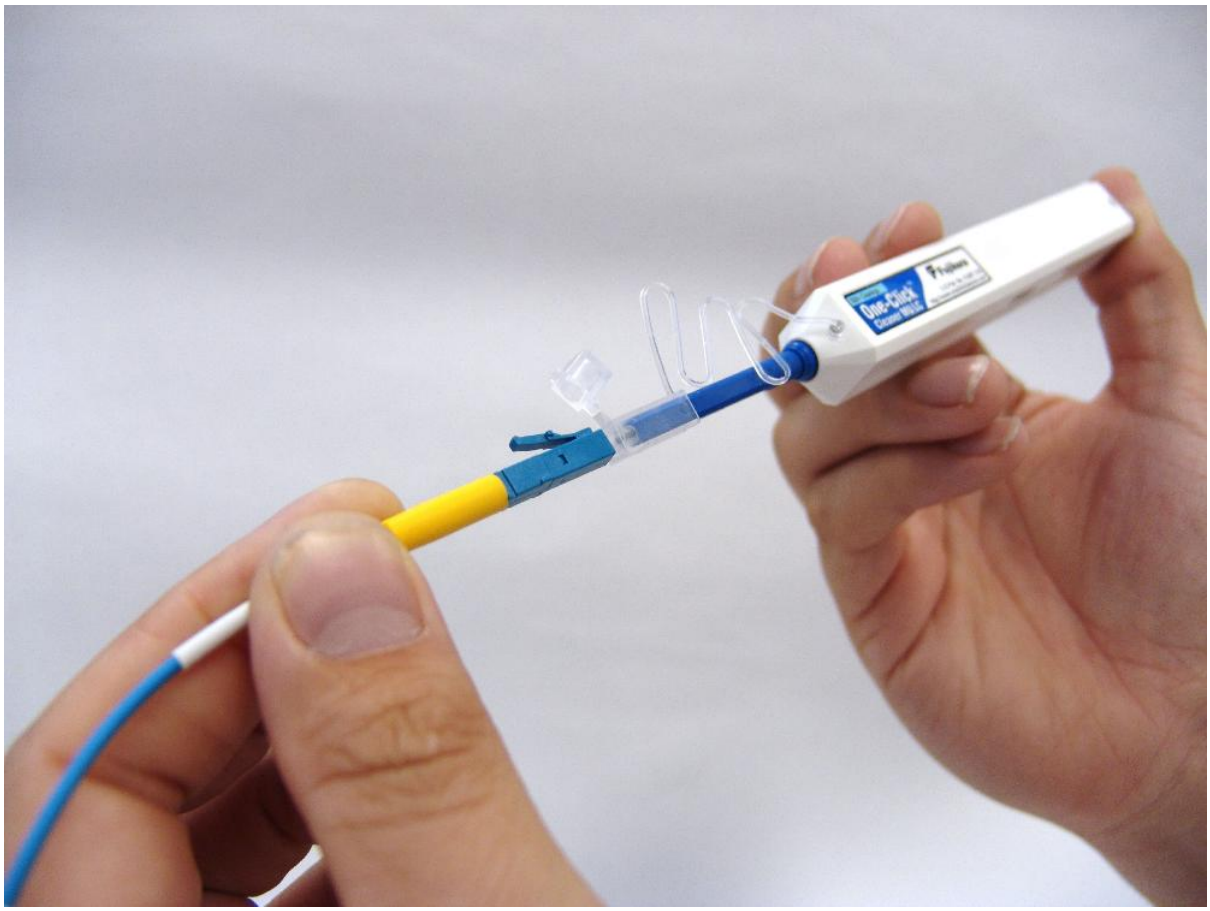
LONG READ – CLEANLINESS IS A VIRTUE

You can't see it. You can't sense it. Until later. It's impossible to distinguish a dirty optical connector from a clean one with the unaided eye, but the optical system will be handicapped if it gets dirty. A few dirty connectors in a system may create as much attenuation as the whole 37 miles of SUNET between Stockholm and Uppsala. Of course it won't work!

It's all about the fact that dust, pollen, loose flakes of skin, mites, fat and other stuff that we humans naturally surround ourselves with all the time, isn't transparent. If it sticks to the front face of an optical connector, laser light won't get trough and the connection is degraded. If there is a lot of dirt, the connectors you are trying to connect, such as in a patch panel, won't touch each other, rendering all communication impossible, or sporadic at best. If you are in luck, the result is "only" performance degradation.

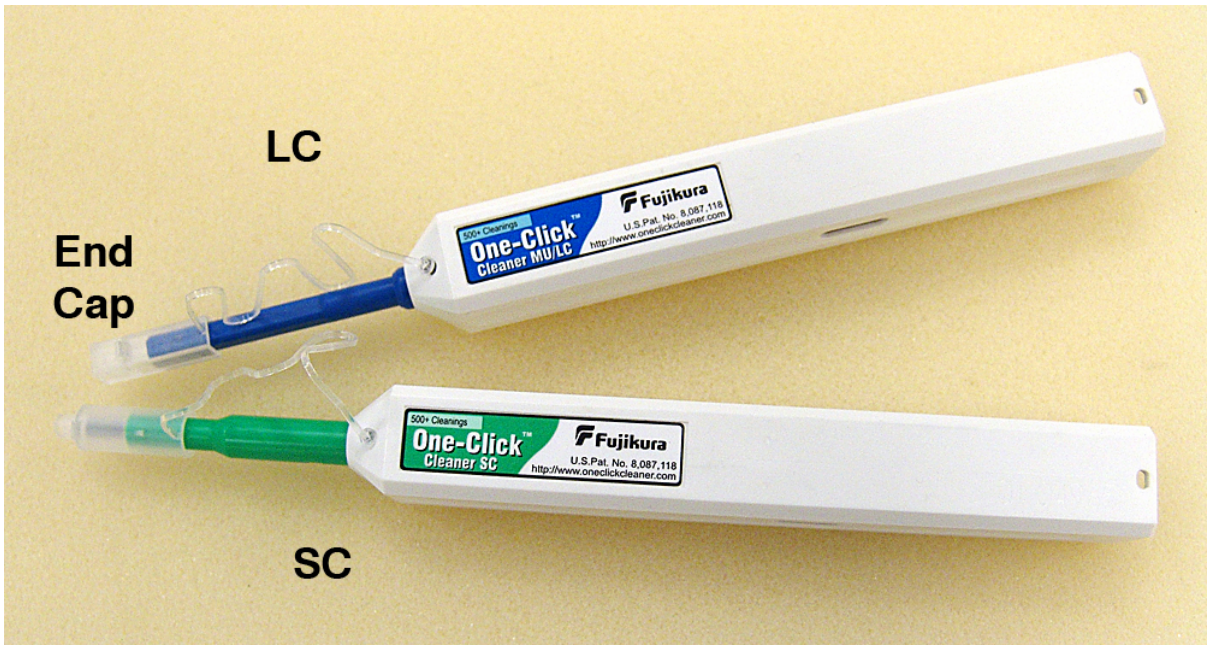


As soon as you take the dust cap off a fibre optic connector, it is vulnerable to attack. The same goes for patch panels, which may not necessarily be clean after installation. Dirt can even be transferred between insufficiently cleaned connectors.

Distances are microscopic. A fibre core is some 9 micrometers in diameter and the mating connectors must be centred within parts of a micrometer. As they meet inside a patch panel, they must mate perfectly. The allowable distance is in the order of light wavelengths, that is, a few hundred nanometres. Scratches that may render the connector unusable are also in the range of light wavelengths.

