Fibre Optic Installation and Testing Guide

Cloud Scale Data Centre Cabling

AFL HYPERSCALEb

Forward

This document has been prepared for the purpose of providing general guidance to installers using FibreFab products to construct, extend and maintain cloud scale data centre communication infrastructure. The Guide is a living document and will be updated at least semi-annually to reflect the constantly evolving technology.

This document is based solely on our own understanding of best practices. Consequently, it has been written as an advisory document and is not prescriptive. Data Centre owner guidance should always take precedence over the recommendations of this Guide.

We look forward to continuing to work with the cloud scale infrastructure community and welcome all comments for the purpose of continuously improving the reliability, effectiveness and competitiveness we collectively bring to the world of global information technology.

Please contact me or any of the FibreFab team at any time if you have any suggestions, issues in installation or any other matters.

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21 October 2014

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FibreFab

Fibre Optic Installation and Testing Guide

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1 Naming Conventions/Glossary

1.1 Definitions

The following naming conventions and abbreviations are used throughout the document:

dB – Decibel is a logarithmic unit used to express the ratio between two power values, such as input and output power

dBm – Is the power value expressed as the logarithm of the ratio relative to one milliwatt

IT – Information Technology

LAN – Local Area Network

MPO – Multi-fibre Push On, a multiple fibre, polymer connector ferrule, for the purposes of this document mostly related to 12 and 24 core versions. Available in male (with guide pins) and female (without guide pins)

MTP – A brand of high performance MPO connector manufactured by US Conec

OLTS – Optical Loss Test Set, also referred to as Light Source and Power Meter

OTDR – Optical Time Domain Reflectometer

SCS – Structured Cabling System

VCSEL – Vertical Cavity Surface Emitting Laser, commonly used as the signal transmitter for 10Gigabit Ethernet over fibre optics

VFL – Visual Fault Locator that transmits a light signal in the visible spectrum (typically red) to aid fault finding and checking polarity

2 Introduction

2.1 General

This document provides guidance and best practice methods related to the installation, cleaning and testing of FibreFab cables, patch cords, pre-terminated fibre optic cable assemblies, patch panels, fibre shelves and cable management.

These products are designed to provide connectivity between various items of equipment, IT equipment racks and cabling patch frames within a cloud scale Data Centre environment.

This document also provides basic background information relating to the transmission of fibre optic signals, installation planning and safety.

3 Product Performance

3.1 General

Fibre optic cables provide one of the most capable media for the transmission of communications signals from one location to another ever developed. When installed with care in a suitable environment, these cables can continue to perform to the highest standards virtually indefinitely. Fibre cables however, like other communications cables, can be damaged by poor installation and care practices, which can result in a reduced ability to carry signals, damaged signals or, in the extreme, signal carrying capabilities are lost completely.

It is vital that fibre optic cabling, connectors and assemblies are installed with care in accordance with this guide and associated relevant standards.

3.2 Fibre Optic Basics

At its most fundamental level fibre optic transmission is the conveyance of information in the form of light pulses from one location to another via a very small strand of flexible glass.

The transmitter of the fibre optic signal takes electronic signals, typically in a digital format (ones and zeroes), and sends light pulses to a receiver at the other end of the fibre optic link. The receiver to deciphers the light pulses and converts the signal back into a digital electronic format. These digital signals can be used to carry data, voice, video, pictures, music or almost any other form of information.

The individual light pulses used in fibre optic communications are actually made up of many atomic sized particles of energy that are created by, in most cases now, a laser. It is important to understand this as it will help in understanding some of the limitations of fibre optic signalling, and some of the key reasons for signal degradation that will be described later in this document.

All fibre optic cables are initially made up of two basic elements. The glass strand mentioned earlier is called the core. Surrounding the core is another tube of glass called the cladding. The purpose of the cladding is to keep light in the core. Without the cladding light travelling through the core would leave the core, particularly at bends. The cladding glass has different properties to the core glass which causes the light in the core to reflect back into the core. This process is called internal reflection.

Internal reflection is not a perfect process and some light will still leave the core, typically when fibre optic cables are bent too tightly.

Around the cladding there is another coating to provide some protection and strength; typically this will be a 250 or 900 micron plastic buffer. Further strength members, tubes and cable jackets are then used for protection and strength, depending upon the environment where the fibre cable is to be installed.

3.2.1 Multimode

Multimode refers to a type of fibre with a core that enables multiple "modes" of light to travel down it. High order modes are the particles of light energy in a single pulse that refract or "bounce" the most between the cladding. Low order modes are those that travel mostly down the centre of the core and refract very little.

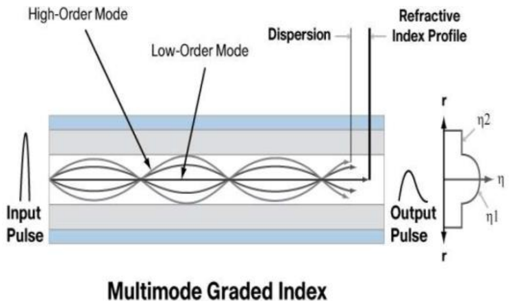


Figure 1 – Core and Cladding

FibreFab multimode cabled fibres have a 50 micron core and 125 micron cladding (50/125) and meet cabled performance standards OM3 or OM4.

3.2.2 Singlemode

Singlemode refers to fibres with a core that is much smaller than multimode ones (approximately 9 micron) and which can only support the primary mode of light due to its size. FibreFab single mode cabling complies to OS2 requirements.

3.3 Performance Degradation

The following sub-sections detail some of the reasons for degradation of fibre optic signals.

3.3.1 Attenuation

Attenuation is the term used to describe the loss in optical power in the system between one end of a link and the other. Attenuation is measured in decibels, using the abbreviation dB. For fibre optic cable, attenuation may be related to distance; for example a fibre optic cable may have an inherent attenuation of 0.3 dB per kilometre (0.3dB/km).

To measure attenuation a light source is used to inject a signal (light energy) into one end of a link and power meter is used at the other to measure how much light energy was received, the difference between the two then being reported as a number (dB loss).

Attenuation can be caused by many factors, key amongst them are:

- Impurities in the core glass itself and absorption of light energy by the core glass.
- Over bending of fibre cables which causes some of the energy to escape into the cladding and so not collected by the receiver.
- Poor termination where the glass core at the end of the connector is chipped or pitted causing light energy to be directed away from the core.
- Contaminated connector end faces which can block the light energy.
- Non-aligned connectors where the core of one fibre isn't aligned correctly with the next fibre. Light energy can be lost into the cladding where connectors are not aligned well.
- Connectors between fibre cables need to be flush to each other with no air gap. Gaps, even very small ones, will allow light energy to escape from the core.

3.3.2 Attenuation, Insertion Loss and Return Loss

The term Insertion Loss (IL) is used to define the loss at a specific optical interface, such as a connector. For link testing purposes the focus is on overall attenuation, as described above, of which insertion loss forms a part. FibreFab recommends primary attenuation testing of links and channels using optical light sources and power meters (OLTS).

OTDR testing is useful for troubleshooting. OTDR results are usually presented as a visual display or print out (trace) of the link from end-to-end. A poor connector to connector interface, resulting in a high reflection at that point, will show as a spike in the trace which is very useful in fault finding.

Return Loss (RL) is a term used to describe the level of light energy reflected at an interface back towards the source. Like attenuation this is measured in dB but may be expressed as a positive or negative number, such as 40 dB or -40 dB. Negative or positive, the higher absolute value, the lower the reflected power; therefore -60 dB return loss is better than -40 dB.

For most multimode installations return loss is not reported as a separate number. Multimode communications are not RL sensitive. For single mode installations return loss can be more of an issue. RL can be improved by use of special "angle polished" or APC connectors.

3.3.3 Dispersion

In fibre optics dispersion relates to the "spreading" of the light pulse such that some of the energy in the pulse reaches the far end before the main bulk, which is then followed by a "tail" of energy. For links less than 2km, dispersion is not a factor in single mode networks. In multimode networks, dispersion can be caused by variations of velocity of different modes and different wavelengths. This spreading of the light energy is a key limiting factor in the number of pulses that can be injected into a fibre over a period of time (bandwidth). This is because the energy pulses can start to overlap to the degree that the receiver is unable to detect the start and finish of the pulses, and is therefore unable to decipher the signal.

Figure 2 – The effects of dispersion on a light pulse

3.4 Summary

The performance of fibre optic cables and connectors can be greatly impacted by installation practices; therefore it is vital that the installer takes care during the installation of fibre optic systems and understands what practices can impact upon performance.

Historically in Local Area Network fibre optic systems, there could be several dB of loss in a link, even up to 9 dB, but in today's high performance systems the amount of loss acceptable in a link has decreased dramatically, to the extent that on some systems the maximum loss may be only 1 or 2 dB. The amount of loss acceptable is usually referred to "loss budget", which is taken up by cable and connector losses. Therefore it is easy to see that the installer must take real care when installing fibre optic systems and as such this work should only be undertaken by suitably trained personnel.

4 Standards

4.1 Fibre Optic Installation and Testing

Standards are important reference documents for all installers providing guidance relating to design, installation and testing of fibre optic systems.

Within this section key standards are highlighted but the list is not exhaustive, there are many published standards which installers can refer to.

Standards do vary by region with TIA (Telecommunications Industry Association) being widely followed in the USA and globally. In Europe the EN (European Norm) standards are common. Global standards are produced by ISO (International Organisation for Standardisation) and the IEC (International Electrotechnical Commission). There are also industry organisations such as BICSI that produce installation manuals.

The following standards are particularly relevant to the installation and testing of fibre optic systems; however it is always important to bear in mind that the latest revision of any standard is the one that should be referenced.

4.1.1 ISO/IEC 11801 (2nd edition); ANSI/TIA-568-C.1; EN 50173-1

These standards provide general requirements relating to the performance and installation of generic cabling systems.

4.1.2 ISO/IEC 24764; ANSI/TIA-942; EN 50173-5:2007

These standards provide general requirements relating to the performance and installation of generic cabling systems within Data Centres.

