FIBER OPTICS FOR IFE –

PART 2: AIRCRAFT INSTALLATION

By Rich Salter

Welcome back for Part 2 of the primer on fiber optics. In the last issue, Part 1 explained the basics of fiber optics, and now we will get into the nuts and bolts of installing it on aircraft: connectors, special cleaning/inspecting, splicing, and mechanical issues. As we know, the "devil's in the details" so lets focus on them!

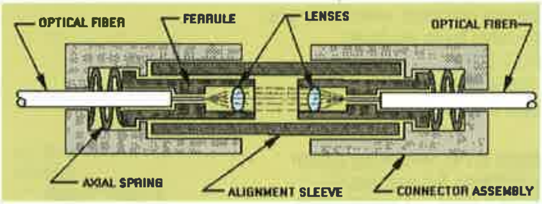


Figure 1: Diagram of expanded beam concept (courtesy of Integrated Publishing http://www.tpub.com/neets/tm/108-9.htm)

OPTICAL CONNECTORS

Fiber optics in the cabin have been talked about for many years, but the optical connectors previously available were from the telecoms business—not compatible with the military circular and Arinc rectangular connectors we use in airborne avionics. Today, tremendous advances over the past five years have resulted in termini (contacts) and inserts for mil circular and Arinc 600 rectangular connectors that allow optical fiber to use similar (and in some cases share the same) connectors as copper and coax in airborne installations.

However, the requirements for a fiber optic connection and a copper wire connection are very different. Whereas two copper conductors can be joined by solder or connectors that have been crimped or soldered to the wires, a fiber optic connection requires precise alignment of the two fiber cores so that all the light is coupled across the junction from one fiber to the other.

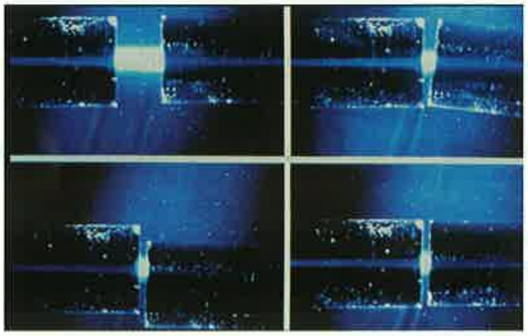
There are two basic types of avionics connectors for fiber optics: physical contact (butt joint) and expanded beam (air gap). Physical contact (PC), as the name implies, mates two fibers by aligning and positioning their end faces together such that they are physically touching. Expanded beam (EB) uses small lenses at the ends of the fibers to expand the light in a small air gap and then re-focus it on the other side (i.e., the two fibers do not physically touch each other).

You will recall that the fiber core is extremely small (about as thick as a human hair), and the job of the connector is to line up two fibers precisely so that the light shines straight through the connection (any misalignment results in loss of light power). The expanding of the light in the EB connector has the effect of enlarging the surface area of the fiber by hundreds of times; therefore, it is not as sensitive to misalignment or small specks of dust that might otherwise block the thin beam of light. By comparison, the PC connector must be precisely aligned or problems will result as shown in Figure 2. Physical contact connectors have insertion loss in the range of 0.1 to 0.3 dB, while expanded beam connectors typically have losses from 0.3 to 0.7dB.

Figure 2: Magnified photos of optical fibers showing light-loss mechanisms in a physical contact (PC) connector:

1. Upper left: End Gap problem
2. Upper right: Angular Misalignment
3. Lower left: Lateral Misalignment
4. Lower right: Core/Clad Concentricity issues

Photos courtesy of Tyco Electronics



Now let's look at the parts of optical contacts (termini) and the connectors into which they fit for aircraft installations. Since the fiber strand is so small, it is necessary to affix (i.e., glue) the fiber into a terminus so that it can be easily handled and inserted into a connector. The two main types of termini are LuxCis and Elio.

As can be seen in Figure 3, both termini include a ferrule, spring, housing, and a boot or crimp tube to connect to the cable surrounding the fiber strand. Note that the ferrule is a small, ceramic alignment tube attached to the end of the fiber, used to hold the fiber and provide alignment.