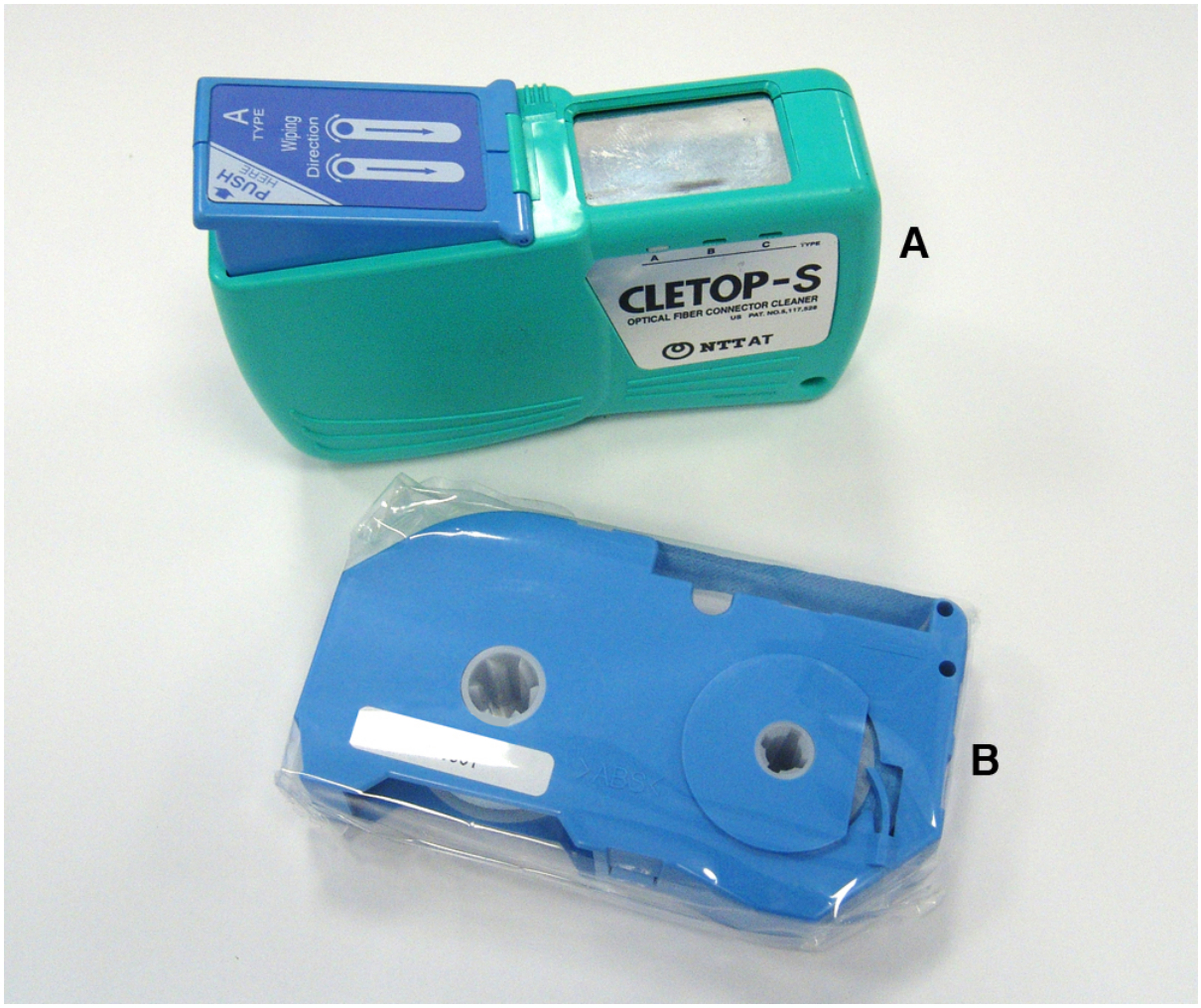
CLEANING EQUIPMENT

There are lots of types of cleaning utensils on the market – from one-click cleaning pens for lightly soiled connectors, to propanol and wet wipes for heavily soiled surfaces.

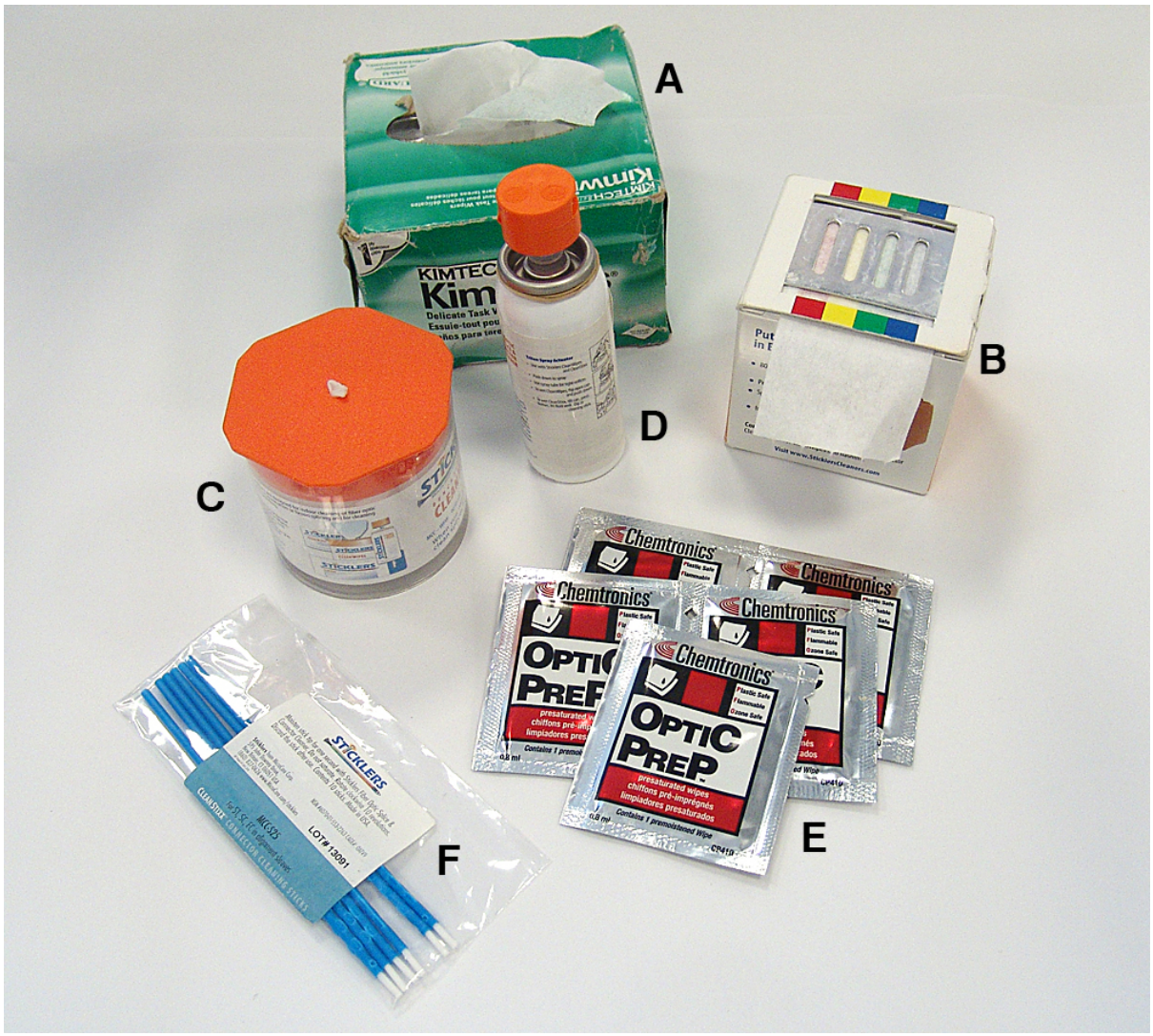


The pen-style click cleaner is a dry, sealed, all-in-one product. There are several types for various connectors, like the LC and SC shown above. It contains everything needed, and is used with its end cap on for male connectors, and the cap off for female connectors (patch panels and transceivers).

To use it, just press the pen against the connector until it clicks. A cleaning tip will spring forth and a small silk ribbon will spin around and absorb the dirt. The ribbon will then be wound onto a receiving spool. The pen is good for some 700-800 clicks. When it is spent and must be discarded, it indicates this by ceasing to click.



The cassette type cleaner (A) is slightly bigger, needs a few manual steps and somewhat more experience to use. The application force needed is different for various makes, which takes some experimenting. On the other hand, this device works on dirtier connectors. The downside is that it only works for male connectors. When the inner tape cartridge (B) is spent, it must be exchanged. The tape cartridge is good for some 400 clicks.



