available fluorine-gas lasers and femtosecond solid-state lasers, however, very-high-quality machining of silica is now possible. Since most fibers and waveguides are made from silica, this has been an important development.

Another benefit of laser machining is that even after devices have been fabricated, lasers can be used to tune or trim their performance. Excimer lasers can tune modulator characteristics, for example, and fluorine-gas lasers can trim the transmission of optical waveguides.

The range of options offered by laser techniques in photonics manufacturing is expanding rapidly. These advances are set to change the way that telecommunications devices are



▲ Figure 1 Sections of SMF28 fiber have been stripped by an Nd:vanadate laser (Spectra Physics; Mountain View, CA) emitting 355 nm at 30 kHz (left) and a radio-frequency excited CO₂ laser (DEOS; Bloomfield, CT) emitting 9.6 μm at 5.5 kHz.

▲ Figure 2 This microstructure, machined out of a 4-in., 525-μm-thick silicon wafer by a diode-pumped Nd:vanadate laser, shows excellent edge quality, and minimal thermal damage and debris.

produced by offering greater automation and a far wider technical scope for new generations of products. Although a method using a single laser source is unlikely, the combination of two or three lasers to encompass the majority of fabrication tasks is probably the most likely scenario. Lasers may again prove to be the way forward. **oe**

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