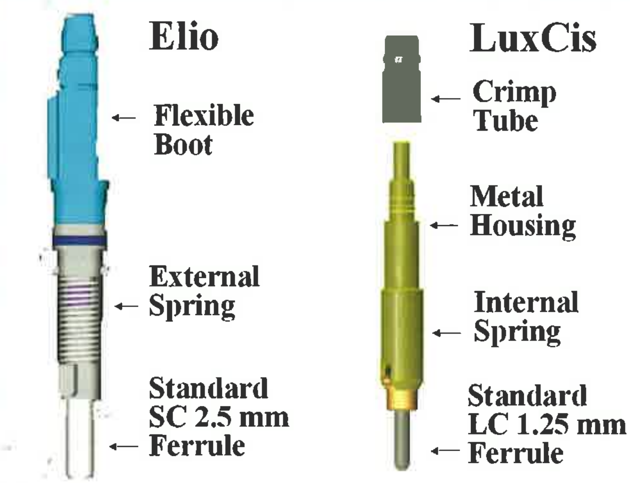


Figure 3: Elio and LuxCis termini (note the difference in Ferrule diameters)

Both of these termini can be inserted into circular and rectangular connectors similar to those used on aircraft for copper and coaxial wiring. Figure 4 shows the Elio terminus that is used in the Souriau connectors used by Airbus on the A380, and Figure 5 shows the LuxCis terminus used in the Radiall/Tyco connectors selected by Boeing for the B7E7.

Figure 4: Elio termini, Mil-DTL-38999 circular connector, and Arinc 600 connector

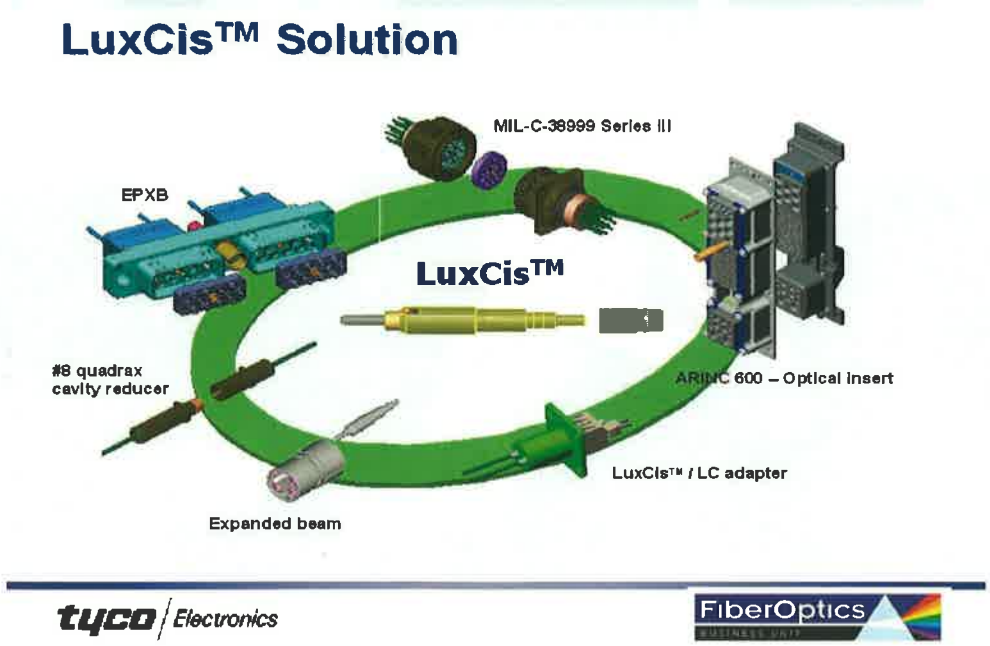


Figure 5: LuxCis terminus (from Radiall/Tyco) and its insertion into mil circular, Arinc 600, expanded beam, and EPX (general purpose rectangular) connectors

continued on page 26

FIELD HANDLING OF FIBER CABLING

To be sure, fiber optic cabling must be cared for in the field much differently than copper cables. Here are three operations that require special handling and tools:

1. Mating and de-mating connectors

Every time a fiber connector is de-mated (disconnected), the fiber end-face must be inspected and cleaned (if inspection shows it is dirty) before re-connecting. Inspecting and cleaning fibers requires special tools including:

- Cleaning fluid and lint-free wipes [swabs for expanded beam (EB) connector]
- Polishing tool if inspection reveals a scratched physical contact (PC) terminus
- 10x eye loupe for EB connector
- 200x and 400x microscope for PC termini
- Or a video test unit with camera probe and video display (if fiber contact is to be inspected while inserted in connector)

Figure 6: Expanded Beam (EB) connector lenses can be cleaned with a lint-free swab (left photo) and inspected with a 10x eye loupe (right photo).

