# Optocore Guideline for Fiber Optical Cabling in Permanent Installations

This guideline is designed to assist Optocore customers with basic information and principles for fiber optical cabling in permanent installations. It also contains many details, which can also refer to non-permanent applications. Following these guidelines will narrow down possible errors and mistakes during installation. However, Optocore would like to point out that fiber optics is an extremely complex subject matter and should be treated with the necessary respect, especially regarding health and safety. Optocore is not liable for any damage caused to persons or devices due to inappropriate handling and operation. Please refer to Optocore manuals and the according document for further Optocore guarantee and liability terms.

## Cable Guidelines

The total loss between two Optocore devices has to be < 6dB. This should allow enough headroom in order to run a system seamlessly. When using SC or LC connectors, no more than six connections should be made between two devices in order to avoid signal loss. When using Expended Beam connectors, no more than three connections should be inserted. Generally, Optocore suggests to limit down multiple connection as much as possible. This also counts for wall panels and distribution boards. Every SC cable plugged directly into a device will limit down signal loss. E.g., when laying fiber optic cables in an audio or video control room, always assure to leave enough cable behind the central rack in order to reach any point of the room instead of working with additional connections. If multiple connection points are required, Optocore recommends to insert a DD8RP in order to refresh the signal.

Industrially manufactured cables may be safer than self-made ones, especially when they are quickly mounted on the installation site. It is also of great advantage to plan for future expansions. Outlets and cable channels should be planed in adequate size in order to be able to pull the cables through them as smooth as possible and to ensure that also the connectors will fit through. It is furthermore most important to handle the cables and connectors as careful as possible. The most typical reasons for signal loss are connections, which are not, plugged together correctly, connectors that are manufactured inaccurately during the set up of the system and connectors as well as fiber cables that are not treated properly or were exposed to fragments of dust or dirt.

Optocore offers and uses cables of highest quality and state-of-the-art design. Optocore cable and fiber characteristics are listed below.

## Fiber Cable Recommendations for Permanent Installations

All fiber cables delivered by Optocore are compliant with these recommendations.

**Connector characteristics**

| Connector | Mode | Insertion Loss | | Return Loss |
|---|---|---|---|---|
| | | Typical | Maximum | |
| SC or LC | Multimode | < -0.2 dB | -0.35 dB | |
| SC or LC | Monomode | < -0.2 dB | -0,5 dB | SPC: >45 dB<br>UPC: >50 dB<br>APC: >60 dB |

**Fiber characteristics**

| Fiber Type | Mode | Wavelength nm | Attenuation dB/km | Bandwidth MHz/km | Numerical Aperture |
|---|---|---|---|---|---|
| 50/125 | Multimode | 850 | ≤ 0.35 | ≥500 | 0.2 |

| Fiber Type | Mode | Wavelength nm | Attenuation dB/km | Dispersion ps/nm.km: |
|---|---|---|---|---|
| 9/125 | Monomode | 1310 | ≤ 0.4 | 3.5 |

Optocore **OptoCable with Expanded Beam Connector**

### Connector characteristics

| | |
|---|---|
| Insertion Loss | 50/125 at 850nm - Max 1.5dB |
| Durability | 2000 Matings minimum |
| Operating Temperature | -40℃ to +80℃ |
| Storage Temperature | -55℃ to +85℃ |
| Water Immersion | 1m Maximum |
| Free Fall Resistance | 500 Falls from 1.0m height |
| Crush Resistance | 3000N/cm |
| Corrosion Resistance | 500 Hours salt spray |
| Cable Retention | 1800N |

### Cable characteristics

| | |
|---|---|
| Diameter | 2 Core: 5.0mm / 4 Core: 5.5mm |
| Weight | 2 Core: 23g/m / 4 Core: 28g/m |
| Tensile Load (short term) | 1800N Maximum |
| Operating Temperature | -55℃ to +85℃ |
| Storage Temperature | -70℃ to +85℃ |
| Crush Resistance | 440N/cm TIA/EIA-455-41 mil. |
| Impact Resistance | 200 Impacts TIA/EIA-455-25 mil. |
| Flex Resistance | 2000 Cycles TIA/EIA-455-104 mil. |
| Minimum Bend Radius | 16X Sheath Diameter |