4.1.3 ISO/IEC 14763-2; EN 50174-1 (-2 and -3)

These standards provide information relating to the specification, administration, planning, installation, handover, maintenance and repair of cabling systems. The US standards TIA-606-A, TIA-569-B, TIA-758-A and ANSI-J-STD-607-A cover most of these topics.

4.1.4 IEC 14763-3; IEC 61280; TIA-568-C; EN 50346

These standards focus on the inspection and testing of cabling systems.

4.1.5 ISO/IEC TR14763-2-1; ANSI/TIA 606-B

These standards are widely used as reference guides for the labelling of Structured Cabling Systems.

4.2 Summary

Many standards exist and it is incumbent upon the installer to check that the work of designing, planning, installing and testing is undertaken to the appropriate standards. There may be specific standards requirements set by the facility owner, a consultant, a main contractor and/or by FibreFab.

Installation guides, such as those produced by BICSI, are excellent resources regarding the design and installation of Structured Cabling Systems and are highly recommended reference materials.

Fibre optic installations should not be undertaken by those without proper training and experience. Many training courses exist for fibre optic installation and testing and it is recommended that installers have suitable qualifications.

5 Installation Requirements

5.1 Overview

This section of the document provides general guidance to the installer related to good practices that should be followed when installing FibreFab fibre optic systems, particularly in cloud scale Data Centres.

5.2 Planning

Planning is a fundamental requirement, usually the better the plan the better the outcome. The following text provides key considerations when planning an installation within a Data Centre.

5.2.1 Create a project plan

A project plan can be created using a simple list of tasks with dates or by using software tools such as spreadsheet or project management applications. The project plan must identify the tasks and the key dates, particularly for those tasks that must be completed in order to allow other tasks to commence. The plan creator must also consider which tasks can be undertaken alongside others and which cannot, and set the plan out accordingly.

5.2.2 Agree the point of contact

There must be a nominated installer contact for every Data Centre installation, even if it is the person actually undertaking the installation.

5.2.3 Site access

Access to site, particularly relating to Data Centres, is often very strict and can involve obtaining security clearance for staff. The installer must ensure that all staff who need access are suitably cleared in good time.

Vehicle access must also be agreed with the Data Centre owner when requesting personnel clearance.

Delivery slots must be agreed with the Data Centre owner in advance.

5.3 Installation – General

5.3.1 Overview

In order to undertake a safe, effective and efficient installation the works must be approached in a professional manner using the proper processes, products and equipment. Data Centres in particular are not places where ad-hoc working practices are acceptable. Necessary permits must be obtained in advance or work dates.

5.3.2 Product storage

All products delivered to site that are not used immediately must be stored in a safe, secure and suitable environment. Products must not be left in places such as loading bays and corridors. The installer must agree in advance with the Data Centre owner what, if any, storage is available on site and whether this storage is suitable.

5.3.3 Planning of routes

The installer must survey the routes available for the cabling. Where pre-terminated cable assemblies are being installed it is important that route planning has been performed and appropriate length of assemblies ordered. Regardless of when the planning is undertaken the following comments in this sub-section are relevant.

The route to be taken may not always be the shortest distance between the two end points, other factors usually have some impact and include the following:

- The containment routes available between the two points
- Specific requirements for cables to be installed at high-level or low-level
- Containment capacity for the planned cable(s)
- Spare capacity available within the containment following the installation and is that acceptable to the Data Centre owner
- Sufficient capacity on cable matting
- Where cables are to be laid on top of existing cables in containment ensure that the existing cables are not damaged by the weight of additional cables placed on top. Where any doubt exists relating to the stacking of cables contact FibreFab for further advice
- Data Centre owner’s diversity requirements, such as primary and secondary routes to each location that need to be kept separate throughout
- Adequate space to lay out the cable outside of the containment, where routes change direction, so allow the next section of the cable pull to be undertaken with minimal risk of damage
- Adequate space for the deployment of cable drums and/or jacks
- When cable installation cannot be completed in a working day suitable storage or coiling space must be available if cables are left out of the containment. The Data Centre owner must agree with these overnight storage requirements
- The installer must be aware of any security requirements that the Data Centre owner has regarding works inside the facility, for example it is highly unlikely that the installer will be allowed to leave doors open whilst installing cables

The installer must be aware that the provision of any additional containment must be agreed in advance with the Data Centre owner and completed prior to the installation of any cabling.

5.3.4 Working areas

Working areas must be agreed in advance with the Data Centre owner, stating which areas the installer wishes to work in and when.

Use of high level access equipment may require the Data Centre owner to arrange access for this equipment and to coordinate this activity with any other activities that may be planned for the same period. Where floor tiles need to be lifted the installer must clearly state to the Data Centre owner which areas of the floor need to be lifted and when. Lifting of floor tiles can present a trip or falling hazard to personnel; lifting too many floor tiles at one time could destabilize the floor; lifting of floor tiles can have a detrimental effect on cooling where cold air is delivered via the floor void; and the Data Centre owner may wish to arrange for its own specialist contractor to be responsible for the lifting and replacement of floor tiles.

Where a project requires the installation of cables from one part of the Data Centre Hall to another the whole route must be surveyed by the installer and plans made accordingly. Regardless of whether the installation is at high-level, low-level or both the route must be cordoned off using safety barriers that are approved by the Data Centre owner.

Reducing the risk of damage to the products during installation is an important factor in achieving a fault free result. Cables can often be damaged during an installation, and sometimes by others who are not aware of the damage that they may be causing.

5.4 Cable Installation

The careful installation of the cables themselves reduces the risk of damage, and later faults that can be problematic and expensive to rectify.

There are many factors to consider when installing FibreFab pre-terminated assemblies or cables in Data Centres, the following sub-sections provide information regarding those factors which, if observed, can greatly reduce the risk of a faulty installation.

5.4.1 Cable drums and jacks

Where cables or assemblies are delivered on reels it is generally best to deploy straight from the reel rather than un-roll the cable from the reel prior to installation. Always use purpose made cable jacks and locate them at the end of the run that offers the most space and convenience.

Figure 3 – Cable jack/trolley

Where cables or assemblies are delivered as a coil then it is best to un-coil as you install, as un-coiling a lot of cable at once can leave it at risk of damage. When cables are un-coiled there is a much greater risk of cables kinking, and if that happens the likelihood of damaged fibre cores is very high. Laying out of un-coiled cables in a "figure of eight" can help to avoid cable twists and kinks.

5.4.2 Cable pulling

Fibre optic cables should only be pulled as a last resort; wherever possible fibre cables should be laid into containment. When fibre cables are pulled different stresses can be applied to different parts of the cable, these stresses could cause one or more of the fibre cores to break.

Where fibre assemblies can only be installed by pulling the installer must use a cable sock or other similar device recommended by FibreFab and not pull the cable by the connector or the jacket. The cable sock should have a swivel mechanism to help prevent cables twisting.

Figure 4 – Cable with sock

Where fibre cables need to be pulled this should only be done by pulling on the strength members, and not the whole cable or jacket. Always refer to any FibreFab specific requirements for cable pulling and use recommended lubricants.

When installing any pre-terminated cables ALWAYS ensure that the protective covers over the connectors remain in place throughout the installation process.

5.4.3 Cable bend radii

Damage can occur to fibre optic cables when they are bent in excess of FibreFab guidelines. This damage can result in increased losses within the cores or even broken fibres.

The minimum permissible bend radius for an assembly or cable varies by construction. Prior to starting the installation itself the installer must be aware of the minimum bend radius of the FibreFab cables or assemblies in question.

The installer must also be aware that during installation the minimum bend radius is much greater than the figure quoted for the placed cable; therefore a cable or assembly with a placed minimum bend radius of 50 mm could have a minimum bend radius during installation of 100 mm or more. The reason for this difference is the stresses that can be applied to a cable during installation which aren't there when the cable is finally placed.

One "rule of thumb" often applied to fibre optic cable bend radii is that the minimum placed radius is 10 times the outside diameter and the installation minimum bend radius is 15 or 20 times the outside diameter; however checking the requirements for each cable is best.

The installer must always be aware of bend radii when surveying containment routes to ensure that adequate space exists. Containment should have swept or gusseted bends and not right-angle bends.

The installer must also ensure that exits from containment have suitable "drop-offs" or "waterfalls" to manage the bend radius. Routing cables directly out of containment or cable baskets is not acceptable as this will usually result in the minimum bend radius being exceeded.

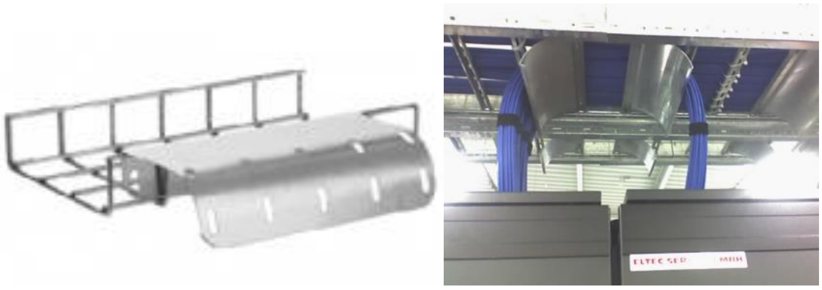


Figure 5 – Containment "waterfalls"

When installing the cable or assembly into its final location, such as a rack and patch panel, continue to be vigilant regarding bend radii. Where cables enter patch panels via cable glands there is often little space left at the rear or side of the rack which can result in over bending. Also consider the space available for any cables to move when used in conjunction with patch panels that have sliding trays.

5.4.4 Cabling environment

Prior to installation the installer must check the environment throughout and ensure that no corrosive or otherwise damaging substances come in contact with the cable. Also the installer should be aware of environments that can occur in an emergency or other event, such as sprinkler or gas suppression systems being activated or localised flooding.

Some floors can also have potentially corrosive paints or acids in their construction, in this event always use cable baskets or cable matting to lay cables on.