Figure 7: Each time a Physical Contact (PC) fiber connector is de-mated (disconnected), the PC terminus must be inspected and cleaned (if necessary) with a lint-free wipe (left photo) and re-inspected with a hand-held 200–400x microscope (center photo) or video camera scope (see Figure 8).

Figure 8: Field test tools can include a camera probe and video display (black test unit) that provides the ability to clip onto a PC terminus while still in the connector (right photo). The blue box in the middle of the left photo is a box of lint-free cleaning wipes, and the white and blue unit in the right photo is a calibrated light source. These tools are supplied by Noyce as well as others.

continued on page 28

If the surface appears to be scratched or chipped, then polishing is necessary before repeating the inspection and cleaning steps. Polishing a PC terminus is accomplished by inserting the contact into a "polishing puck" and lightly stroking it in a round figure-8 pattern on polishing paper.

2. Testing for continuity/integrity

With copper wiring, the technician can connect probes of an ohmmeter at both ends of a wire and "ohm it out" to test for low impedance continuity. For optical cables, a calibrated light source and light receiver are needed. Light source products are available in small packages as shown in Figures 8 and 9. Optical time domain reflectometers (OTDRs) are available to automate the detection of defects (broken fibers, bad splices, connector misalignments, etc.) in the glass along the length of the fiber cable.

Figure 9: Handheld fiber cable test units are available from many test equipment suppliers, such as these units from Fluke used to measure optical loss per unit length and locations of defects in the glass fiber.

3. Splicing

If a fiber cable is damaged or broken and needs to be repaired (i.e., the two fibers need to be spliced back together), there are specific procedures that must be followed to insure that an effective optical splice is achieved. Depending on where the splice is performed, different techniques are used. For example, in the aircraft factory, a fusion splicer may be available, whereas in the field a mechanical splice procedure and tool kit will be used.

There are two procedures and splice kits for line maintenance repair: 1) for mechanical splicing using UV adhesive index matching gel, and 2) for mechanical splicing using a crimp. To give an overview of the procedure, here is a summary of the steps for mechanical splicing using the UV adhesive:

- Clean your hands and work area (cleanliness is critical).
- Observe safety precautions (wear safety glasses when handling bare fibers or dispensing UV adhesive, do not touch razor sharp ends of fiber, avoid skin contact with UV adhesives, and do not stare into end of fiber until verifying that it is not connected to a light source).
- Prepare the cable and fiber (cut away damaged section, slide on heat shrink tubing, remove 3 inches of the fiber optic outer cable jacket, remove 2 inches of the buffer and coatings). Repeat for the other end of the cable/fiber.
- Cleave the fibers (use a cleave tool with a scribe blade, fiber clamp, and alignment tool to score and then cleanly break the two glass fibers).
- Install the UV adhesive and cleaved fiber ends into the mechanical splice (mount the first fiber into a splice holder fixture, fill the splice sleeve with UV adhesive using a syringe, slide the splice sleeve onto the first fiber in the splice fixture, then slide the second fiber into the other end of the splice sleeve so that it contacts the first fiber).
- Use the hand-held UV lamp to cure the adhesive for 4 minutes.
- Center the heat shrink tubing over the spice sleeve and shrink it down with a heat gun.

As you can see, optical splicing is very different from splicing electrical wires. However, it is not complicated; rather, it is a well-defined series of simple steps. With a little practice and given the proper tools, it is easily accomplished in about 10 minutes.

There are other fiber assembly and repair operations that require special tools and training, but these are more likely to be done on the shop bench rather than on the aircraft (such as terminating the glass fiber into a ferrule, and subsequently installing the fiber/ferrule into an Elio or LuxCis termini). Fortunately, there are fiber maintenance kits of all range of complexities and capabilities for these delicate procedures.

