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No, Not That One —
Imaging Systems And The ‘Other’ Fiber Optics

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Well known as an enabling technology of telecommunications, fiber optics is also playing a pivotal role in imaging. This paper takes a closer look at the "other" fiber optics, illuminating the special qualities that make it the best solution for some of imaging's most challenging problems and environments.

It would be hard to overstate the seismic role fiber optics technology has played in enabling the Internet Age. After all, fused silica fiber bundles are the medium of choice for carrying signals, data, and information over today's omnipresent telecommunications, cable, and Internet networks.

But what if I told you fiber optics can play, and is playing, an equally pivotal role in imaging? That the same light-transmitting capabilities responsible for moving an optical signal seamlessly along miles of cable can deftly bring an image — a pristine one at that — around a corner, out of a tight space, or away from a hot, dark, or otherwise challenging place?

From the dentist's office to the battlefield, from the hospital emergency room to the cockpit, the fiber optic bundle — born out of Cold War spy craft and ground-breaking science — is an enabling technology for some of today's most innovative imaging systems. Ironically, that will come as news to most optical engineers.

What silica is to fiber optics in telecommunications, optical glass is to fiber optics in imaging. Understanding the advantages and unique characteristics of this 'other fiber optics' technology can help ensure the smooth and successful development of your next optical system.

A 'NEW' SOLUTION 70 YEARS IN THE MAKING

Before fiber optics became a staple of telecommunications networks, it was whiteboarded to transmit images — namely, secret code. In fact, flexible fiber optics was invented to scramble and unscramble images as a kind of cipher key, for the U.S. military back in the 1950s. While this particular approach to sending and receiving sensitive information never flourished — it turned out to be too easy to decode — the technologies that enabled it did grow.

Thanks to the efforts of optics pioneer Dr. Brian O'Brien and others, research into transmitting light more efficiently yielded a number of breakthroughs. Leveraging Snell's Law, which describes the angles of incidence and refraction of light as it passes through air, glass or water, and the theory of “total internal reflection,” O’Brien made a discovery.

By adding low-index-of-refraction clad glass to the outside of high-index of refraction core glass, O’Brien unlocked the medium’s ability to move light effectively over long distances. Later, using high quality optical glasses, he and co-collaborator Will Hicks formulated the first wound fiber bundles (WFBs), finding that individual glass fibers grouped together in an ordered, coherent way could effectively transfer an image from one end of a fiber bundle to the other over short distances.

To this day, these advances forged in the 1950s remain the building blocks of today’s fiber optics technology successes and new applications.

GETTING THE PICTURE: THE STARRING ROLES OF FLEXIBLE AND FUSED FIBER

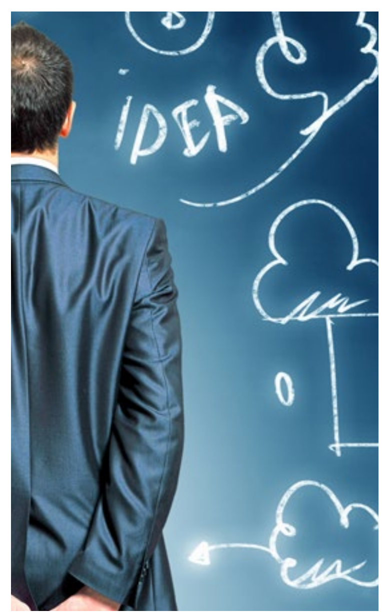
Fiber optics for imaging fall into two distinct camps: flexible fiber optics and fused fiber optics. The first is, well, flexible — think of cooked spaghetti. This malleability comes in handy when the sought after image lies around a corner or inside the human body. Medical endoscopy, for example, relies on flexible fiber optics, where it remains a mainstay.

On the other hand, fused fiber bundles are rigid and built to withstand extreme conditions. Think of optical systems that monitor the performance of large engines or furnaces, or others that can protect imaging components from the effects of X-rays.

What both fiber optic types share, however, are the inherent — and unique — characteristics of glass fiber that make them just right for a wide array of practical imaging solutions. Optical glass fiber optics are first and foremost:

1. **Non-metallic and non-magnetic.**
2. **Passive (non-electric).**
3. And provide a **zero-thickness window** effect.

Let’s examine each of these qualities in the context of current-use cases.