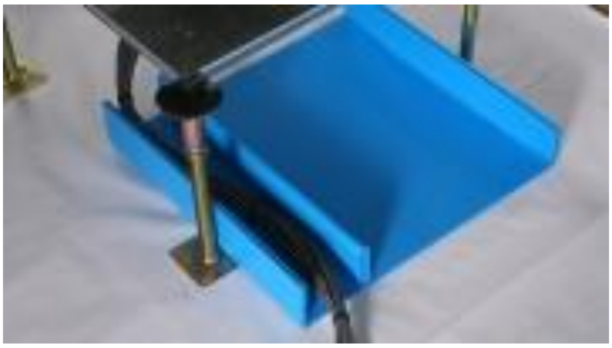


Figure 6 – Cable matting

5.4.5 Separation

It is recommended that fibre optic cables be kept separate from copper cables for two reasons, safety and potential damage.

From a safety perspective, keeping communications installers away from containment housing electrical cables reduces the risk of electric shock or damage to electrical cables and connections.

From a damage perspective, it is possible that when installing fibre cables in containment housing copper communications cables, damage can occur to the copper cables; however the greater concern is the possible later addition of copper cables causing damage to previously installed fibre cables, either due to the installation exercise itself or because fibre cables getting crushed by heavier copper cables placed on top.

Most cabling standards have separation recommendations based on performance, and it is good practice to apply these to fibre installations.

5.4.6 Cable organisation

The neat and tidy routing of cables should always be observed when cables are laid on floors, matting or cable baskets/trays. Proper routing aids later cable tracing or removal. It also helps to manage cable weights where cables are placed on top of others as it is easier to see what quantities of cables are in place.

Where an installation involves only the addition of one or two cables, these should be neatly added to any existing harnesses, taking care not to disturb what is already installed. If adequate space exists then new harnesses can be created which can be added to in the future.

It is important to plan the route of cable installations with regards to looms, particularly in relation to how cables exit containment. Where cables are to be routed into a rack or other location to the right of the containment route, the cables should be installed on the right-hand side of the containment and vice-versa. Crossing over containment is likely to result in an untidy installation and one which is likely to encounter problems in the future.

Where cables are to be routed in racks, they should be attached to containment within the rack on the appropriate side, which isn't necessarily the side of the rack where a cable is to enter an enclosure like a patch panel. It can often be beneficial to route a cable up one side of the rack and then dress the cable across to the other side of the rack for cable entry, this can allow some slack cable to be accommodated for future changes, and help to avoid over-bending of cables.

Figure 7 – Cable management in racks

Figure 8 – Cable routing

5.4.7 Cable fixings

Within an Data Centre environment it is often the case that cabling is installed on cable matting or in cable baskets, and in these situations cables are ideally fixed using Velcro™ cable ties or similar. When this type of tie is used it is very difficult to over tighten the fixing and damage the cable. Cables can be crushed by cable ties if not used correctly, creating fibre micro bends which cause transmission losses and possible failures.

The maximum distance between cable ties in a horizontal cable basket or matting installation is 300 mm. Shorter distances should be applied where these would improve the neatness and appearance of the installation.

Vertical cable fixing distances are usually predicated on the size and weight of the cable being fixed. In an equipment rack it may be that distances as low as 100 mm between fixings are required to ensure a neat and tidy appearance. Further advice can be sought from FibreFab in the event of any doubt.

5.5 Product Installation

5.5.1 MTP to LC FibreFab Super Cassette installation

The installer must agree, well in advance, with the Data Centre owner the exact "U" and front or rear positioning within the rack or frame for the FibreFab Super Cassette. The installer must ensure that cable routes to the proposed position are accessible and that suitable patch cord management exists around the location for patch leads. If patch cord management is lacking, the installer must agree with the Data Centre owner the provision of additional patch management or the location of the FibreFab Super Cassette elsewhere.

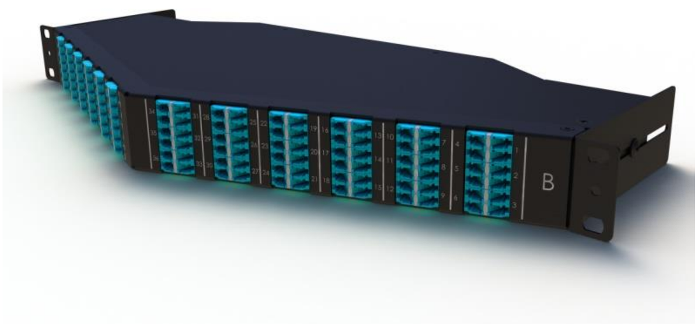


Figure 9 – Super Cassette

The FibreFab Super Cassette should only be installed in a clean and dry environment and protected from damage throughout the installation. The installer must ensure that all connector dust caps stay in place until a patch cord or connector is to be inserted. This will reduce the risk of connector contamination and subsequent poor or failed test results.

It is recommended that labelling be undertaken prior to the location of the FibreFab Super Cassette in a rack or frame.

5.5.2 FibreFab patch panel and fibre shelf installation

Similarly to the FibreFab Super Cassette, agree the locations of FibreFab patch panels and fibre shelves well in advance; ensure that adequate patch management either exists or will be installed; only install in a clean and

dry environment and ensure that connector dust caps are only removed when a patch lead or connector is to be inserted. Leave all removed dust caps with the Data Centre owner for later re-use if needed.

Figure 10 – Patch panel / fibre shelf

5.5.3 FibreFab cable management bars and rings

Provision of adequate cable management is required. Insufficient cable management usually results in patch cords being squeezed into overcrowded management bars or rings, or patch cords being installed without using any management. The result of this on fibre optic patch cords is often a higher loss or even the failure of links completely.

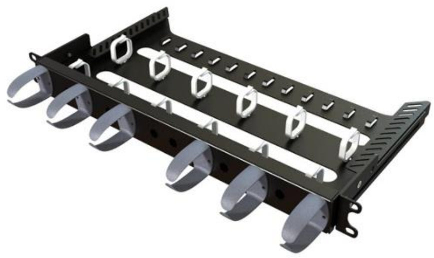


Figure 11 – Multi-function Cable Manager

The amount of cable management required in any given situation varies depending upon the type of installation; of course in high density patching environments more cable management is needed than in those locations where there is more active equipment.

The installer may well need to estimate the maximum number of patch cords needed at a given location and then calculate the size of cable management needed to accommodate that number of cords.

5.5.4 FibreFab patch cords and assemblies

The patch cords and pre-terminated assemblies are used within racks and between sets of racks and zones within Data Centres.

Prior to commencing the installation of FibreFab patch cords and assemblies the installer MUST ensure that adequate and safe routing of the cords and assemblies is available. Poor installation will almost certainly result in higher losses or failed links. Suitable routing might be a containment system that sits on top of the racks that is used to link them together. Links between racks can also be formed by the use of horizontal cable management bars that are aligned with the adjacent racks and have brush strips in the side panels of the racks for the cables to pass through. Routing patch cords and assemblies via floor voids is not recommended unless suitable containment systems are provided.

Figure 12 – Cable management

The installer must inspect and clean all patch cords and assemblies prior to plugging in, see Section 6 below for further details regarding connector cleaning.

5.5.5 FibreFab pigtails

Pigtails, when used to splice to cables, must be housed in patch panels or distribution shelves that can accommodate the appropriate splice holders. It is recommended that pigtails be spliced to cables using a fusion splice.

The patch panel or distribution shelf must also be fitted with spools to manage the pigtail and fibre optic cable cores.

Figure 13 – Patch panel with pigtails

5.6 Labelling

5.6.1 General

Without proper labelling of racks, frames, patch panels, fibre shelves, cables and terminations the future administration of the installation will be undertaken by guess work and this is, of course, unacceptable.

There are many and varied types of labelling solutions including physical labels, software and electronic systems.

Many standards provide detailed information relating to labelling, including EN 50174-4, ISO/IEC TR14763-2-1 and ANSI/TIA-606-B along with industry organisation guides such as the BICSI Information Technology Systems Installation Methods Manual.

The most basic form of labelling is physical labels themselves. There are wide varieties of physical labels; however for communications purposes the labels must be robust and able to withstand a communications environment for at least 20 years. What this means in real life is that labels must be made of laminated paper, plastic or engraved plate and any adhesives used to secure them must be equally permanent. There are many companies offering comprehensive labelling solutions, such as Silver Fox (www.silverfox.co.uk) and Brady (www.brady.co.uk). Installers are strongly recommended to use specialist labelling companies such as these. Hand written labels are not acceptable.

The location of the proposed label often dictates the type of label to be used. Cable labels in particular are often laminated paper, wrap-around types which allow cables to be easily labelled that already have terminations fitted. Cable labels are usually applied approximately 20 mm from the rear of the connector.

Patch panels and ports are better suited to having engraved plastic type labels fitted.

The labelling scheme used must be in accordance with whatever scheme is already in place in the Data Centre, and is normally a mix of letters and numbers. Some labelling schemes use bar-codes, and where these are used the installer must ensure that initial and subsequent labels follow this format.

Labelling schemes must be agreed in advance with the Data Centre owner.

Figure 14 – Labels

The installer must agree in advance what is expected of it in terms of data input to the Data Centre owner’s electronic cable management systems, and provide that service alongside the installation of the cables.

In order to reduce the risk of patching or other cabling errors in the future it is imperative that a proper and fully functioning labelling and documentation system is in place. It is widely accepted in the Data Centre industry that the biggest source of downtime is human error. Proper labelling and documentation can go a long way to reducing this risk.

6 Inspection and Cleaning

6.1 Overview

The majority of faults found when testing fibre optic installations are due to the contamination of connector end faces. Whilst a connector end face may appear clean to the naked eye, microscope deposits of or grease can seriously impair performance.

The installer must be aware of the need for cleanliness and take all measures to minimise the risk of connector contamination.

6.2 Cleanliness

A high level of cleanliness is demanded within Data Centres, with many requiring laboratory level environments, and there several reasons for this.

In terms of general cleanliness this is demanded because of the electronic and electrical equipment typically found in Data Centres and the cooling methods often deployed.