### Fiber characteristics

| Fiber Type | Mode | Wavelength nm | Attenuation dB/km | Bandwidth MHz/km | Numerical Aperture |
|---|---|---|---|---|---|
| 50/125 | Multimode | 850 | ≤ 0.28 | ≥500 | 0.20 |

### Optocore Liability

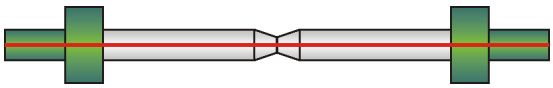
Optocore GmbH takes no responsibility in terms of guarantee issues concerning the optical cabling if the cables/connectors are not purchased from Optocore. The threshold values described in this document have to be followed in order to ensure system functionality if cables/connectors from other manufacturers are used. This also counts particularly in regard to the design of the cabling topology of the system and the application of fiber optic connectors. Optocore recommends connectors, which are designed to avoid operating errors (inaccurate plugging causing transfer loss).

Please refer to the according document for further Optocore guarantee and liability terms.

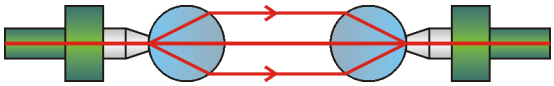
## Cable and Connectors for Optocore Devices

The standard multimode transmitters in the Optocore devices produce an 850 nm light wave; the cables are graded-index fibers with a 50 µm nominal core diameter and a 125 µm nominal cladding diameter. The maximum cable length can be 700 m.

The Optocore devices are equipped with SC-type interfaces, with exception of the DD8RP and YG2-card, which has the smaller LC-type interfaces. Both types are commonly used in computer networks, so cable sets and accessories can be purchased all over the world. They are absolutely reliable in permanent indoor installations. For rougher temporary applications such as mobile racks in a theater the 1RU OptoCon panel, with rugged and secure fiber optic connectors can be used. These Expanded Beam connectors have a spherical lens at the end of the fiber to spread the light out into a parallel beam. The light is magnified; the beam becomes up to 900 times bigger than the original one. Small items on the lens such as dust and debris have a much lesser influence on the connection in comparison to a normal connection with SC or LC connectors. Additionally the lens protects the fiber and the Expanded Beam connectors have a full rubber body. They are well equipped for harsh environments, weather extremities and frequent deployment.



**Principle of SC and LC connectors**



**Principle of Expanded Beam connectors**

Every connector increases the attenuation. A SC- or LC- connector will add approx. 0.1 – 0.3 dB, an Expanded Beam connector will add approx. 0.8 – 1.0 dB.

### Attenuation

The overall attenuation on the fiber optical connection between two Optocore devices should not exceed 6 dB.

### Latency and Cable Length

The speed of light and therefore the delay caused by the cable depends on the refraction index of the core. For glass, the refraction index is approx. 1.5. As a result the speed of light is approx. 200,000,000 m/s. The delay caused by a 1km long cable is approx. 5µs. Thus, the delay can be considered as insignificant.

### Pulling Strength

Some cables are simply laid into cable channels or ditches, thus it is not so important to consider the pull strength. Other cables, however, may be pulled thorough rugged environments for several meters, even kilometers and pulling tension can be high, despite the use of cable lubricant. Most cables obtain their strength from an Aramid fiber, also referred too as Kevlar, a unique polymer fiber that is very strong and does not stretch - consequently pulling on it will not put any tension on any of the other components in the cable. Fiber cables can be pulled with much greater force than copper wire if they are pulled correctly. Never pull on the fibers or jacket, pull on the strength member only! Any other method can harm the fibers. Maximum pulling load rating should never be exceeded and proper lubricants should come to account on long distances. On really long runs, the cable should be pulled from the middle out to both ends. An automated puller with tension control or a breakaway pulling eye is recommended for long distances.

