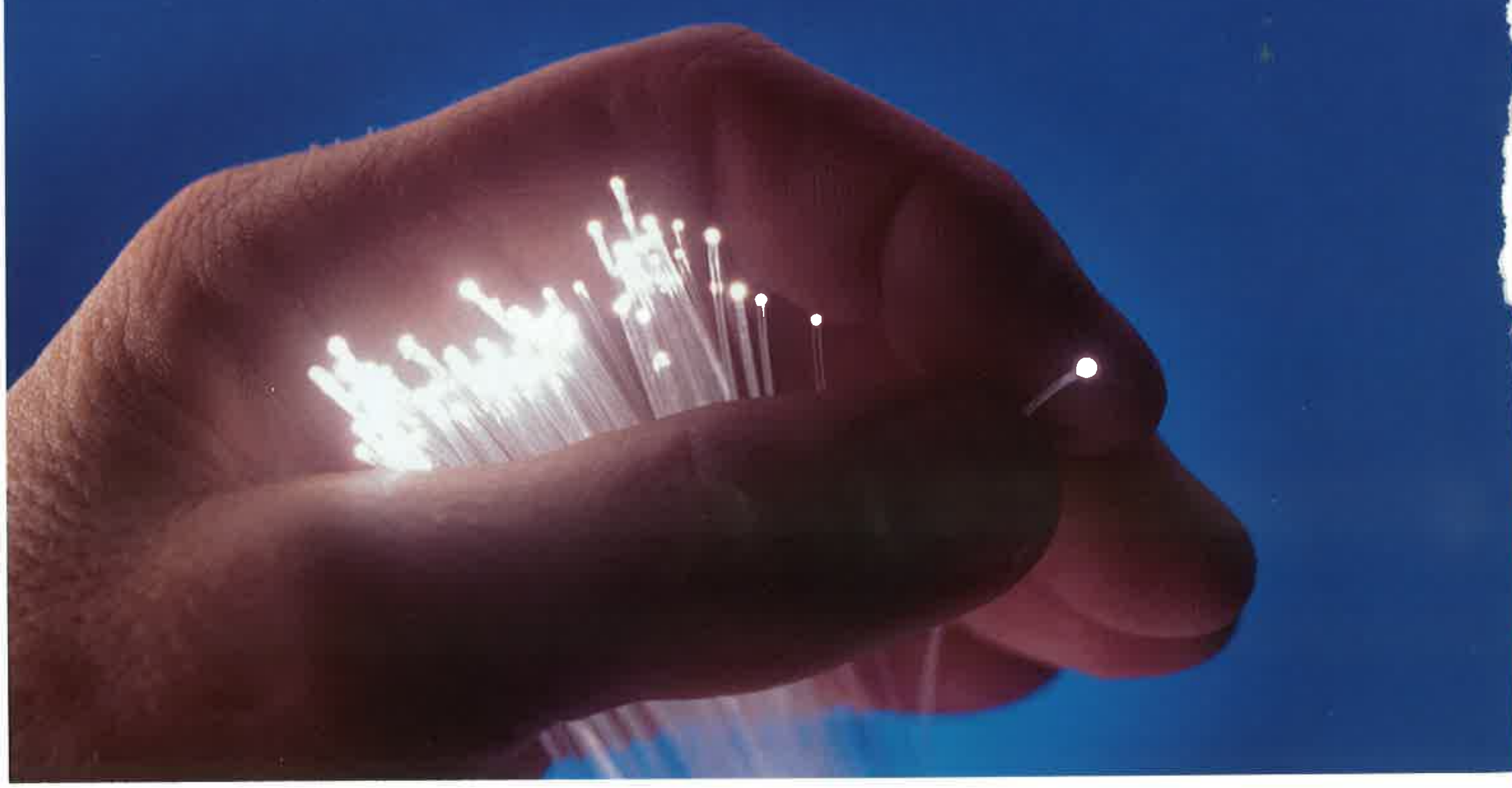
FIBER OPTICS FOR IFE –

PART 1: THE BASICS

By Rich Salter

We've all heard about fiber optics being used in telephone systems, cable TV, and computer networks for quite some time, and fiber is used extensively in military aircraft. However, commercial airline applications have been slower to roll-out, and many of us in IFE don't know much about it other than it's also used in those trick fiber optic table-top lamps and party wands that the kids like to swirl around!

Therefore, this article will address the what, when, why and how of fiber optics in language that IFErs can understand. Part 1 explains the basics of fiber optics, and Part 2 (next issue) will address the aircraft-specific aspects that we are concerned about for IFE.



WHY FIBER VS. COPPER WIRE?

FIBER OPTICS USES LIGHT TO SEND INFORMATION (data) at greater data rates over longer distances at less cost than copper wire systems.

Fiber optic cable can transport all types of data (discrete, analog, digital, RF, etc.) on a strand of glass as thin as a human hair, although after all the various protective layers are wrapped around the glass core, the fiber cable is often as thick as a copper cable (typically 0.1 to 0.5 inches depending on the numbers of fibers in the cable).