Fibre specific cleanliness is extremely important. Many "faults" on fibre optic systems are introduced because fibre optic connector end-faces get dirty, and this dirt can even be something simple like the natural oils that are found on the skin.

Installers must always avoid touching the end faces of fibre optic connectors to reduce the risk of contamination and the resultant higher losses that can occur.

6.3 Connector cleaning

The installer can use a variety of cleaning materials; however even after cleaning it is not always possible to tell by use of the naked eye whether the connector is clean enough. Whilst debris might show on a connector is much more difficult to see oils or grease on the connector face.

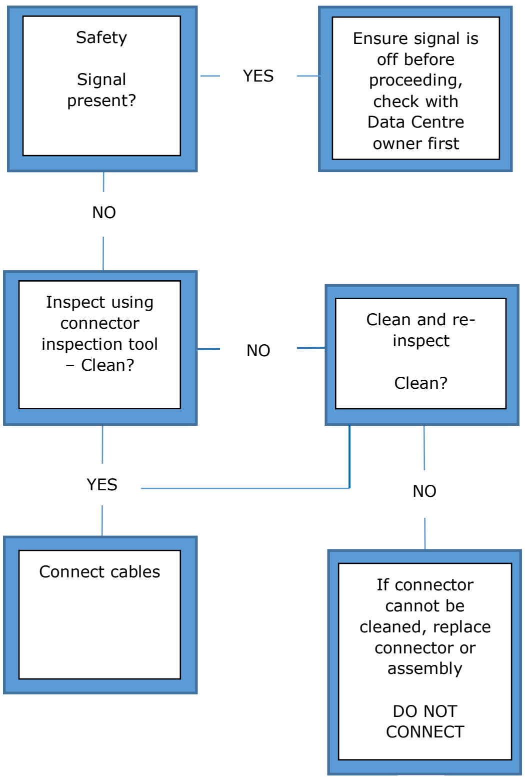
Fibre optic connector end faces can be cleaned; this is achieved in two main ways. To remove dust or other loose contaminants small cans of compressed air are used to blow dust off of the connectors, this is also useful when trying to clean connectors that are already fixed into housings prior to the insertion of a patch cord. When using products like compressed air the installer must take all safety measures recommended by the manufacturer.

It is highly recommended that the installer uses purpose made cleaning tools such as the Fujikura "one click" cleaners.

Figure 15 – One Click Cleaning Tools

Prior to connector cleaning, the installer must ensure that there is no signal being applied to the other end of the assembly or link being cleaned. A test tool such a power meter or a connector video inspection device can inform the installer whether there is a signal on the fibre at that particular time; however it is still recommended to also go to the remote end of the assembly or link, check that it isn't plugged in to anything, and mark it as "link under test" to reduce the risk of anyone plugging in a working device. The installer is also recommended to wear safety goggles at all times that reduce the risk of laser damage to the eye.

The recommended process for connector cleaning is as follows:



The use of a connector inspection tool, as shown in the following sub-section, will save an installer many hours of fault finding time and costs related to product replacement.

Unless a patch cord is inserted into a connector housing, either for actual use or for testing, a dust cap must be fitted. When dust caps are removed for installation of patch cords, always store the caps in a secure and clean container.

6.4 Inspection

All connectors, whether part of the installed cable plant or patch cords, must be inspected by the installer prior to connection into bulkhead adaptors. A connector that is dirty when plugged in will almost certainly leave some of that dirt on the connector that it is mated with. If this is in a bulkhead adapter in a patch panel or shelf it will be much more difficult to clean.

Best practice is to inspect a connector with specialist inspection devices, clean and re-inspect before inserting into a piece of test equipment or into a link or channel.

Test cords must always be inspected before connecting to links and devices when testing.

Typical equipment for the inspection of connectors is shown below.

Visual checks of connector end faces is also very useful when fault finding. Different devices are needed to view MTP/MPO and simplex LC connectors.

Figure 16 – LC Connector inspection device

7 Safety

7.1.1 Overview

Safety is of prime importance in all environments, whether that be at work or elsewhere. All installers should be aware of the safety requirements for Data Centres and their responsibilities with regards to those requirements.

This document does NOT prescribe what safety measures the installer needs to implement on a project, it merely informs the reader that it is the responsibility of the installer and its operatives to ensure that appropriate safety measures are implemented.

In addition to the Data Centre requirements installers must work in accordance with their company's own processes and Risk Assessments. In some instances an installation company may need to undertake specific Risk Assessments relating to individual projects. Prior to starting any works it is incumbent upon those working on the project to ensure that they are aware of any specific requirements.

Working within Data Centres often presents readily identifiable risks such as working at height, working in risers, lifting, and working in the presence of open floor voids. These should be documented and recognised by installers and appropriate safety measures employed to mitigate the risks.

There are also other risks related particularly to fibre optic installations that installers need to be aware of.

Most fibre optic systems now use lasers of one type or another. These lasers can cause permanent eye damage if the light energy is directed into the eye. Be warned that most laser light is NOT in the visible spectrum, therefore always treat fibre optic cores as "live" and avoid looking directly into the cores. There is no way of easily detecting if a fibre cable has light being injected into it from a source that may be metres or even kilometres away. Even if you are able to use a detector to discover whether the fibre is carrying light, you could still find that at the time of the test it had no light being transmitted, but damaging light could be present moment later when the transmitter starts sending a signal.

Further risks relate to substances used to clean fibre optic connectors such as IPA or Isopropyl Alcohol. The installer must adhere to all handling and operation requirements stated by the manufacturers of these substances.

8 Test Equipment Requirements

8.1 Test equipment overview

The primary purpose of testing is to validate that the installed cable or system will support the transmission of the intended signals.

There are many types of test devices used to measure different criteria related to fibre optic systems. At its most basic level tests are undertaken to determine continuity, polarity, length and loss of signal strength.

In order to validate fibre optic cables used on installations it is requirement that the loss in the cable or system falls within set criteria, which are detailed in the following section of this document. Length is not often an issue within Data Centres as most cables are 100 metres or less. Continuity and polarity are of course fundamental, if there is no continuity, or the polarity is incorrect, then the system will not work.

Full details of testing processes are provided in Section 9.

8.1.1 Connector inspection

Prior to undertaking any polarity or loss testing it is recommended that the end-faces of connectors be visually checked to see whether there is any contamination or damage. Any contamination or damage found should be rectified through cleaning or replacement prior to further testing. Visual checks of connector end faces is also very useful when fault finding. Different devices or adaptors may be needed to view MTP/MPO and simplex LC connectors.

Figure 17 – LC Connector inspection device

If a fault is found on a test it is always best to clean all of the connector end faces in a link and check using the connector inspection device, prior to continuing with any other fault finding.

8.1.2 Testing for continuity and polarity

Both continuity and polarity can be checked using the most basic of fibre optic testers which is often referred to as a Visual Fault Locator (VFL).

Figure 18 – Typical VFL

These devices are useful for simple checking of simplex and duplex fibre optic links.

The best way to test polarity, continuity and fibre mismatch on 12 core, MTP/MPO fibre assemblies is to use purpose made test equipment that has a 12 fibre MTP/MPO output such as the MT Tracer. This is a much faster way of testing MTP/MPO links than using the simplex VFL above.

Figure 19 – MTP/MPO 12 fibre tester

8.1.3 Testing for loss

Loss tests can be undertaken with equipment that injects light at one end of the link and measures the received light at the other, these are often referred to as Light Source and Power Meter or Optical Loss Test Set (OLTS).

Figure 20 – Typical OLTS

8.1.4 Cable and link validation

Testing to the latest requirements and standards is required for formal cable and link validation. This requires a comprehensive tester that is able to test accurately and record the results. Test equipment manufacturers that have such equipment include AFL/Noyes and Fluke, and are recommended by FibreFab.

Figure 21 – Typical link certification testers

8.1.5 Optical Time Domain Reflectometer (OTDR)

An OTDR is the an important instrument for testing fibre optic cables. It provides a visual trace of a complete link or channel showing segment length and any areas of loss or reflection such as connectors, splices, tight bends and fibre breaks. OTDRs are used for the testing of long single mode fibre optic cables and troubleshooting in the Data Centre environment. OTDRs are not recommended as the first choice for quantitative measurement of attenuation; OLTS methods are recommended as the primary test approach.

Figure 22 – Typical OTDR

9 Testing Instructions and Acceptance Requirements

9.1 Overview

Fibre optic assemblies and links must be tested following installation to ensure that the test result falls within the required parameters; however these parameters can vary according to the type of installation. This section of the document provides details of the tests required on FibreFab assemblies and links installed in Data Centres.

9.2 Installation review

The installer must review what is to be tested in order that the correct tests are undertaken. With regards to the installation there are two initial types, one is a single cable assembly or cable link with connectors at both ends and the other is where two or more cable assemblies or cable links are connected together to form a longer link or "channel".

The single cable assembly or cable link test is straightforward and simply requires the appropriate test equipment to be plugged in at each end and the test carried out.

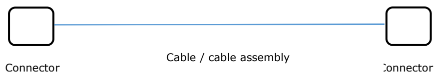


Figure 23 – Typical link

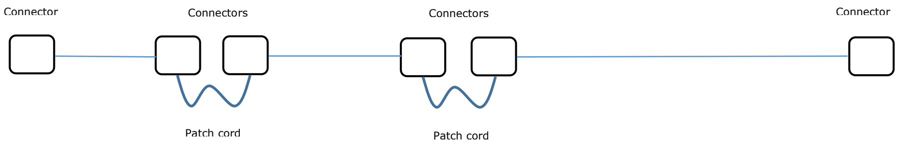


Figure 24 – Typical channel

When testing a channel the installer will need to install patch cords at each end of fixed links. The patch cords remain in the channel.

Where multiple assemblies or cable links are connected together to form a channel the installer needs to consider different criteria. When testing the individual elements of the channel can verify each section, this will not necessarily prove that the full channel will work. In this situation the installer must place all required patch cords between sections of the channel and test from end-to-end; therefore the installer must be aware of what the Data Centre owner requires in terms of the complete channel.