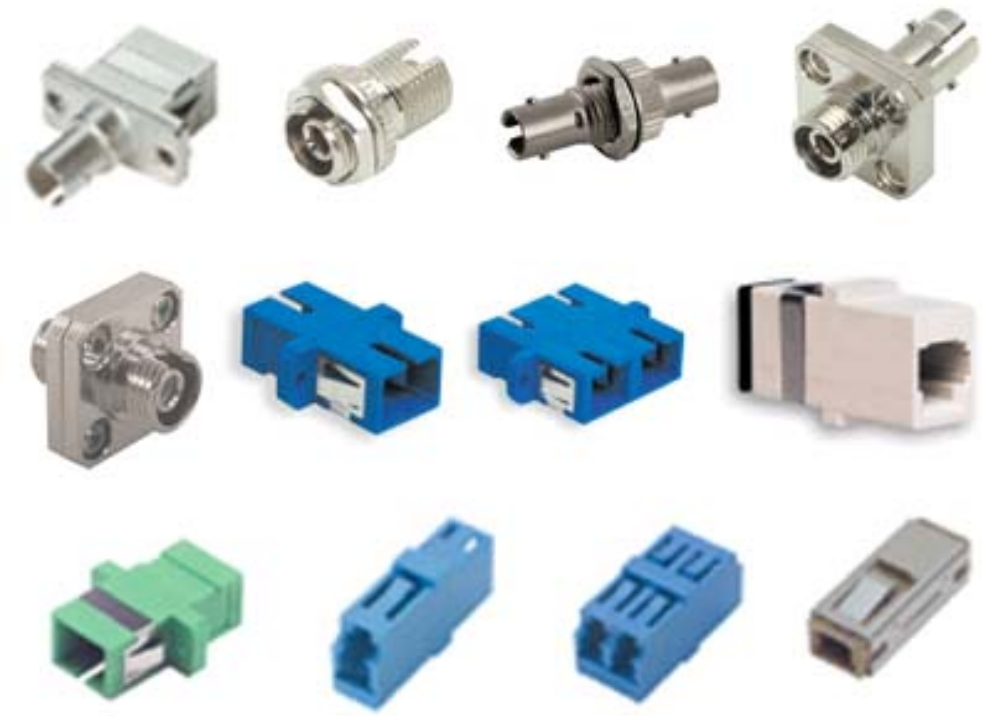
There are various types of wipes for use on very dirty connectors. (A) is a large type of wipe to be pulled up individually. Alternatively, the wipes may be stored on a roll (B) to be torn off at the perforation, against the box edge. (C) is another type of dust-free wipe storage. Propanol (Isopropyl alcohol) along with some suitable additives is supplied in a spray can (D). You may also use pre-moisturised wet wipes (E). Complicated washing is carried out using cotton swabs on a stick (F). They look like, and work like ordinary cosmetic cotton swabs but are much smaller.

COLOUR STANDARDS AND FIBRE TYPES

How do you know which type of fibre you have? The LC connector is more or less universal and looks the same whether it is mounted on a multi mode (MMF) or single mode fibre (SMF). The jacket colour is somewhat manufacturer-specific, but generally single mode fibre has a yellow or blue jacket, whereas multi mode fibre is orange, turquoise or grey depending on fibre subtype.

LC Connector

The connector colour is also manufacturer-specific, although there is a semi-standard you should know. Blue connectors normally have straight cut end faces, intended for physical contact (PC), whereas green connectors have an angled end face (APC, Angle Polished). The two types cannot be mated directly.



Adapters and Couplers

Just because the two fibre types (SMF and MMF) have the same connector, they can't be interconnected using an adapter or coupler. The core of the single mode fibre is a mere 9 micrometers in diameter, whereas the multi mode fibre core is 50 micrometers. Regardless of where the light originates from, a lot of light will be lost in the junction. In other words, the junction represents a large attenuation. In this case, a special type of adapting fibre must be used, but signal range will be limited to a few hundred feet. Also, the method is not useful above 10 Gbps.

Wikipedia has a list of colour codes that you should study: **https://en.wikipedia.org/wiki/Optical_fiber_cable#Color_coding**

CLEANING PROCEDURES FOR FIBRE OPTIC CONNECTORS

Fibre connectors may be smudged to different degrees, and may require different cleaning methods. Of course the small handheld pen-type cleaner is the most convenient, but it is only capable of handling the mildest cases. If the contact area has become really dirty or dusty, you may need to resort to using a cleaning cartridge. If the dirt consists of grease from fingers or skin, you need to use propanol (Isopropyl alcohol) sprayed onto dust free tissue to dissolve the fat and then finish by using the one-click pen again, to dry the connector face. This leaves us with the most serious cases, where the contact surface has become scratched beyond all possibility of cleaning. Such fibre cables unfortunately have to be discarded.

Cleaning Fibre Optic Connectors - Cleanliness is a Virtue

SUNET

PROCEDURE

How to clean a fibre connector

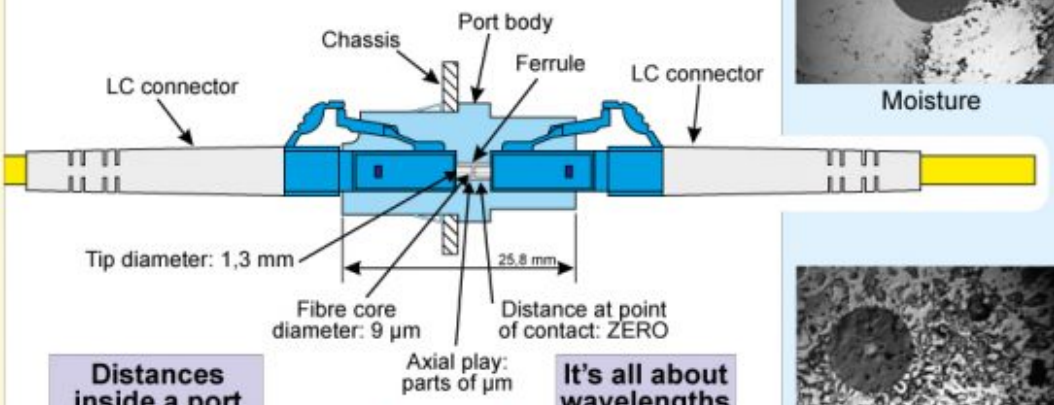
1. Examine

2. Clean with a pen. Three pushes.
3. Examine

4. If neccessary, clean with cassette.
5. Examine

6. If neccessary, clean with alcohol.
7. Examine

How to clean an LC connector with a pen-style click cleaner

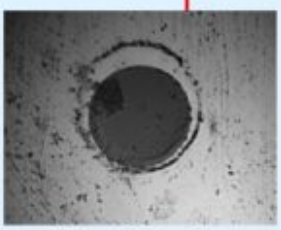


Distances inside a port are minimal!

It's all about wavelengths of light!