Fiber cable can carry much more data (has higher bandwidth) than an equivalent amount of copper wiring (twisted pairs or coax) – more than 1000 times more data. Thus, for an IFE system using fiber it is possible to eliminate a lot of copper wires and put the data on a single fiber. This elimination of copper wiring results in reduced weight, and less weight results in reduced fuel burn (cost) to carry the fiber-based system onboard.

Table 1: Benefits of Fiber Optics

Higher bandwidth	Lower cost
Lighter weight	Higher reliability
Less power	Future–proofing
No EMI/RFI	

Fewer wires means fewer connections means higher reliability, and the use of light rather than electricity means that there is no EMI/RFI problems with fiber cable (i.e., no electromagnetic emissions to interfere with navigation systems or other IFE systems). However, perhaps the biggest advantage of fiber to our business (airlines) comes back to its huge bandwidth capacity: it can "future-proof" the aircraft installation. This means that fiber has ample bandwidth to accommodate data growth that will be needed by currently unforeseen features / functions as they become available in the future – no more re-wiring the airplane to add a new system!

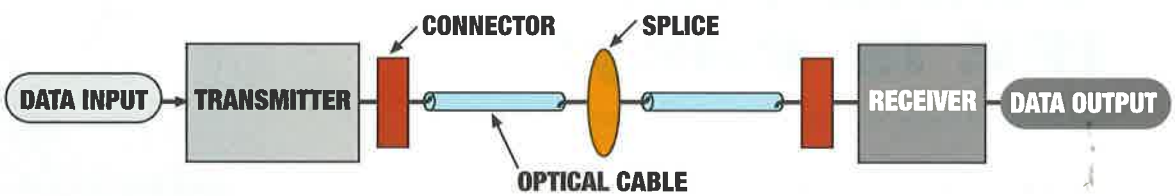


Figure 1: Basic fiber optic data link

HOW DOES A FIBER OPTIC LINK WORK?

A fiber optic data link sends input data through fiber optic components and provides this data as output information. It accomplishes the following three basic functions (see Figure 1):

- Converts an electrical input signal to an optical signal - **transmitter**
- Transports the optical signal over an **optical fiber**
- Converts the optical signal back to an electrical signal - **receiver**

The **transmitter** consists of an interface circuit (to condition the electrical signal) and a source drive circuit (to convert the electrical signal to an optical signal (light)). It does this "E-to-O" conversion by varying the current flow through a light source (i.e., a light-emitting diode (LED) or laser diode), and the light source then launches the optical signal into the fiber.

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The **receiver** converts the optical signal exiting the fiber back into an electrical signal using an optical detector (a semiconductor positive-intrinsic-negative (PIN) diode or an avalanche photodiode (APD)) and signal-conditioning circuits, so that the receiver electrical output exactly matches the original input to the transmitter.

We usually need to have data flow in both directions on the fiber, and so the transmitter and receiver are packaged together at each end, and this is known as a **transceiver**.

Of course, Figure 1 is a simplified view, and an actual fiber optic data link may include more active components (e.g., optical amplifiers) and passive components that can affect the performance (e.g., fiber connectors, splices, and couplers/splitters). More about splices and connectors in the next issue, when we talk about the aircraft-specific aspects of fiber optics. Now, let's look at the fiber itself and how the light travels through it.

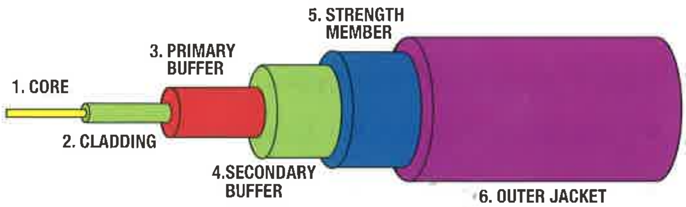

Figure 2: Structure of Fiber Optic Cable for Aircraft Use

WHAT DOES FIBER OPTIC CABLE LOOK LIKE?

An optical fiber cable for aircraft use consists of six parts (layers). See Figure 2.

The **core** is a thin strand of very pure glass where the light travels, with a diameter of 62.5 microns (millionths of a meter) for multi-mode fiber (MMF) and 9.0 microns for single-mode fiber (SMF) - more about modes later. For comparison, a human hair has a thickness of 50-75 microns. The core is surrounded by another layer of glass (that reflects the light back into the core) called the **cladding**, with a diameter of 125 microns. The primary and secondary **buffer** are made of plastics and protect the glass from moisture and abrasions. The **strength member** is made of aramid yarn (e.g., Kevlar), steel strands, or fiberglass filaments that increase the tensile (pulling) strength of the cable. And the outer **jacket** provides for mechanical protection, sealing at the connector, and cable marking, and it is always purple in color.