9.3 Acceptance requirements

The installer must agree with FibreFab and the Data Centre owner what the acceptance criteria are for a specific assembly or link. There are different loss criteria based on applications such as 10 Gigabit Ethernet and 40 Gigabit Ethernet, whilst the relevant standards have their own requirements, typically based on the maximum length loss figure.

Different loss budgets also apply to multimode and single mode links or channels.

For OM3 links operating at 10G or 40G, the transmission wavelength is centred at 850nm. Attenuation testing must be performed at this wavelength. FibreFab advises that 1300nm testing is not required unless 1300nm applications are anticipated or such testing is directed by authorised personnel.

For OS2 links the loss must not exceed the stated figure at either of its main wavelengths of 1310nm and 1550nm.

The standards committees have created four different "classes" for fibre optic systems, these being OF-100; OF-300; OF-500 and OF-2000 where these classes relate to the length of a channel over which applications, such as 10Gigabit Ethernet, can be designed to work. Using this approach an electronic equipment manufacturer can design products to be compliant to, for example, OF-300. So a 10Gigabit Ethernet transceiver in this case would be designed to work over a maximum link length of 300 metres.

These classes can be used as test parameters as they are included in some test equipment that has pre-set standards to test to, which also provide pass/fail reports.

Typical, full length channel, standards stated, maximum attenuation figures are as follows:

	Maximum Channel Attenuation (dB)			
Class	**850 nm**	**1300 nm**	**1310**	**1550**
OF-100	1.85	1.65	-	-
OF-300	2.55	1.95	1.8	1.8
OF-500	3.25	2.25	2	2
OF-2000	8.5	4.5	3.5	3.5

Table 1 – Fibre Class Channel Performance

It is becoming increasingly common to also state maximum attenuation values according to the application to be supported, as well as the figures given in Table 1. In this case the installer will be required to ensure that the installed channel does not exceed these attenuation figures.

The total loss in a channel is also often referred to as "Insertion Loss".

For OM3 multimode the maximum attenuation figures by application are as follows:

Application	Length (m)	Maximum Attenuation (dB)
100Base-LX (1300nm)	2000	6.3
1000Base-SX (850nm)	550	3.56
10Gbase-SR/SW (850nm)	300	2.6
40Gbase-SR (850nm)	100	1.9

Table 2 – OM3 attenuation by application

For OS2 singlemode the maximum attenuation figures by application are as follows:

Application	Length (m)	Maximum Attenuation (dB)
1000Base-LX (1310nm)	5000	4.56
10Gbase-LX4 (1310nm)	10,000	6.2
40Gbase-LX4 (850nm)	10,000	6.7

Table 3 – OS2 attenuation by application

It is preferable however to ensure that losses are in-line with what might be expected commensurate with the length of the link and the number of connectors. For instance a four connector link at 100 metres might have a link loss of 1.85dB but a two connector link at 20 metres might be expected to have a loss of 0.67dB.

9.4 Multiple Connection Testing and Troubleshooting

When testing a channel made up of several different sections of pre-terminated links, the installer may find that a relatively small excess Insertion Loss (IL) failure is reported, but the failure cannot be associated with one particular connector or assembly.

When experiencing this type of fault it is best to first check the number of assemblies and connectors in the channel to see what level of IL might be expected.

What IL should be expected? The attenuation to be expected at each point of connection is not the IL value found on the product test certificate. The test certificate shows the loss measured in the factory using a high precision test reference lead. Actual IL is a property of the specific combination both connectors in the mated pair. Change either connector and different IL will be measured.

A group of products made using common specification components and processes can be characterised by an expected "random mating" IL distribution. Average and worst case random mating performance give a good indication of what IL to expect in real use. Average random mating IL is lower than the acceptance test limit but worst case random mating is typically twice the acceptance limit. "Worst case" is usually defined as the IL value for which 97% of random mating results will be within this value.

When a channel is made up of multiple connections, the expected total attenuation can be estimated using statistical methods. Consider a channel with four connections. It is very unlikely that all four mated pairs will be at the worst case limit. For this reason, it is overly conservative to plan links and channels by multiplying the worst case IL by the number of connectors.

Please see **Appendix I** which provides tables of product capability based loss limits. These are statistically estimated "worst case" loss limits for links comprising various numbers and types of connector and link length. Use this table when deciding whether further investigation into losses higher than expected is likely to prove beneficial.

Even if a link tests within the allowed limit, it is always recommended that further investigation be undertaken when encountering losses that are higher than expected based on the tables.

These tables can also be used as a reference guide when designing different links and channels. If a design is being considered that is close to the maximum expected based on connector types and number and cable length, alternate designs should be considered. It is reasonable to expect that more than 97% of links can be expected to be within the IL limit as calculated from these tables; however it is always difficult to account for the impact of site conditions such as tight bends in fibres and connectors not being as clean as they might be. The installer is always advised to err on the side of caution during design stages.

9.5 Tests

The tests in the following sub-sections should be carried out.

9.5.1 End face check

Following completion of the safety checks and cleaning procedures detailed above the installer should undertake checks of the quality of the connector end faces. Whilst it is possible to view connector end faces using a purpose made microscope, the connector inspection device detailed in the previous section of this document is highly recommended. This device also better protects the user from the possibility of eye damage should the connector being checked be connected to a signal carrying fibre.

The connector end face should be perfectly clean and free from dirt, grease, oils, pitting, scratching and the like. It is possible that some pitting or scratching might not impair the performance of the connector, providing that the pitting or scratching is minor and away from the fibre core itself. Scratches in the cladding area that could be deemed acceptable must be less than 3 microns and other defects less than 2 microns or a maximum of five defects between 2 and 5 microns. Scratches in the ceramic or polymer connector area should not cause a problem and nor should defects less than 10 microns. It is really only possible to measure such defects using a connector inspection device.

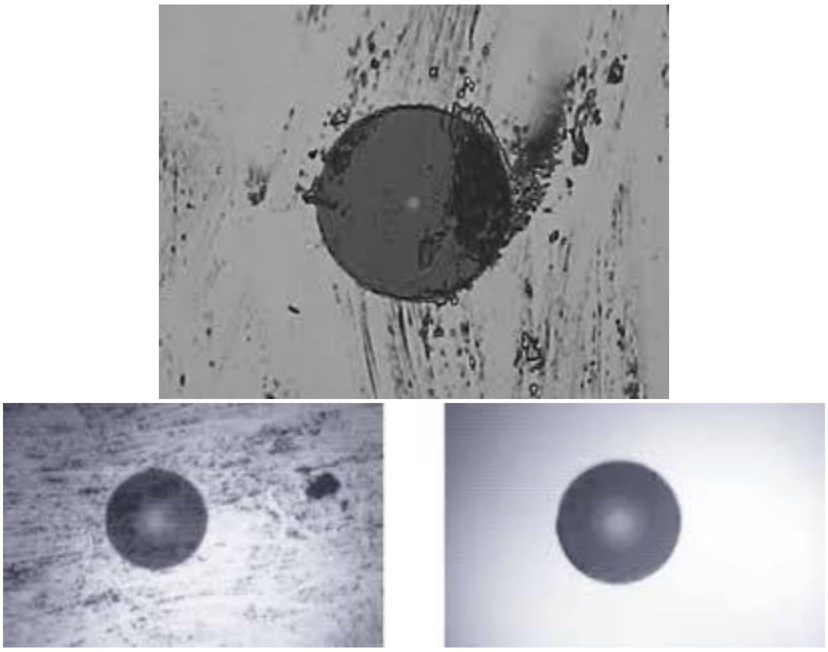


Figure 25 – Contaminated and clean connector end faces

Further details regarding connector end face inspection criteria can be found in the IEC standard 61300-3-35.

9.5.2 Polarity check

The polarity of the fibre optic links must be checked by the installer to ensure that when the Data Centre owner connects a device to the link or channel that it works correctly, first time. As mentioned previously in this document a transmitter must connect to a receiver and vice-versa. Historically, in two-fibre circuits, it was common for fibre links to be connected A to A and B to B, and when the final patch cord connection was made the ends were swapped round if the link didn't work.

Duplex fibre connectors, like the LC, are much more difficult to swap so in most two fibre circuits a cross is placed in the fixed cabling link (A to B and B to A), and all patch cords are crossed, and therefore with this making an odd number of crosses the polarity is made correct.

This cross over methodology is the one recommended by FibreFab.

Where MTP fibre assemblies are used the polarity is managed by the FibreFab termination facility, and the pair swap is put in place during manufacture so that position 1 at end A is position 2 at end B and vice versa; position 3 at end A is position 4 at end B and vice versa; and so on through the 12 positions.

When testing MTP solutions the installer is recommended to use the 12 fibre tester detailed in the previous section.

Where a simple light test is used the installer will need to have an engineer at both ends of the link to confirm the polarity.

Should a pre-terminated MTP assembly have a problem with polarity the installer must contact FibreFab for further advice, after checking the test leads and any inserted patch cords for any errors. The installer must rectify any polarity problems encountered on cable links that it terminates itself.

The installer should be aware that different polarity requirements can exist for 10, 40 and 100Gigabit transmission. For instance, a typical 10Gigabit link is formed of a single fibre transmit and a single fibre receive; however a 40Gigabit link could be formed of 4 cores transmit and 4 cores receive with, on an MPO/MTP link, 4 cores spare. The installer MUST be aware of what type of link the Data Centre owner requires and order/install/test products accordingly.

The polarity test results should be recorded, detailing what tests have been undertaken and what the results were. One copy of the test report should be given to the Data Centre owner with the installer retaining another.

9.5.3 Loss test – general

The overall loss (referred to as attenuation or insertion loss) of a link or channel must be measured to ensure that it falls within the maximum figure allowed. As the amount of loss acceptable in a link has become much less in recent years, testing has needed to become much more accurate. Along with the decrease in the amount of loss that is acceptable, the use of Vertical Cavity Surface Emitting Lasers (VCSELs) in electronic equipment has introduced its own challenges with regards to testing.