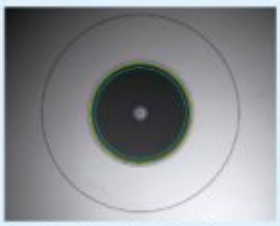
SUNET

35 universities
21 museums
32 authorities
100 Gbps



Ring of fat after mating fatty surfaces

Dust inside receptacle is hard to remove

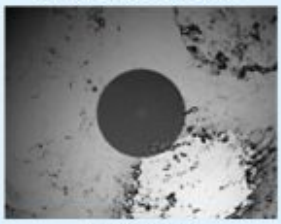


Perfect look after proper cleaning

MICROSCOPIC REVELATIONS

Dirty connectors and bad cleaning

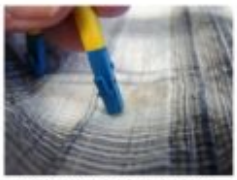
Rubbing on jeans



Moisture

Dragged along floor

Don't crush the fibre



Your sweater is dirty

Your fingers are fatty

Too small a bend radius

Common office mishap

Don't drag on the floor

Roll no rolls

This one lives on your skin and eats skin flakes

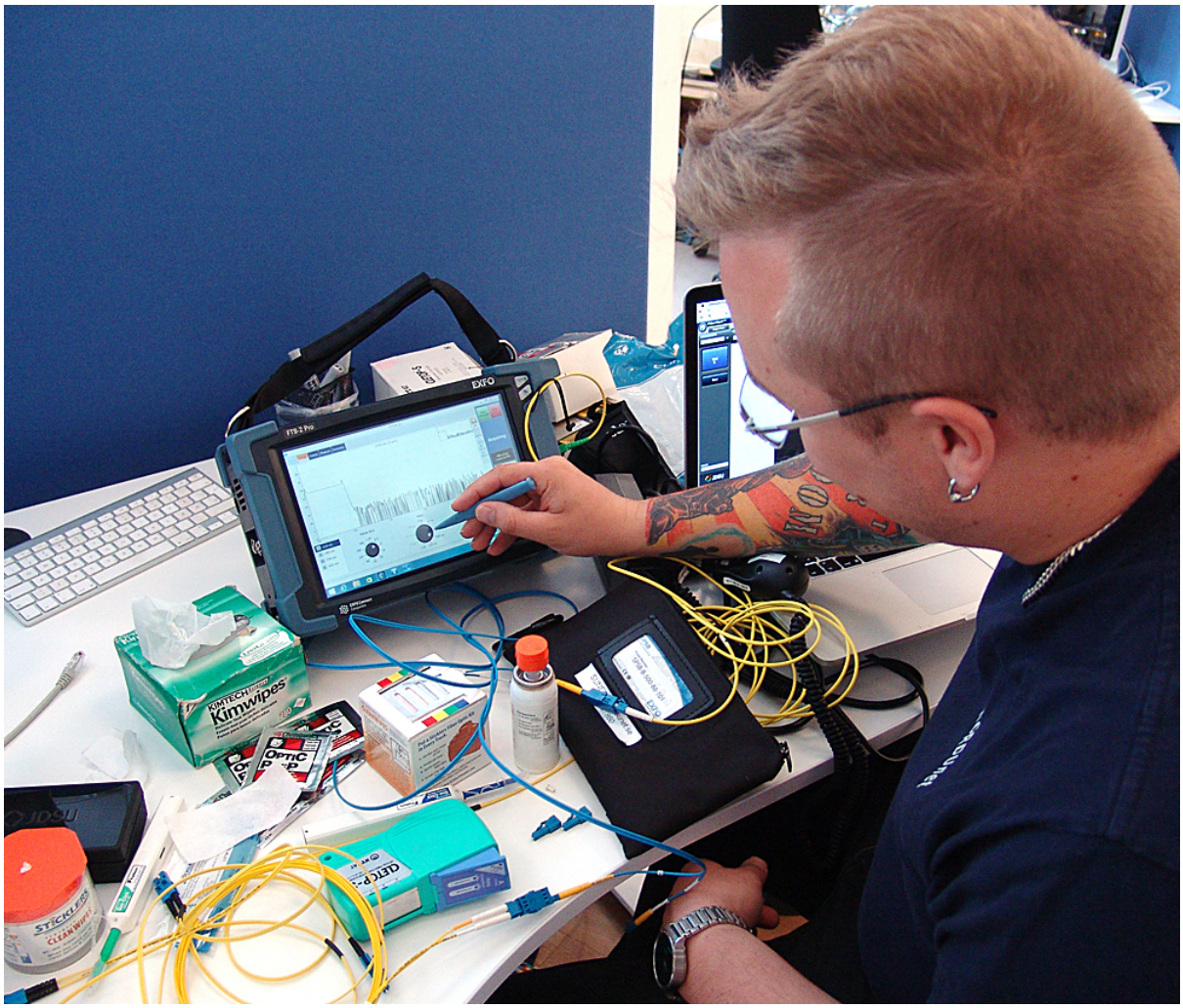
How to store fibre

How to store junk

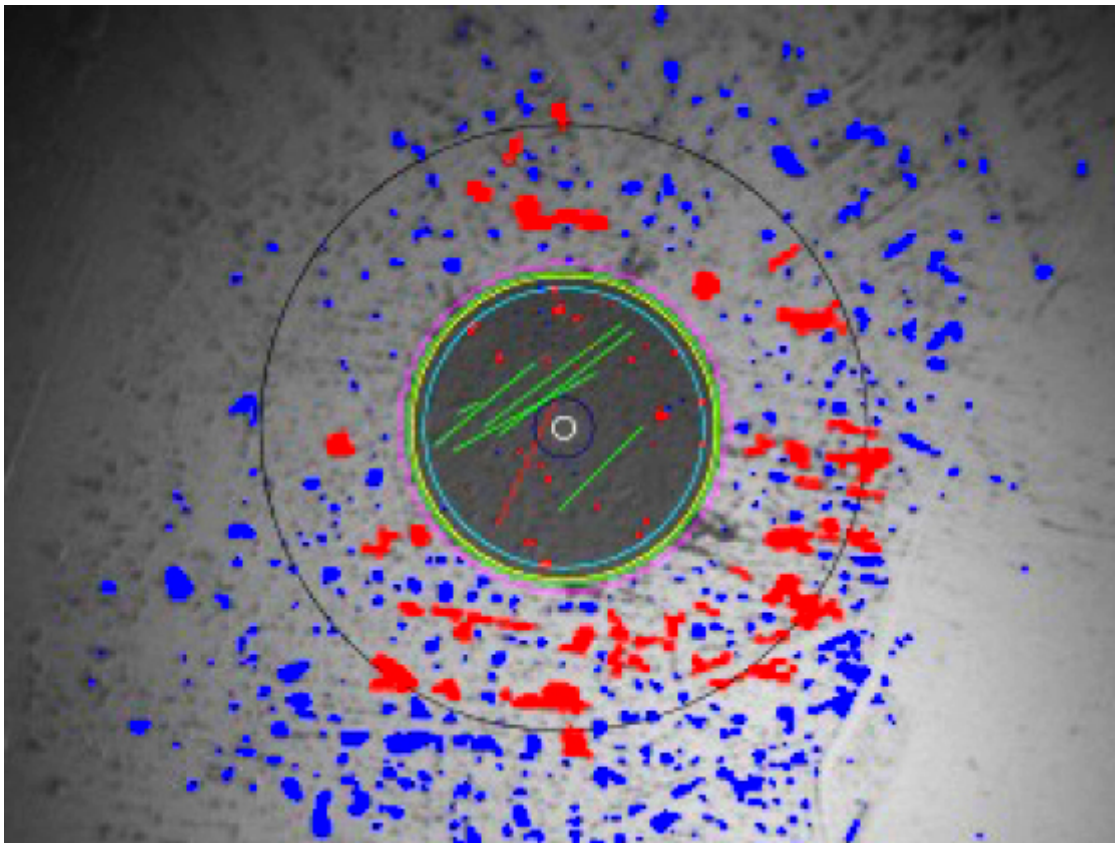
The procedure is schematically demonstrated on this poster, which you can download as a PDF by clicking **HERE.** Stick it to the wall or use as teaching material.

The Golden Rule: Before using any fibre cable, whether fresh from the factory or one that has been lying around in your desk drawer for some time, it should be examined to find out if it has become dirty. Dirty connectors will not only impair the connection, they may transfer the dirt onto other connectors, as well. Dirt that has gotten into panel ports is extra difficult to get rid of.

1. Examine the connector with a microscope.

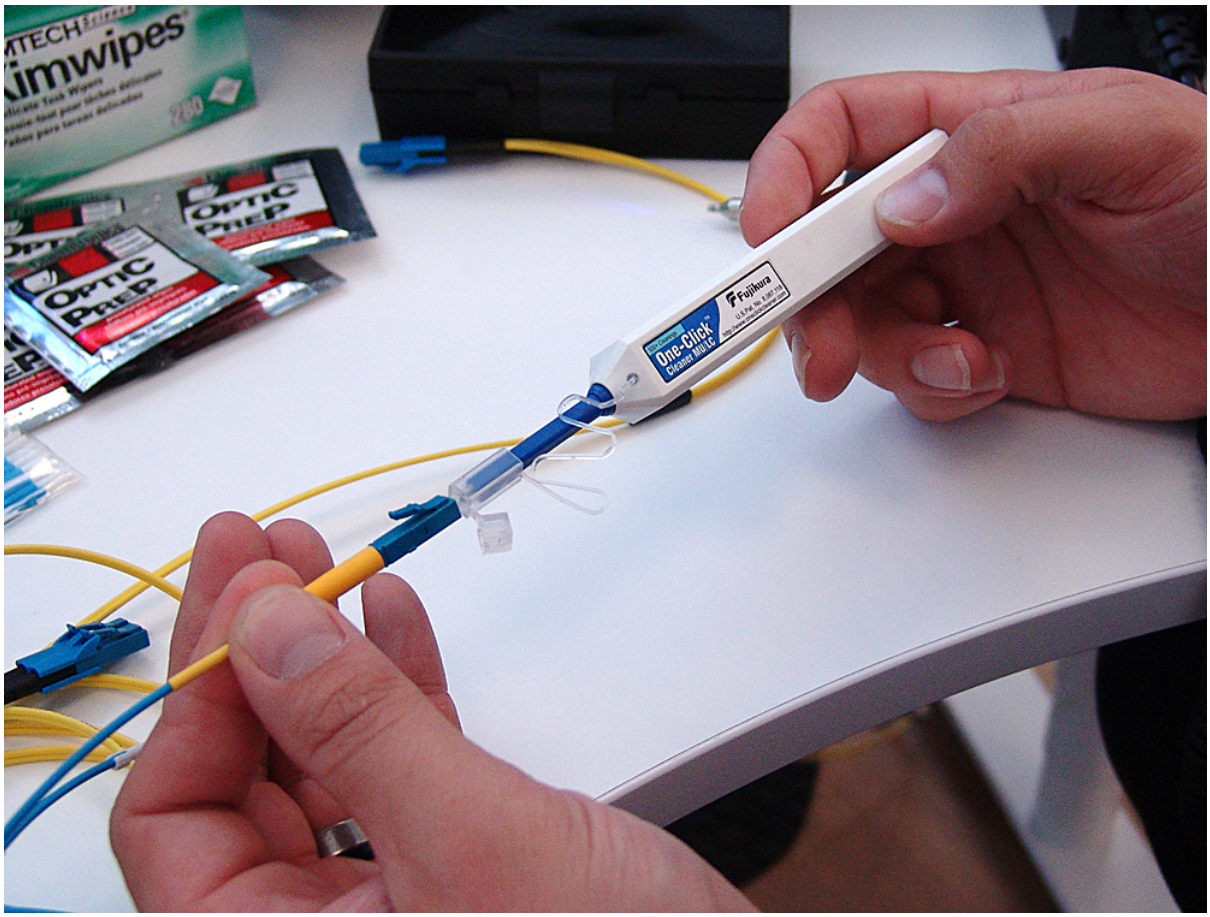


Regardless of the fibre cable's condition, it must be examined before it is commissioned. A speck of dust that can completely disable the connection may be so small that it can not be seen with the naked eye. It is necessary to use a fibre microscope. More on how to use it and interpret the images, follows below.