Table 2: Fiber optic cable construction

Layer	MMF Diameter	SMF Diameter	Material
Core	62.5 microns	9.0 microns	Glass
Cladding	125.0 microns	125.0 microns	Glass
Primary buffer			Plastic
Secondary buffer	0.9 mm	0.9 mm	Plastic
Strength member			Kevlar, other
Outer jacket	1.8 mm	1.8 mm	Plastic

HOW LIGHT MOVES THROUGH FIBER

The glass used in the core and the cladding differ in their **index of refraction**, which means that the cladding is similar to a mirror surrounding the core. The light is "guided" down the core, essentially being trapped in the core by the cladding using an optical technique called **total internal reflection**. Since the cladding does not absorb any light from the core, the light wave can travel great distances.

There are two types of optical fibers, and both are 125 microns in diameter (core + cladding), but they have different core diameters. **Multi-mode fiber** (MMF) has a larger core (62.5 microns) and transmits infrared light (wavelength = 850 to 1,300 nanometers) from light-emitting diodes

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About the author: Rich Salter is a well-respected consultant in IFE. In 2003 he also co-founded a new company named Lumexis Corporation to develop and market fiber optic networks for aerospace applications. The name "Lumexis" was derived from the Greek root "Lum" which means "light" and "exis" which is from the speed prefix "exa" meaning 10 to the 18th. Other principles in Lumexis are Doug Cline (former CEO of Sony Trans Com) and Dr. Greg Petrisor (an expert in optics previously with Raytheon).

(LEDs). **Single-mode fiber** (SMF) has a smaller core (9 microns) and transmits infrared laser light (wavelength = 1,300 to 1,550 nm). Light moves differently through single-mode and multi-mode fibers, as shown in Figure 3.

In MMF, since the core diameter is larger, there are many modes (rays or wave fronts) traveling at angles through the core, and these many wave fronts travel different path lengths due to their angles and reflections, thus arriving at the receiver at many different times, resulting in dispersion (overlapping or "blurring") of the received signal. This dispersion limits the receiver's ability to resolve faster data rates – i.e., limits the bandwidth.

In SMF, the core is smaller and supports only one single mode (ray) of propagation, so that a single, distinct light wave arrives at the receiver. This eliminates any distortion that could result from overlapping light pulses, providing the least signal attenuation and the highest transmission speeds of any fiber cable type.

The 1550nm wavelength of light used in SMF is a frequency of 193.1 THz (a TerraHertz is 1000 GigaHertz), and the ability to resolve the received signal very precisely allows the use of many wavelengths (channels) around 1550nm. These channels can be spaced at intervals of 200 GHz, 100 GHz, 50GHz, etc. For example, a channel spacing of 100 GHz allows a single SMF to carry 45 channels of optical signals.

This multiplexing of multiple wavelengths (colors) of light to create many channels on a single fiber is called Wavelength Division Multiplexing (WDM). Spacing the channels closer together with spacings of 200GHz, 100 GHz, 50 GHz, etc. is known as Dense Wave Division Multiplexing (DWDM). It is this ability to multiplex and resolve so many wavelengths that gives SMF its tremendous bandwidth that is continually increasing as opto-electronics improve every year.

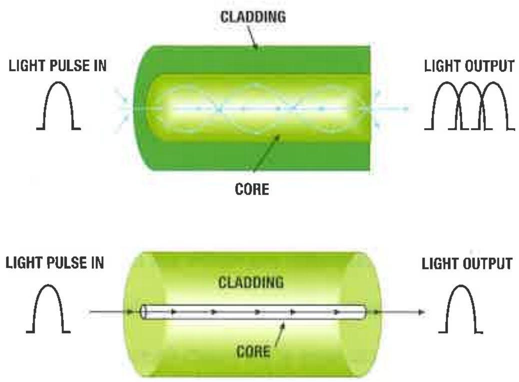

Figure 3: Multi-Mode Fiber (MMF) top and Single-Mode Fiber (SMF) bottom

WHEN WILL FIBER BE USED IN IFE?

Fiber optics has already seen limited use in IFE. Several IFE systems use fiber networks in the headend between disk storage arrays and servers. Plus, in the cockpit avionics area, Boeing's B777 has had an avionics local area network flying since the mid-1990s.

Perhaps the most notable use of fiber optics in IFE systems beyond the headend has been in Sony Trans Com's P@ssport system. This system, put into first use by airlines in 1999, uses fiber optic backbone from headend to the zone boxes. Since that time, three major airlines have been flying the Passport system on 27 widebody aircraft all around the world without a single failure of the fiber portion of the P@ssport system.

Now, fiber is taking another step into the cabin via the "3GCN" guidelines. 3GCN means **Third Generation Cabin Network**, and it was an effort started by the WAEA Technology Committee in April 2001 and concluding in May 2003. Now, those guidelines are being reviewed and refined by the Arinc CEI subcommittee for inclusion in gray cover characteristics. In this guideline that will be used for future aircraft including the A380 and B7E7, fiber optics cables are specified for the cabin network backbone (from headend to area distribution boxes).

In the near future, IFE systems may be developed by suppliers that use fiber optics cabling from the head end all the way to the floor disconnect box or even to the seat itself.

IN THE NEXT ISSUE

Now that we have covered the basics of how fiber optics work, we will tackle the specific issues that are critical for its use in aircraft for IFE: aircraft connectors, splicing, bend radius, and many more in AVION's next issue.