The recommended test equipment for measuring loss is a link certification tester, as detailed in the previous section of this document. A device of this type usually has pre-set parameters built into the software to make it easy for the installer to undertake the appropriate test. The device will normally keep a record of the test results for later download.

Following the cleaning mentioned earlier there are steps that MUST be followed when undertaking loss tests, these steps are as follows:

- Check that the tester is within its calibration period, it is normal for testers to need re-calibration annually

- Check that the appropriate test leads are available for the type of link being tested
- Test leads have a finite lifetime based on the number of insertions or tests, the installer must ensure that the test leads are within the lifetime recommended by the manufacturer of the tester
- The test equipment must be zero referenced prior to undertaking any testing. The zero referencing process can vary but the following process detailed below is the one recommended by FibreFab and detailed in IEC 14763-3
- Insert test leads into the link under test, run the test and record the result
- If the link fails, undertake fault finding and, once repaired, run the test again from the start of the list above
- If the fault cannot be rectified contact FibreFab for further advice or product return information

9.5.4 Loss test – mandrel wraps

Earlier in this document reference was made to high and low order modes relating to light transmission through a fibre. When a light pulse is injected into a fibre core there can be modes that that hit the cladding at angles that result in those modes entering the cladding, instead of being reflected back into the core. Light energy that enters the cladding is not recoverable as part of the original light pulse which has therefore lost some of its power.

In earlier multimode fibre optic systems this loss of power didn't present a significant problem as there was a greater loss budget, or headroom, typically around 9dB for many applications. With today's low loss budgets this loss of light energy could indicate that a link or channel exceeds its permitted loss, but in fact the cables and connectors are within limits.

To overcome this problem a method was found that removed or "stripped out" from testing the modes of light that escape into the cladding at launch. This method was mandrel wraps. These mandrel wraps are plastic reels, with a diameter of 18mm to 25mm around which the test lead is wrapped at the transmit end.

Figure 26 – Typical mandrel wrap

The installer must use a mandrel wrap when testing which must be as specified by the tester equipment manufacturer as the diameter of the mandrel wrap will vary according to the test lead and fibre type used.

For general use, FibreFab recommend use of a 22mm mandrel with standard multimode fibre and 2mm cable. It is not recommended to use test leads manufactured using reduced bend sensitivity fibre.

9.5.5 Loss test – Encircled Flux

The increased use of 10G and 40G systems now requires even greater testing accuracy, and this requires improved accuracy of the light launch into the fibre itself.

The mandrel wrap, as detailed above, is effective in removing unwanted light modes from the test result itself; however Encircled Flux takes this a step further.

The IEEE has issued specifications that define the percentages of light energy that are acceptable in various areas of the fibre core. The result of this is the required improvement in tester accuracy, as the launch "condition" is controlled and unwanted modes are greatly reduced.

FibreFab offers an Encircled Flux test kit which allows the installer to simply plug in the Encircled Flux controllers prior to undertaking the loss test. The Encircled Flux test also eliminates the need for mandrel wraps.

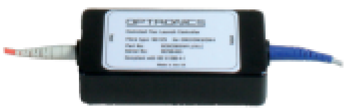


Figure 27 – Encircled Flux launch controller

9.5.6 Loss test – zero referencing

Fibre optic test equipment must be zero referenced prior to undertaking any testing and again if the test leads are removed from the tester or if it is powered off and then on again during a sequence of tests.

Prior to zero referencing the light source and power meter must both be switched on for approximately 10 minutes, or other such time as the tester manufacturer states, to allow them to settle. They should also be at the same temperature as the room where the testing in being carried out, brining testers in from a cold environment to a warm one and testing immediately is likely to lead to testing errors.

Zero referencing coordinates the light source tester with the receiving power meter so that any power loss, due to test leads and the mandrel wrap (or encircled flux controller), between the light source and the power meter is effectively cancelled out, as the amount of light received by the power meter is then registered as "zero". Clearly then when the tester is connected to a link or channel a loss will be seen on the test equipment, such as -0.8dB.

The zero referencing test set up is shown in the figure below.

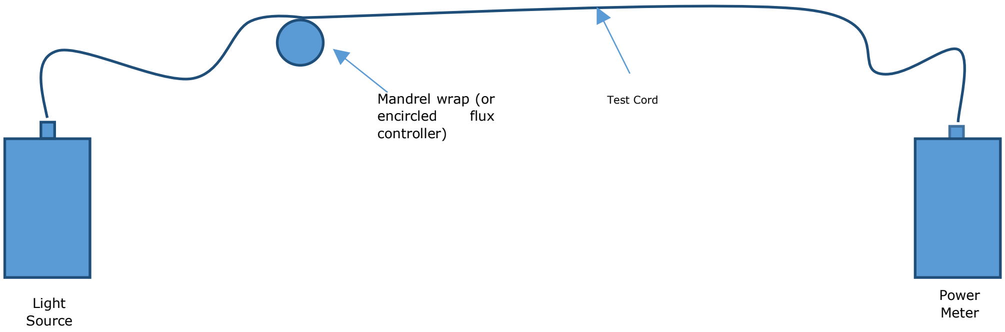


Figure 28 – Zero reference test reference set-up

Most optical loss testers will require the installer to set the light source in the dBm range, this is measurement of power. The power meter is then adjusted until it shows zero.

Following completion of the zero reference the connector at the power meter end is the only one that is to be removed. If the test cord is removed from the light source the zero reference procedure must be carried out again.

9.5.7 Loss test – one-cord test reference

The process described above for zero referencing is also called the one-cord test reference method, which the method preferred by most standards organisations. The figure above shows test referencing for a single fibre test. Some testers have dual fibre capability with light source and power meter at both ends. In this case the mandrel wrap (or encircled flux controller) is placed on the transmit fibre at each end. The one-cord method requires that the power meter adaptor type be compatible with the reference cord connector.

9.5.8 Loss test – two-cord test reference

There is a further test method sometimes used, which is referred to as a "two cord" method. As the name suggests this uses two reference cords, one at the source end and one at the power meter end.

The source end is set up the same as for the one-cord method described above but in the two-cord method the power meter end also has a reference cord attached. The two cords are connected together using an in-line connector and the zero reference made as described above.

Once the zero reference has been made the connector mating the two cords is removed; however the cords themselves must not be removed from the light source or the power meter. If either is removed the zero reference must be carried out again.

The two-cord method can often provide a lower loss figure than the one-cord method. This is due to the loss created by the in-line connector during referencing being deducted from the loss test result as it is no longer in place. Conversely, the one-cord method can often provide a slightly worse test result due to the addition of the reference cord at the power meter end that was not in place during the zero reference process. This is usually a much lower loss figure than found with the in-line connector in the two-cord method. The one-cord method can therefore be more repeatable than the two cord method, but it may err on the side of caution.

The two-cord method is often used where the light source and power meter have different connectors than the cable plant under test and also when testing long distance single mode circuits where, after zero referencing at the start of the day, the source and power meter may not be together again until the end of the day's testing.

The preferred FibreFab process is the one-cord method and this process will be reflected in this document. The two cord method is an acceptable alternate method and may be used when test equipment connectors are different than installed network connectors.

9.5.9 Loss test procedure

Once the zero reference is complete remove the test cord from the power meter and plug this into one end of the link under test. Plug the power meter into the other end using another test reference cord. Ensure that all connectors are cleaned again prior to insertion and, in addition, clean the connectors in the bulkhead adaptors at each end of the link under test.

Run the loss test according to the test equipment manufacturer's instructions and record the result. The light source should be set to the dBm range and the power meter will then record the difference in power transmitted and power received, and report this as loss measured in dB.

For both single mode and multimode, testing must be undertaken at the intended wavelength of use. This will usually be 850nm for multimode and can be either 1310nm or 1550nm for single mode.

For multimode, supplemental testing at 1300nm may be specified by the Data Centre owner. The loss should be within the acceptable FibreFab parameters; at 850nm this is 1.9dB and at 1300nm it is 1.65db.

For single mode, the testing FibreFab recommends testing of fixed links and installed trunks at both 1310nm and 1550nm. The loss at both wavelengths should be within the acceptable FibreFab parameters; at both 1310nm and at 1550nm it is 1.8db.

A typical test set up is shown in the figure below.

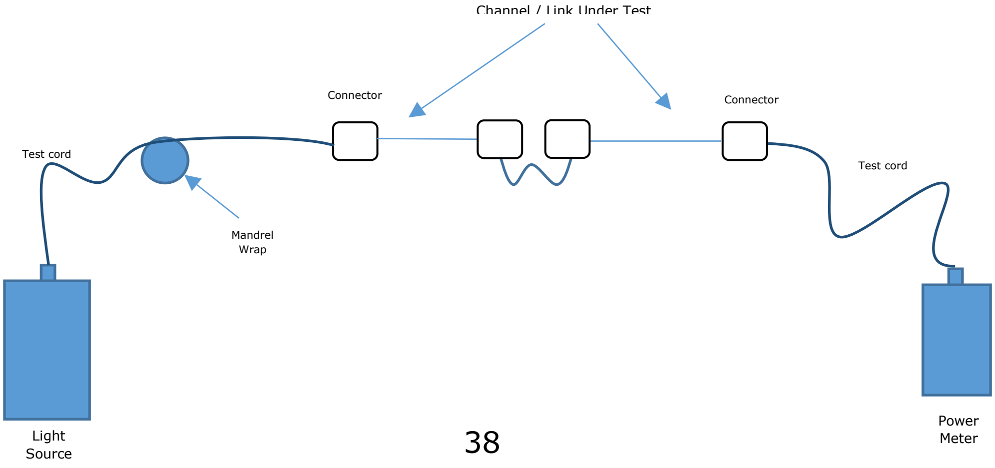


Figure 29 – Typical test set-up

The test result must reference the labelling on the link under test. Wherever possible test results should be recorded in software format and issued to the Data Centre owner with the installer retaining another copy.