The assessment software in the computer that operates the microscope, characterizes lesions in three areas. Damage or dirt in the interior, grey ring (zone A, the fibre core and cladding) must be eliminated at all costs. The program marks the scratches in green and other dirt in red. The damage inside the outer ring (zone B, the buffer) is marked in red and must also be removed before the connector can be approved. Damages outside the outer ring (zone C, jacket) are insignificant if they are small, because the outer surface is not involved in the transfer of light. Larger particles or damages, marked in blue, however, prevent the two surfaces from making proper contact.

The diameter of the area shown in the image above is about 250 micrometers, or 0.25 millimetres.

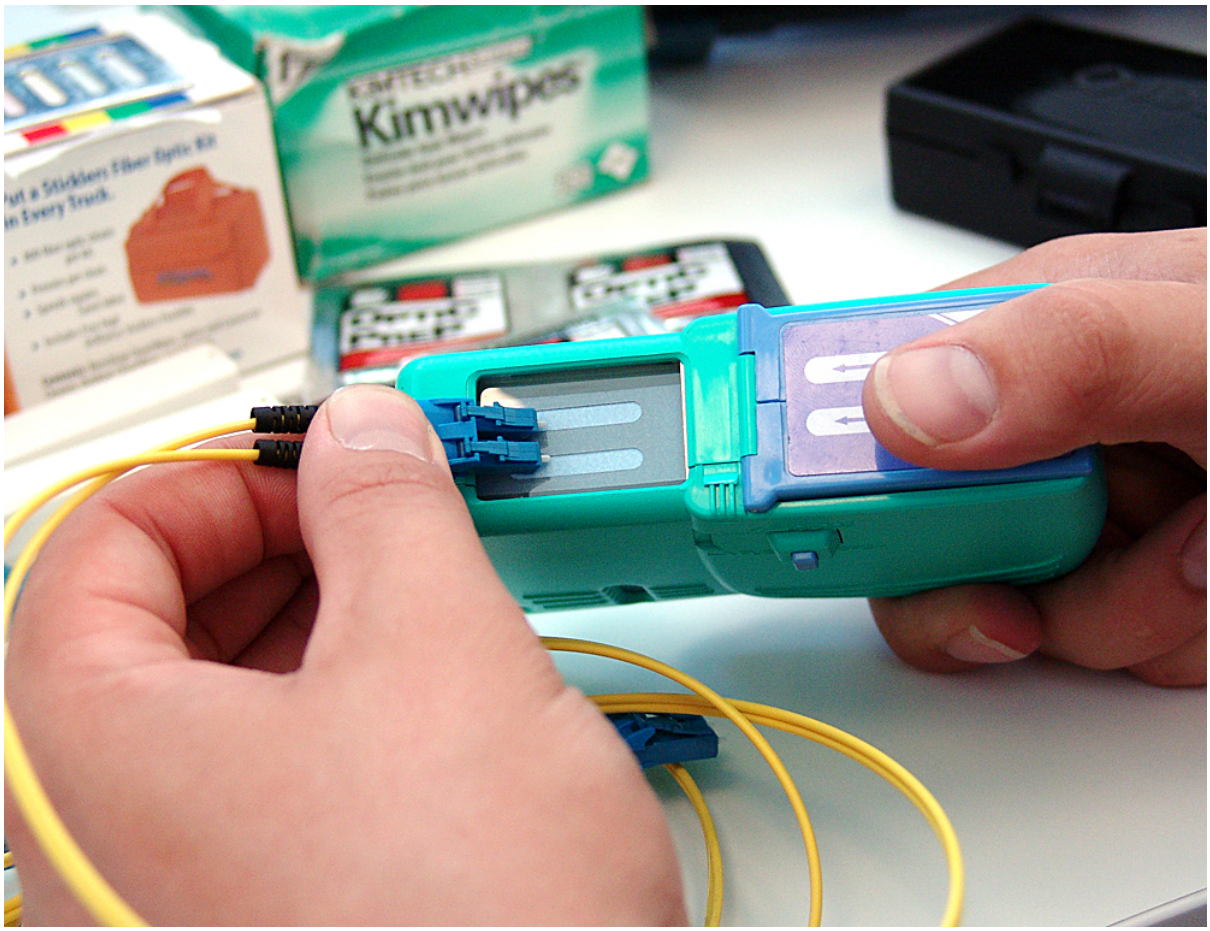


2. Clean using a pen. The pen's transparent end cap should remain on. Enter the connector in the hole in the end cap and push the pen against the connector three times, making it click. A small fabric tape is exposed and rotates against the contact surface, and is then pulled away.

The pen is exhausted when it no longer clicks. It can not be recharged, and should be discarded.