### Bend radius

The minimum bend radius is specified by the manufacture of the cable and may differ. It is important not to bend the cable to a smaller radius than specified. A smaller radius will increase the attenuation and could damage the cable.

The minimum bend radius for the OFC cables (Optocore rugged environment cable) is 45 mm. The minimum bend radii also count for wrapped or coiled cables.

### Maintenance

Even very small debris and dust on a LC- or SC ferrule can hinder the light transmission. To avoid dirt on the ends of the fiber cable and the interfaces of the device the protection caps must be attached as long as the interfaces are not used. Same counts for the Expanded Beam connectors. Small particles will not have such a big influence on the transmission, but the lens must be protected against scratches. The lens should be treated with the same care as a camera lens. It should not be touched.

### Cleaning

Dirty end-faces are the primary cause for fiber failures. Cleaning the end-faces of a SC or LC connector must be done very carefully with lint-free cloth and a special solvent. For interfaces, a lint-free swab can be used instead of the cloth. There are several companies offering cleaning gears. Dry cleaning is not recommended, because not all impurities will be removed and electrostatic charging may add more dust. In comparison to isopropyl alcohol, special solvents can have a few advantages they may clean more efficient. For controlling, the end-faces handheld microscopes are available.

A lint-free cloth can be used for cleaning of the cover of an Expanded Beam connector. Water and solvent could harm the lens; oil and grease are not necessary for the screw threads. The lens can be cleaned very carefully with a lint-free cloth as well as other gears used for the cleaning of camera lenses. Great care has to be taken to avoid scratches. They could be produced by small particles on the lens while trying to remove them by rubbing or scrubbing.

### Testing

There is a broad range of testing equipment and handheld devices for the measurement of attenuation, some just for specific connectors, fibers and wavelength, and others with adapters for different kind of cables. The decisions for a test kit depends on the types of fiber used in the various applications, e.g. if only multimode cables transmitting 850 nm light waves are used or the ability of testing monomode cables is necessary as well. A test kit for measuring the attenuation should be sufficient to decide whether the transmission capacity of a cable is okay. For more detailed analyses, other test equipment such as an Optical Time Domain Reflectometer (OTDR) can be used.

**From left to right: Fiber continuity tester, fiber identifier, light source, OTDR launch box, fiber optic power meter, visual fault locator, fiber optic inspection microscope**

The cables used in temporary applications should be tested regularly. A test is always necessary after outdoor applications in dirty and muddy environments. Tests should be done if any kind of stress exceeding the specified tensile, lateral or torsion strength could have damaged the cable, e.g. by carelessly closed case tops or doors.

Object of a test should always be the cable and the cable connectors, not the Optocore devices. If it is more convenient to use the optical interfaces of a device as a light source instead of an external, calibrated source the interfaces must be measured first. The result of the cable/connector measurement has to be corrected by the result of the interface measurement.

## No tolerance for dirt

Regarding fiber optics, the tolerance to dirt has to be close to zero. Flying particles are about the size of the core of SM fiber- they absorb lots of light and may scrape connectors if they are not removed! Dirt on the connectors is the biggest cause of scratches on connectors and high loss measurements!

No smoking, food, or drink should be allowed if working with fibers.

- Try to work in a clean area. Avoid working around heating outlets, as they blow dust around
- Always keep dust caps on connectors, bulkhead splices, patch panels, or anything else that is going to have a connection made with it.
- Use lint free pads and isopropyl alcohol to clean the connectors.
- Ferrules on the connectors/cables used for testing will get dirty by scraping off the material of the alignment sleeve in the splice bushing - creating a 1-2 dB attenuator. You can see the front edge of the connector ferrule getting black! Use the metal or ceramic alignment sleeve bulkheads only for testing.

### Repair

Professionally trained personnel should only do the repair of connectors and cables.

### Cable Installation

There are general rules that should be followed when fiber optic cables are installed. These rules certainly include the sections above, but it is also very important to follow the correct steps concerning cable support and pulling.