ENVIRONMENTAL ISSUES

As was described in Part 1 of this article (Avion, 3rd Quarter, 2004), fiber optic cables consist of several concentric layers. It should be noted that there are two types of fiber cabling: loose structure (allows slight movement between the inner jacket and the outer strength members) and tight structure (allows no movement between the inner jacket and the outer strength members). The same environmental requirements apply to both types of cabling, and the color of the outer jacket of aircraft fiber cabling is always light purple.

continued on page 30

It goes without saying that all aircraft optical cables must meet the same severe environmental requirements as does copper cabling. The fiber cable must be shown to perform (i.e., continue to transmit light without exceeding its light power loss spec) when subjected to the extremes of temperature, vibration, flammability, smoke and toxicity, etc., found on the aircraft. Recommended tests for aircraft fiber cable are being developed by the AEEC/Arinc Fiber Optic Working Group (FOWG). You can see the list of environmental tests and performance criteria in the draft Arinc 802 document that is posted online at:

http://www.arinc.com/aeec/projects/fowg/index.html.

In addition, there are numerous mechanical performance aspects that have been vastly improved in the past five years:

Bend radius: Contrary to the fiber of old, today's aircraft fiber cabling can bend much like copper and coax. The general rule is that the bend radius can be as small as 10 times the diameter of cable [i.e., generally about an inch in radius (two inches diameter)] for a fiber cable of 1.8 mm diameter.

Knot test: In fact, fiber optic cables are designed to be able to withstand being tied in a knot (up to that one-inch radius) and still operate satisfactorily.

Flexure Endurance: Fiber cables are tested to ensure proper operation even after 10,000 cycles of rigorous flexing.

Impact Resistance: Fiber cable incorporates strong braids in its buffer and strength layers to make it stand up to accidental cutting or breaking upon accidental impact.

Tensile Strength: The fiber cable's tensile (pulling) strength is as great or greater than copper cabling.

Cost: As of this writing, the cost of aerospace qualified fiber cabling is more than an equal length of copper wiring, but of course the bandwidth of the fiber is much greater too (i.e., a single fiber can carry much more data than can many copper wires). Also, the cost of aircraft-qualified fiber cabling is expected to decrease as the usage increases with the roll-out of new aircraft types such as the A380 and B7E7. Similarly, now that there are standards for aircraft fiber connectors, the production volume of these standard connectors will increase, and this volume will drive the cost down. Another cost to be considered is the cost of the test equipment and technician training for fiber optics. The amount of testing and repair that is done on the aircraft vs. in the repair shop must be weighed, as this decision will drive the costs for various sophisticated test tools (such as the probe cameras and OTDRs mentioned above) and the technician training to use them.

BOTTOM LINE: IS FIBER WORTH THE EFFORT?

Yes, you bet it is! Fiber optic cabling is the basic infrastructure that enables tremendous increases in bandwidth (100 to 1000 times more than copper) which enables future proofing of the IFE installation for many years into the future. Compared to copper wire installations, fiber installations offer higher quality audio/video/data at the seat (no RF interference between wires), increased reliability, no EMI, less power consumption, and lighter weight. And all this will result in IFE systems with much lower life cycle costs for airlines.

FOR MORE INFORMATION

My thanks go out to Earle Olson at Tyco Electronics (eoolson@tycoelectronics.com) and Terry Kleeberger at Carlyle (terrykleeberger@carlyle-inc.com) for their help in providing information for this article, and I am sure they will be willing to tell you much more about this subject. For general fiber optics tutorial information, I recommend the book *Technician's Guide to Fiber Optics*, fourth edition, by Donald J. Sterling, Jr.

For information specific to aircraft installation, AEEC/Arinc's Fiber Optic Working Group (FOWG) is developing a series of specifications and recommended practices. Drafts of these documents can be downloaded from
http://www.arinc.com/aeec/projects/fowg/index.html:

1. Arinc 801: Fiber Optic Connectors
2. Arinc 802: Fiber Optic Cables
3. Arinc 803: Fiber Optic System Design Guidelines
4. Arinc 804: Fiber Optic Active Device Specification
5. Arinc 805: Fiber Optic Test Procedures
6. Arinc 806: Fiber Optic Installation and Maintenance Procedures