3. Examine the connector with a microscope.

4. If that is not enough, use a cleaning cassette.

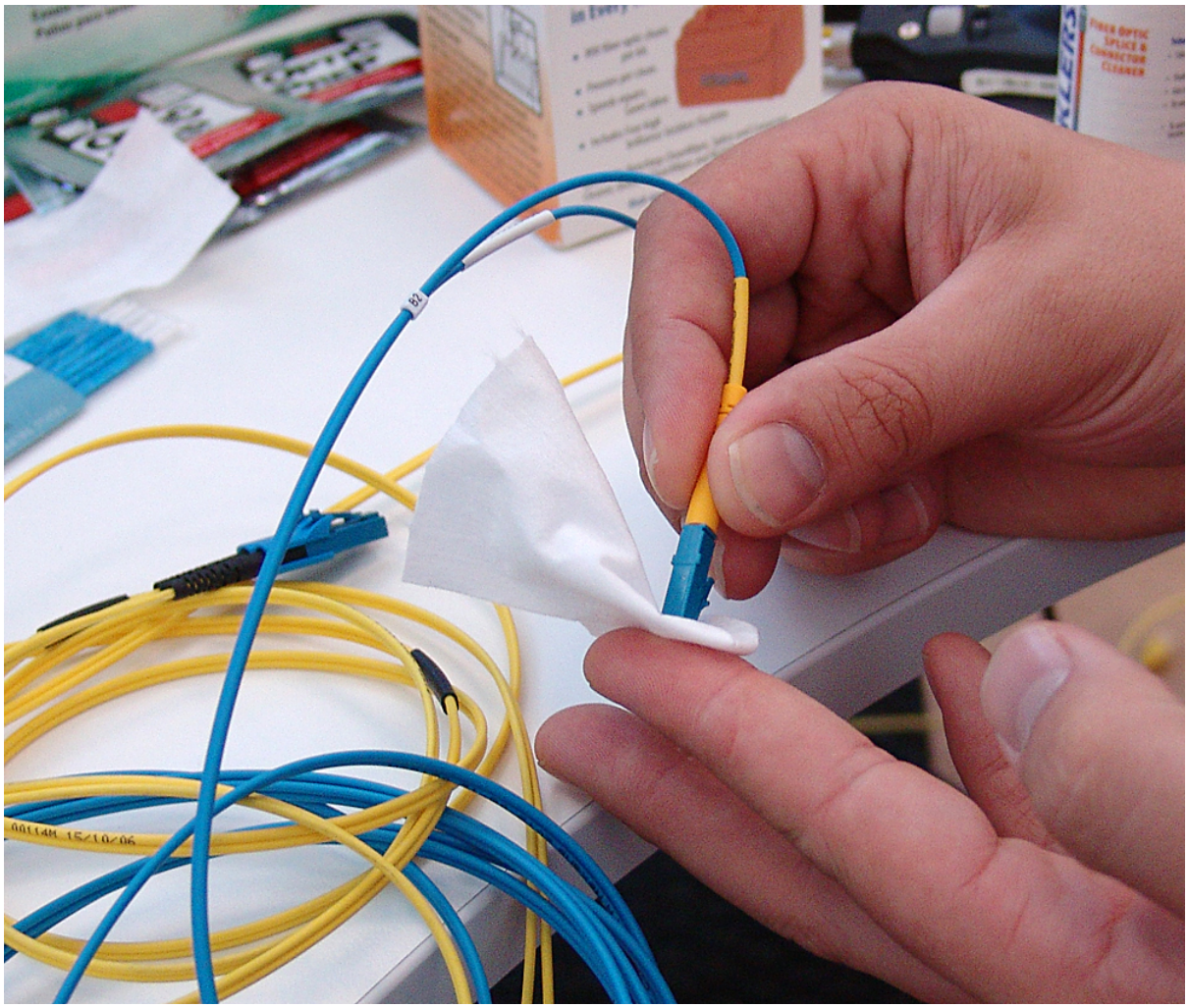


Open the cassette lid by pressing the blue handle, to expose the two dust-free cloth tapes. Drag the connector back and forth on the tapes three times. Rotate the connector 90 degrees between the cleaning cycles to clean around the whole circumference. Repeat three times by releasing the handle, and pushing it again. When the lid is re-opened, the cloth tape has been spooled into the cassette and fresh cloth is exposed.

When the inner tape cartridge is spent, it must be exchanged.

5. Examine the connector with a microscope.

6. If that is not enough, use propanol on a wet wipe.



Pull a new tissue out of its package. Alternatively, tear a piece of tissue from a roll, making sure to always discard the first sheet as it may have become contaminated while handled. Spray some propanol from a spray can onto the tissue. Alternatively, you may use disposable pre-moisturised wet wipes. Whichever method you use, be sure not to touch the paper surface to be used for cleaning.

Cover the connector with the tissue, and gently rotate and rub it. Repeat in various places on the tissue, several times.

The connector front face is now damp. Dry it using a pen-type cleaner, as per item 2, or a cassette, as per item 4.

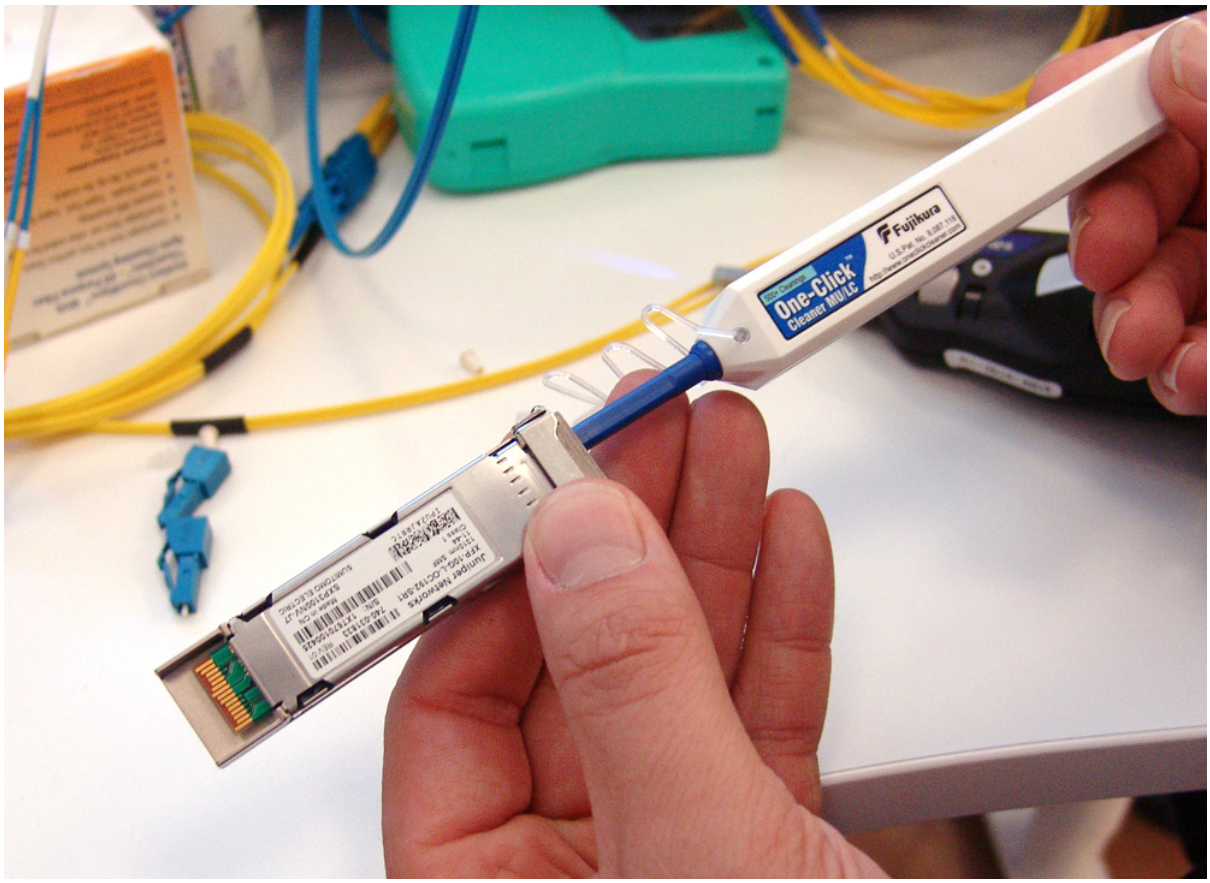
7. Examine the connector with a microscope.

8. If you, after repeated cleaning according to the procedure above, can not get the critical parts of the interface as clean or free from scratches as to be approved by the microscope's assessment software, the cable should unconditionally be discarded. Retaining it, involves a risk of contaminating other contacts or connections, as well as the risk that someone unsuspectingly may create faulty links.

CLEANING INSIDE FEMALE RECEPTACLES

Cleaning female receptacles, such as patch panel ports or optical transceivers, is particularly difficult. The latter can't even be picked apart for cleaning. But you can look inside them with a fibre microscope, using the correct tip adapter on the microscope.

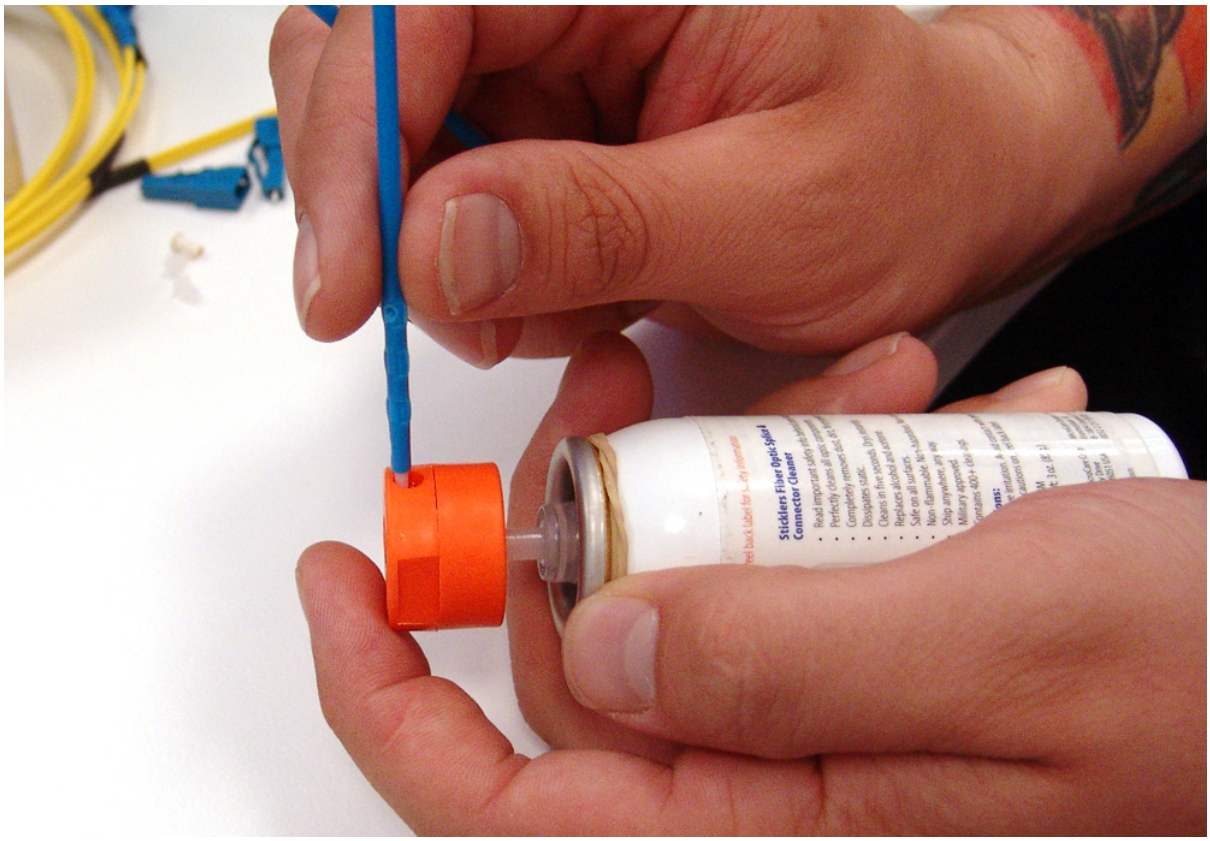
1. Examine the connector with a microscope.