All fiber optic cables have to be securely supported and the support has to be spaced closely enough in order to avoid excessive force on the cable. The cables should be supported in intervals not exceeding 100 cm (3,3 ft). Cables lying in raceways do not necessarily have to be additionally supported. All straps or supports placed on fiber optic cable should be tight enough to hold the cable; however, it should not be so tight that it significantly deforms the shape of the cable. When optical cables are squeezed out of shape, the fibers can easily be damaged.

The incorrect laying and pulling of fiber optic cables is a further common reason for damaged cables and malfunctions in network systems. Therefore, the manufacturer’s instructions have absolute priority. There are several general rules that have to be followed regarding the laying and pulling of both outside- and inside cabling.

For outside and inside cabling Optocore recommends following guidelines:

- All cable ends have to be protected against dirt and moisture before, during and after laying.
- The end caps and corrosion protection of the cables may not be damaged.
- If necessary, cables on reels should only be pulled into the indicated direction.
- When cables are pulled, it is most important to follow the manufacturer’s instructions regarding tensile force and minimum bend radius. The according values are listed in the manufacturer’s specification sheets.
- The mechanical characteristics of the cables are temperature-dependent, depending on the material structure.
- Never pull on the fibers or jacket, pull on the strength member only! Any other method can harm the fibers.
- Optical cables may not be pulled into place by applying tension directly to the fibers (pulling the fibers).
- Optical cables may be attached to a pulling line only by methods recommended by the manufacturer of the cable.
- Optical cables have to be protected against mechanical and thermal damage, especially if they concur other installations or facilities e.g. crossings etc.
- If optical cables are laid into the ground (earth), the bottom of the trench has to be firm and free of stones.

- A corrosion-resistant warning tape should be placed about 30 cm (1 ft) above the cable that is buried in the earth.
- In order to avoid twisting, the cable should always be rolled of the cable drums instead of spinning it off. For long pulls, the cable should be laid out by using the “figure 8” on the ground.
- Cable pulling should be done by hand, except when tension meters, tension-controlled, or breakaway swivels are in use.
- When powered pulling equipment is used to install optical cable, tension monitoring equipment or breakaway swivels have to be used. Swivels have to be used when pulling optical cables into conduits.
- A length of free cable has to be provided at each end of a cable pull, especially at cable distribution cabinets, splice points and transition points.

### Water Protection

Outdoors, every cable must be protected from water or moisture. The cables have a moisture resistant jacket, usually PE (polyethylene), and a filling of water-blocking material. The usual method is to submerge the cable with a water-blocking gel. An alternative is dry water blocking using a special powder developed to absorb moisture. A hard plastic coating on the outside of the fiber additionally protects the glass from moisture or physical damage.

### Fire Code Ratings

Every cable installed indoors must meet certain standards regarding fire. The jacket must be rated for fire resistance, with ratings for general use, riser (a vertical cable feeds flames more than horizontal) and plenum (for installation in air-handling areas). Most indoor cables us PVC (polyvinyl chloride) coating for fire resistance.

All premises cables must carry identification and flammability ratings per the Fire Protection Ordinance: System circuit integrity E90, system circuit integrity E60, system circuit integrity E30, no flame propagation, circuit integrity with shock, flame retardant, low fire load, circuit integrity FE180.

Material properties: Low smoke emission, halogen free, no toxic gases, no corrosive gases, no fluorine.

### Safety Precautions

**Optical fiber systems have enough power to cause eye damage and most broken fiber ends will spread the light passing through them anyway.**

- Live optical fiber ends – live fibers are those with signals being sent through them – may not be inspected, the fibers have to be dark (no signal being transmitted) when inspected.
- If there is a risk of fibers being inspected live; especially when the system light source is a laser, all technicians working on the system have to wear protective glasses, which have infrared filtering.
- Broken fibers can be considered as small glass needles, they can be quite dangerous and can be painful when stuck in the skin as a splinter, they are potentially life threatening if swallowed.