Following completion of the test the installer can move on to the next core to be tested; however test cord connectors must always be cleaned prior to insertion into the next link, along with the connectors in the bulkhead adaptor.

Following completion of all tests from one end the tests are to be repeated by swapping the light source and power meter around so that light is injected into the link from the opposite direction.

Ensure that all dust caps are replaced immediately after the test on each core is completed, this reduces the risk of contamination of connector end faces.

9.6 OTDR test

An OTDR, such as the AFL/Optronics M310, is a highly sensitive and accurate item of test equipment. OTDRs were primarily used in long distance, single mode telecommunications environments; however in recent years they have been used more frequently in multimode LAN environments.

A primary use of OTDRS in Data Centres is accurate location of instances of high loss in a link, which enables the testing teamto work out where in the link the high loss event(s) is occurring.

The way that an OTDR works is by measuring the reflected light that it receives and computing that against the signal reflection propagation time to provide the distance to the loss event. This signal reflection is called backscattering and happens at any type of "event" on the fibre link, including an open circuit.

When used for testing LAN links it is a requirement that the OTDR has a launch cable attached at one end of the link and a receive cable at the other. These launch and receive cables are usually over 250 metres long and are provided as small devices, in which the fibre is wound, with fibre tails at each end for connection into the OTDR and the cable plant at the launch end and only into the link at the far end.

The use of these launch cables enables the operator to isolate the link on the OTDR screen and accurately measure the link loss, including the connectors at both ends which cannot be accomplished without theses launch cables.

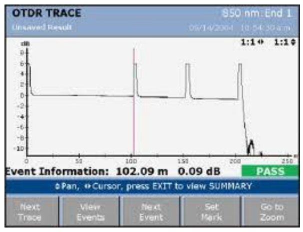


Figure 30 – Typical OTDR trace

It is the recommendation of FibreFab and that OTDRs in the data centre are used for testing only for long links (>300m) and for troubleshooting links greater than 30m.

10 Troubleshooting

10.1 General

Troubleshooting is always best undertaken using a methodical approach; this will generally reduce the time and effort expended in locating a fault.

The information provided in this section will assist the installer in this approach.

10.2 Fault finding equipment

The recommended order of use of fault finding equipment can vary depending upon the fault but in most instances the following is the best order:

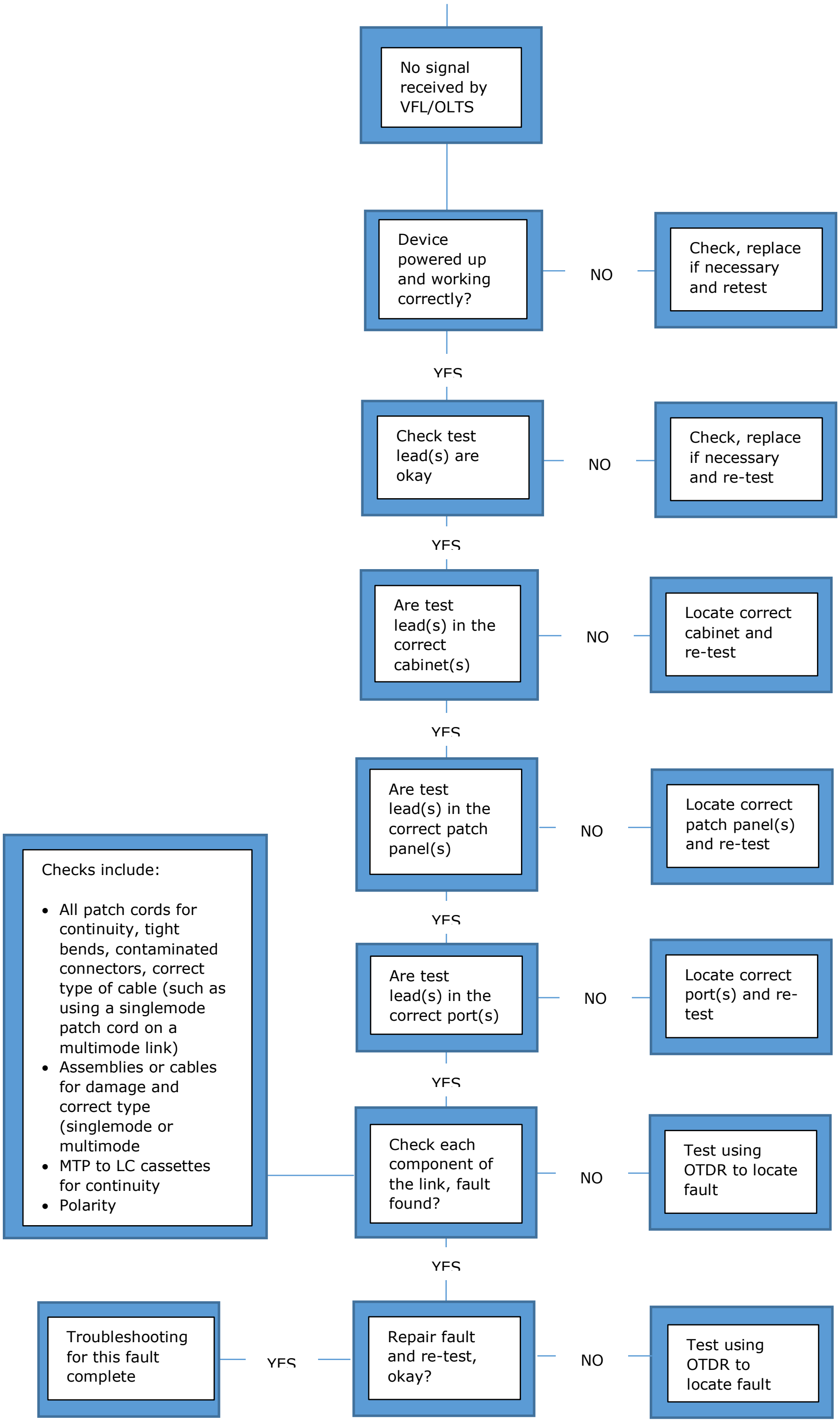
- Visual, although not initially considered a test tool, the eyes are of course vitally important for checking basic criteria
- VFL, a visual fault locater is recommended for checking polarity, connectivity and cable breaks
- OLTS, an optical loss test set is useful for checking loss on individual elements of a failed channel and for re-checking following any disconnection/reconnection or repairs
- OTDR, an optical time domain reflectometer is useful in identifying where any high loss instances are in a failed link or channel

10.3 Fault identification

The initial identification of the type of fault is fundamental in adopting the optimum approach to fault finding. This document initially breaks a fault down into two basic types which are "no signal received" and "signal received but outside of parameters or failed". Following the steps below will assist the installer in adopting a methodical approach to fault finding.

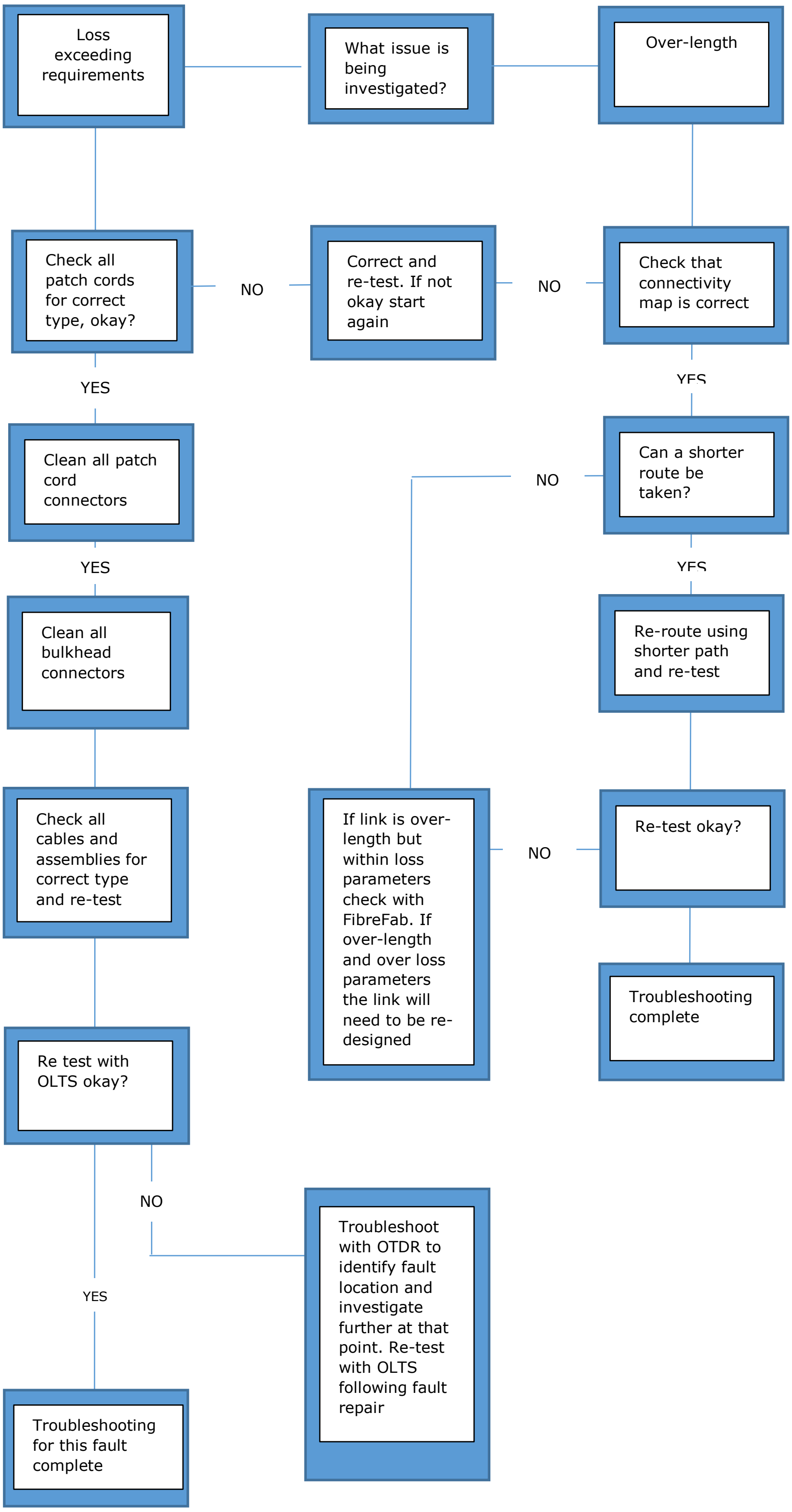
10.4 Fault – "no signal"

Troubleshooting using a visual fault locator is usually the simplest approach to a no signal fault, alternatively an optical loss test set can be used. Remember to clean connectors each time they are inserted. Significant debris or dirt on a connector could block a signal completely.