Medical Imaging

Magnetic resonance imaging (MRI) scanning systems rely on the interplay between a powerful magnetic field, radio waves, and a computer to produce detailed pictures of the inside of the human body non-invasively. For anyone who has had an MRI, you’ll recall having to remove any metal from your person — jewelry perhaps — so as not to interfere with the functioning of the machine.

The same even applies to the imaging system that drives it. All metal off! Anything magnetic in the system would get sucked into the coil. Also, no electronics allowed. Anything other than a "passive" imaging system would create "noise" in the coil, interfering with the MRI's performance.

So where to turn? A wound or leached fiber bundle is comprised of glass and can be made with plastic end tips and plastic sheathing. No metal, no electronics, and no sacrifice of image quality — a clean sweep for fiber optics in MRI.

Passive Imaging Systems For Military And Commercial Use

A growing niche for fiber optics technology can be found in military and commercial adoption of passive imaging systems. This case addresses an emerging need spawned by a reliance — some might argue overreliance — on high-tech electronics. As so many systems go digital, their dependence on power has grown. But what happens in an emergency? What happens when the lights go out, or worse?

The U.S. military has taken a closer look at this problem in its tanks and armored vehicles, and found an ally in fiber optics. Today if a tank or armored vehicle takes a hit to its electrical system, it would be highly vulnerable. In response, the U.S. military is using fiber optics to provide an auxiliary site for the tank's main gun and ancillary ports around the vehicle for situational awareness. By utilizing a flexible fiber optic image cable, the images can be transmitted passively with no thermal signature. In addition, the dielectric nature of glass fiber optics makes it impossible to remotely detect a signal being transmitted within the bundle. Our U.S. Navy is also using our flexible fiber optic bundles to monitor the engines in a new fleet of ships.

These uses highlight another distinguishing feature of fiber optics: a "zero-thickness window." Think of this as the delivery of any image plane directly from one end of a fiber bundle to the other, giving the viewer **a direct 1:1 representation of that image**. With fiber optics, the user gains this zero-thickness window feature without adding any light and without requiring any camera or lenses.

This 1:1 delivery of an image from anywhere in object space directly to the viewer without requiring anything "extra" is optimal for this tank and armored car scenario, and anywhere where the external environment poses risk to the viewer or the performance of the imaging system.

These passive systems are also helping the private jet industry meet new FAA regulations. Private jets now require visibility from the entry door to the outside world in case of on-board emergencies and off-airport landings. New fiber-based passive imaging systems provide that visibility whether the planes have power or not, and their flexibility makes them easy to install.

This flexibility provides additional benefits. What do these plane, tank, and other vehicle scenarios have in common? Movement, pressure, jostling. These factors are the enemy of traditional lens configurations, which need to be held in alignment to hold focus. Flexible fiber on the other hand is like a flexible joint in optics. Jostle away.

A TIME FOR RIGIDITY: A NOTE ON FUSED FIBER OPTICS

Fiber-driven imaging innovations are not limited to flexible fiber. New solutions using fused-fiber optics, which “bake” individual 10 micron, or smaller, fibers together into a “loaf” that can withstand extreme heat and have high vacuum integrity, are growing in popularity. Fused-fiber optics are used to make an array of tapers and faceplates, which can transmit a magnified or reduced image from an input surface to the output surface, especially in extreme conditions. For instance, these same fused-fiber optics are an enabling technology for night vision goggles and systems used by militaries around the world.

Closer to home, these fused-fiber optic faceplates are making dental X-rays faster, safer, and more accurate, providing the compact form factor needed to fit in the mouth comfortably and the protection needed to shield the pixels on the imaging system’s light-sensitive processing chip (CCD or CMOS) from the damaging effects of X-rays thus reducing the signal to noise and improving image quality.

NO LONGER A ‘LAST RESORT’

Application by application, fiber optics is making inroads across vertical markets as an enabler of imaging system excellence. Endowed with flexibility, a zero-thickness window, the ability to withstand extreme conditions, and the ability to be metal-, magnetic- and electrical-free, the potential of this versatile imaging technology merits consideration at the start of the imaging-design process, not only being called upon as a last resort.

A lot like the touring band that has built a cult following through years of relentless gigging only to be “discovered” and touted as an overnight success, fiber optics has paid its dues in imaging, won its converts, and grown along the way. So, too, have the optical engineers who have learned fiber optics isn’t just for telco anymore.

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