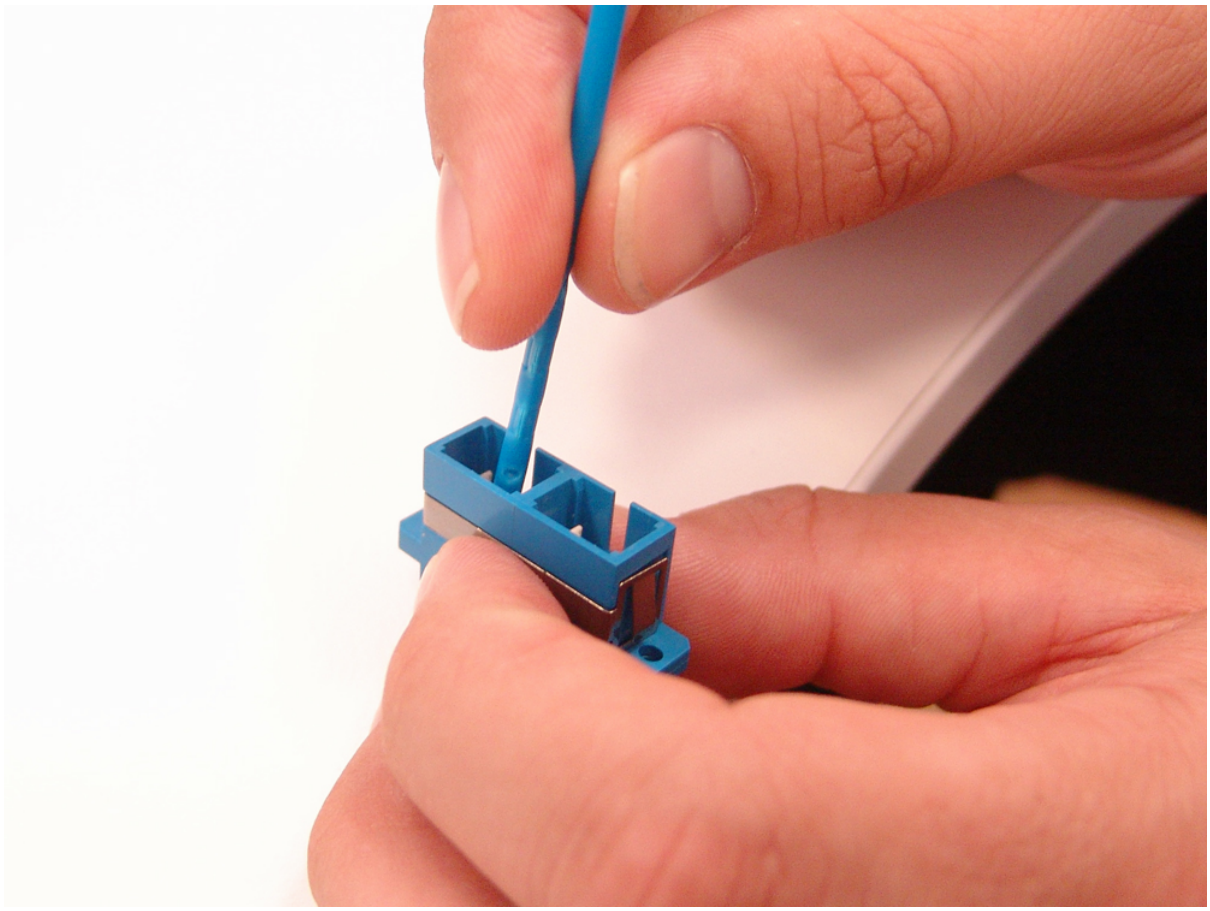
2. Clean using a pen. The pen's transparent end cap must come off. Enter the tip of the pen into the connector and push the pen against the connector three times, making it click. A small fabric tape is exposed and rotates against the contact surface, and is then pulled away.

The pen is exhausted when it no longer clicks. It can not be recharged, and should be discarded.

3. Examine the connector with a microscope.



4. If cleaning with the pen is not sufficient, cotton swabs with propanol must be used. A very modest amount of propanol is needed, so turn the spray can with its opening facing upwards and only let out a single drop. Let the swab absorb the drop.



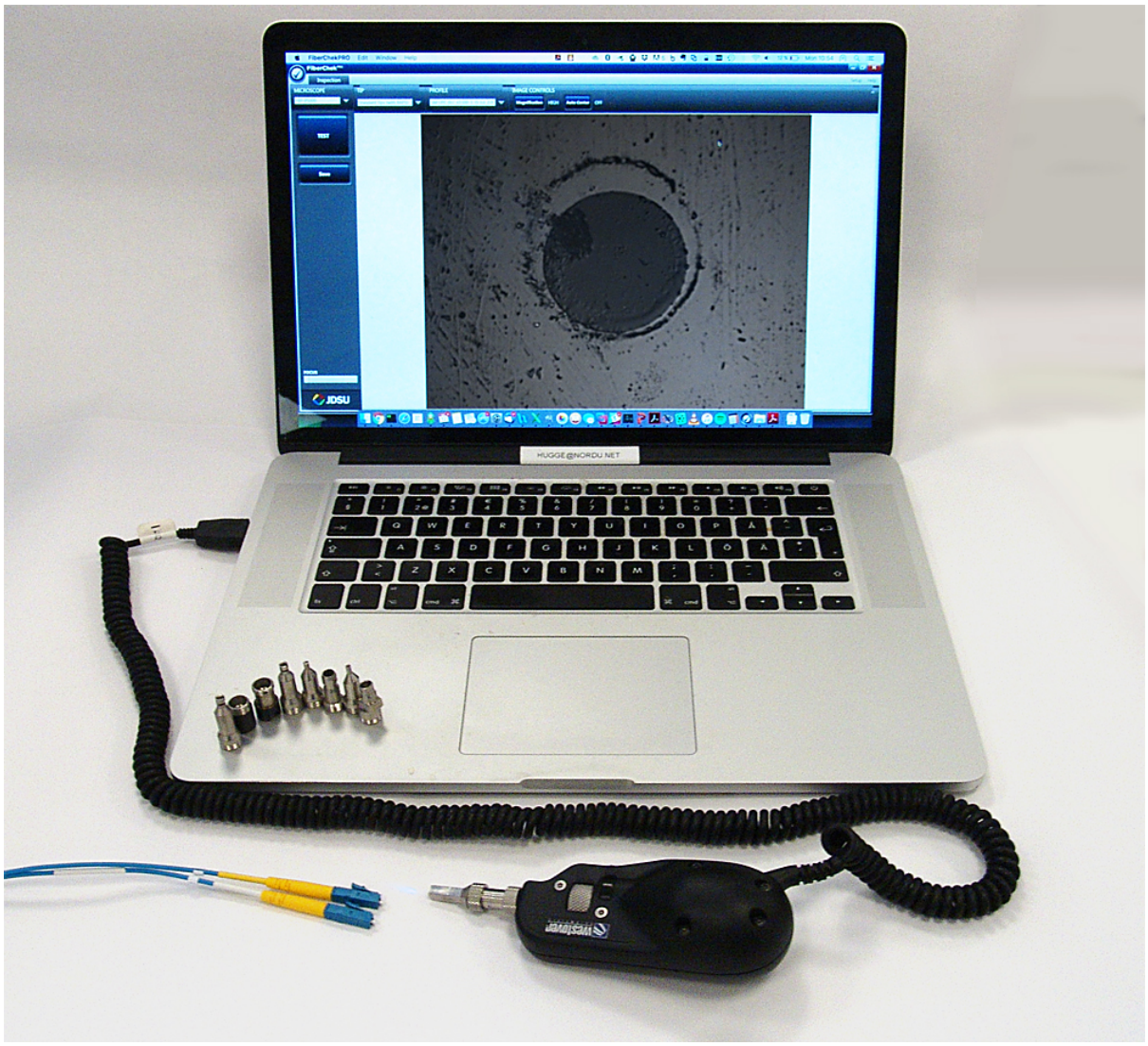
Clean the inside of the receptacle with the swab, and don't forget the ferrule (the shiny area) at the bottom. The receptacle is now damp. Dry it using a dry cotton swab. After the swab has been used, be sure to routinely break it off, signalling to any other users that it is consumed and should not be re-used. Re-using it may make things worse.