10.5 Fault – "signal outside of parameters or fail"

Troubleshooting this type of fault is usually best accomplished using an OLTS or and OTDR. Remember to clean connectors each time they are inserted. Debris or dirt on a connector can cause significant loss.



10.6 Summary

Following the processes outlined above should allow the installer to identify likely faults and take the necessary action to repair. Checking the basics first, such as the test equipment itself and ensuring correct and clean connections, often clears many faults.

Take a measured and methodical approach and record actions taken as the fault finding proceeds, this helps to prevent doing the same things twice. Having a connectivity map of the link or channel in question is also very useful as possible fault locations can be “ticked off” as troubleshooting progresses.

Should the installer fail to find the reason for a particular fault they should contact FibreFab for further advice.

AFL HYPERSCALE.

11 List of Figures and tables

11.1 Tables

12 Appendices

1 - Recommended limits based on product capability

2 - Installation and testing check lists

3 - RMA Procedure

APPENDIX 1

Product Capability Based Loss Limits

		Cable Length in Meters											
		10		20		30		40		50		100	
	No.	850	1300	850	1300	850	1300	850	1300	850	1300	850	1300
LC MM	1	0.47	0.45	0.50	0.46	0.53	0.47	0.56	0.48	0.59	0.49	0.74	0.54
	2	0.77	0.75	0.80	0.76	0.83	0.77	0.86	0.78	0.89	0.79	1.04	0.84
	3	1.05	1.03	1.08	1.04	1.11	1.05	1.14	1.06	1.17	1.07	1.32	1.12
	4	1.31	1.29	1.34	1.30	1.37	1.31	1.40	1.32	1.43	1.33	1.58	1.38
OM3@850	5	1.57	1.55	1.60	1.56	1.63	1.57	1.66	1.58	1.69	1.59	1.84	1.64
OM3@1300	6	1.82	1.80	1.85	1.81	1.88	1.82	1.91	1.83	1.94	1.84	2.09	1.89
	7	2.06	2.04	2.09	2.05	2.12	2.06	2.15	2.07	2.18	2.08	2.33	2.13
	8	2.31	2.29	2.34	2.30	2.37	2.31	2.40	2.32	2.43	2.33	2.58	2.38
LCLL MM	1	0.31	0.29	0.34	0.30	0.37	0.31	0.40	0.32	0.43	0.33	0.58	0.38
	2	0.48	0.46	0.51	0.47	0.54	0.48	0.57	0.49	0.60	0.50	0.75	0.55
	3	0.64	0.62	0.67	0.63	0.70	0.64	0.73	0.65	0.76	0.66	0.91	0.71
	4	0.79	0.77	0.82	0.78	0.85	0.79	0.88	0.80	0.91	0.81	1.06	0.86
	5	0.93	0.91	0.96	0.92	0.99	0.93	1.02	0.94	1.05	0.95	1.20	1.00
	6	1.07	1.05	1.10	1.06	1.13	1.07	1.16	1.08	1.19	1.09	1.34	1.14
	7	1.21	1.19	1.24	1.20	1.27	1.21	1.30	1.22	1.33	1.23	1.48	1.28
	8	1.34	1.32	1.37	1.33	1.40	1.34	1.43	1.35	1.46	1.36	1.61	1.41

		Cable Length in Meters											
		10		20		30		40		50		100	
	No.	850	1300	850	1300	850	1300	850	1300	850	1300	850	1300
MTP MM	1	0.71	0.69	0.74	0.70	0.77	0.71	0.80	0.72	0.83	0.73	0.98	0.78
	2	1.11	1.09	1.14	1.10	1.17	1.11	1.20	1.12	1.23	1.13	1.38	1.18
	3	1.46	1.44	1.49	1.45	1.52	1.46	1.55	1.47	1.58	1.48	1.73	1.53
	4	1.79	1.77	1.82	1.78	1.85	1.79	1.88	1.80	1.91	1.81	2.06	1.86
OM3@850	5	2.10	2.08	2.13	2.09	2.16	2.10	2.19	2.11	2.22	2.12	2.37	2.17
OM3@1300	6	2.41	2.39	2.44	2.40	2.47	2.41	2.50	2.42	2.53	2.43	2.68	2.48
	7	2.70	2.68	2.73	2.69	2.76	2.70	2.79	2.71	2.82	2.72	2.97	2.77
	8	2.99	2.97	3.02	2.98	3.05	2.99	3.08	3.00	3.11	3.01	3.26	3.06
MTPLL MM	1	0.42	0.40	0.45	0.41	0.48	0.42	0.51	0.43	0.54	0.44	0.69	0.49
	2	0.67	0.65	0.70	0.66	0.73	0.67	0.76	0.68	0.79	0.69	0.94	0.74
	3	0.90	0.88	0.93	0.89	0.96	0.90	0.99	0.91	1.02	0.92	1.17	0.97
	4	1.11	1.09	1.14	1.10	1.17	1.11	1.20	1.12	1.23	1.13	1.38	1.18
	5	1.32	1.30	1.35	1.31	1.38	1.32	1.41	1.33	1.44	1.34	1.59	1.39
	6	1.52	1.50	1.55	1.51	1.58	1.52	1.61	1.53	1.64	1.54	1.79	1.59
	7	1.71	1.69	1.74	1.70	1.77	1.71	1.80	1.72	1.83	1.73	1.98	1.78
	8	1.91	1.89	1.94	1.90	1.97	1.91	2.00	1.92	2.03	1.93	2.18	1.98

APPENDIX 2

INSTALLATION AND TEST CHECK SHEETS

	DESCRIPTION	COMPLETE
PRE-TEST	Key dates identified (e.g. start, finish)	
	Key personnel identified and contact details available	
	Site access process agreed	
	Staff security checks carried out	
	Site passes arranged	
	Vehicle access agreed if required	
	Appropriate test equipment available (VFL; OLTS; End-face; OTDR)	
	Test equipment within calibration period	
	Test cords within usage parameters (number of insertions)	
	Appropriate test lead mandrels available	
	Correct test cords available (OM3, OS2, LC, SC, MPO etc.)	
	Test equipment operating instructions available	
	Test team trained in operation of testers being used	
	Test plan created	
	Cleaning equipment available ("one click"; compressed air; lint free alcohol wipes etc.)	
	Installation plans and labelling scheme available	
	Test and pass/fail criteria understood	
	Safety equipment available (e.g. goggles)	
	Method statements and risk assessments completed if required	
TESTING		
	Confirm links to be tested	
	Switch on test equipment and allow to reach room temperature	
	Removal of any patch cords in order to test MUST be agree with JET	
	Check that any link to be tested is not "live"	
	Mark links at remote end as "link under test"	
	Remove dust caps on link to be tested and retain in sealed container	
	Clean any bulkhead connector end face	
	Clean any patch and/or test cords	
	Check end faces of connectors for cleanliness and no damage	
	Ensure OLTS has been switch on for at least 10 minutes	
	Fit appropriate mandrel to test cord where relevant	
	Zero reference OLTS using "one jumper" method	
	Set OLTS to correct test parameters for link under test	
	Check all test cords for cleanliness and correct type for test	
	Check polarity of link using VFL or OLTS	
	If polarity is okay insert Light Source and Power Meter at each end of link	

	Test for link loss and record result on tester or paper with link ID	
	Mark any failed links for troubleshooting	
	Clean connectors following testing	
	Replace all dust caps	
	Store test results	
TROUBLESHOOTING	Select appropriate test equipment for fault	
	Follow process above to set up test equipment	
	Removal of any patch cords in order to test MUST be agreed with the Data Centre owner	
	Check that any link to be tested is not “live”	
	Mark links at remote end as “link under test”	
	Remove dust caps on link to be tested and retain in sealed container	
	Clean any bulkhead connector end face	
	Clean any patch and/or test cords	
	Check end faces of connectors for cleanliness and no damage	
	Ensure OLTS has been switch on for at least 10 minutes	
	Fit appropriate mandrel to test cord where relevant	
	Zero reference OLTS using “one jumper” method	
	Set OLTS to correct test parameters for link under test	
	For polarity errors check all patch cords and sections of link with VFL	
	For no continuity check all patch cords and sections of link with VFL	
	For high loss event check all patch cords and sections of link with OLTS	
	If OLTS fails to find high loss event use OTDR to identify exact location	
	Effect repair according to type of fault found	
	If fault is found in a pre-terminated assembly contact FibreFab for return	
	Once fault is repaired, re-test and record result	
	Clean connectors following testing	
	Replace all dust caps	
	Store test results	
POST-TEST	Issue electronic format test results to JET Data Centre owner	
	Issue copies of FibreFab assembly test certificates to JET Data Centre owner	
	Store test results on installers system	
	Manage any returns/replacement process (RMA) with FibreFab	

APPENDIX 3

RMA PROCEDURE

Contact your FibreFab representative with the following information:

1. Purchase Order Number
2. Product part number and description
3. Failure description (e.g. quantity incorrect, damaged in shipment, excess loss, etc.)
4. Provide as much detail as possible
5. Request for return, replacement, refund or other action
6. FibreFab will respond within one working day with advise on response to request and return shipping details as appropriate
7. In the event of any issues, please contact Alan.Keizer@fibrefab.com or Alan.Richardson@fibrefab.com