5. Examine the connector with a microscope.

THE FIBRE MICROSCOPE AND HOW TO USE IT

A fibre microscope is necessary to see the contaminations on the front face of a connector. The microscope is used to examine connectors according to a standard agreed in the fibre optic business. The connector front face is divided into zones, and the damage in each zone is automatically assessed.

Zone A is the core (core and cladding). It must show no, or very minimal damage.
Zone B is the buffer, where very minimal damage is allowed.
Zone C is the area outside the buffer, where some lesser damages may be acceptable.

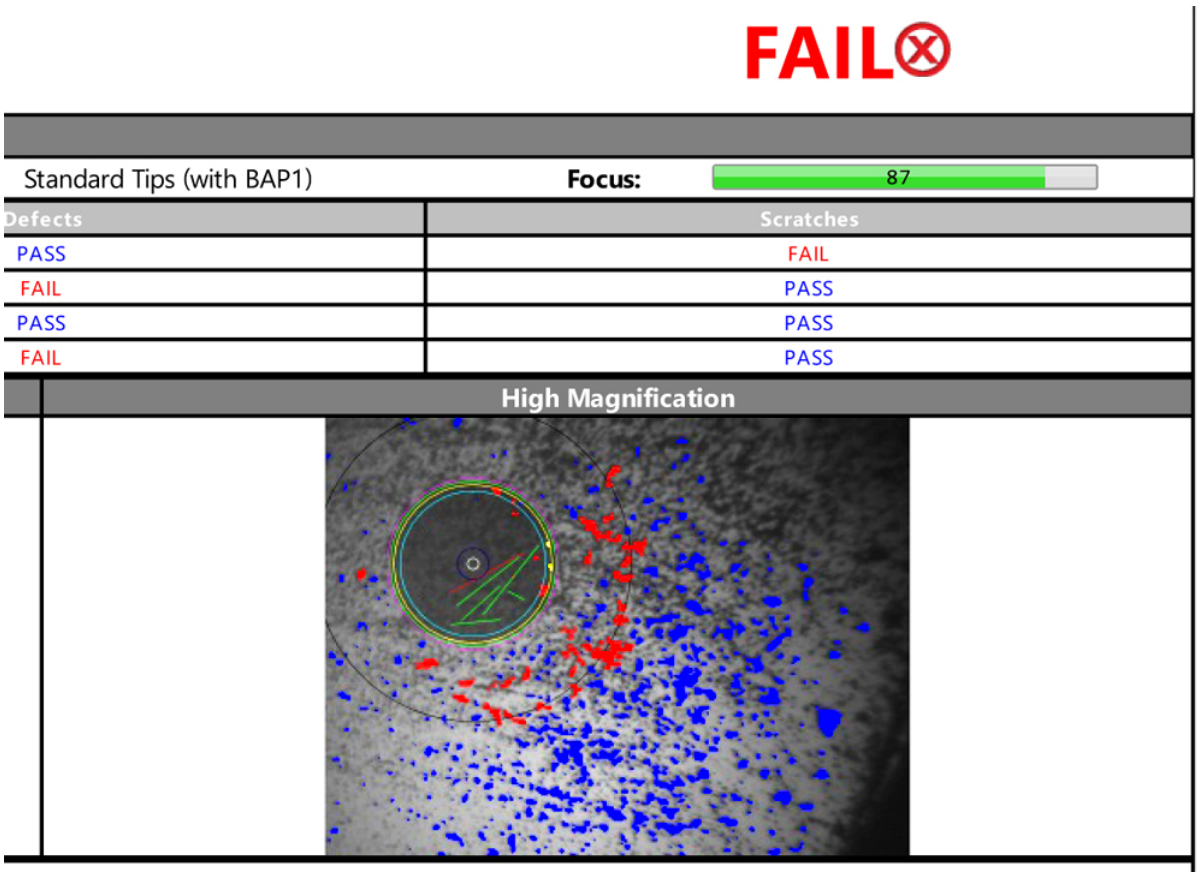


The microscope consists of an optical part (black) connected with a USB connection to a computer that executes the assessment software.

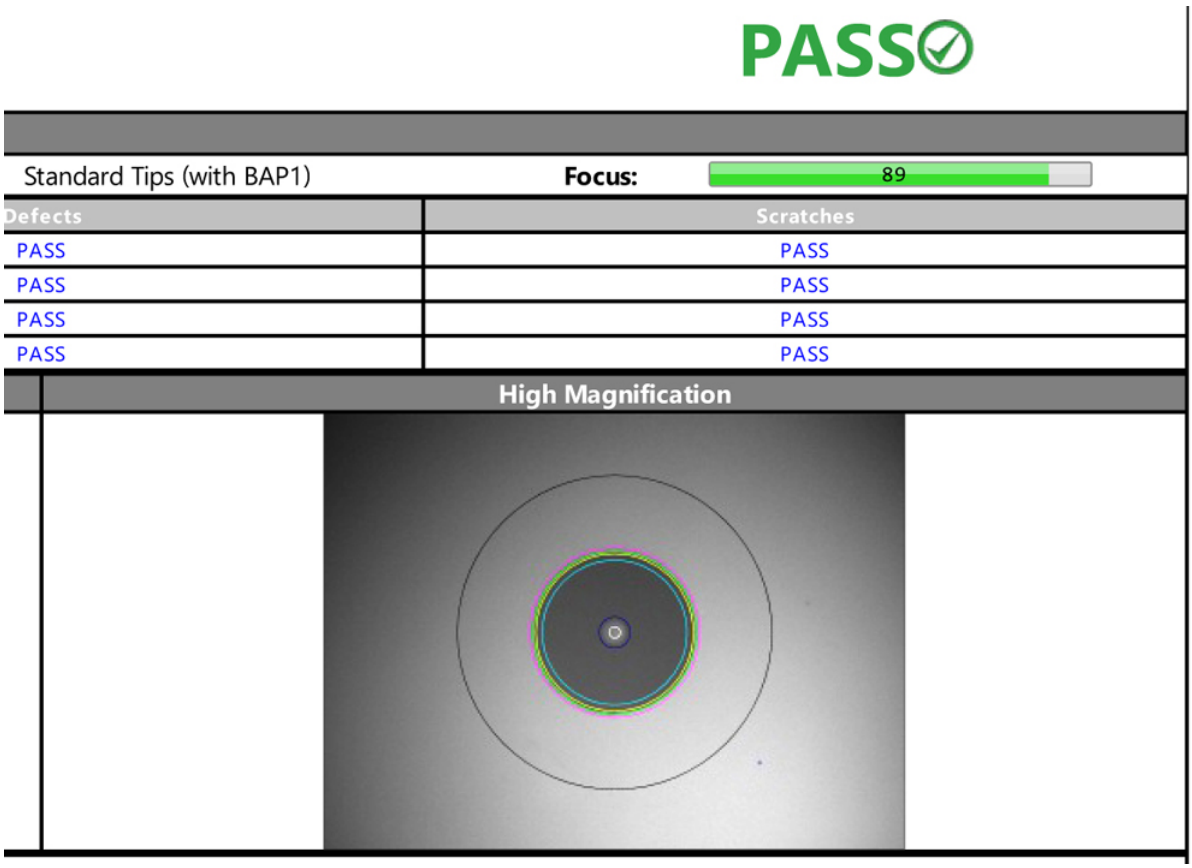
Should everyone who works with optical fibres get a fibre microscope? Yes, without a doubt! Without a microscope, you are basically blind, and can not determine if a contact is usable or not. The details are too small and can not be seen with the naked eye. You may buy a manual, optical microscope and determine the contact surface quality using the eye. However, in this way you can not determine the type of damage reliably, nor determine whether the surface meets any standard for smoothness. The computer-controlled microscope, on the other hand, colour-codes all dangerous damages and dirt that violate the standards.

The microscope comes with a range of tip adapters, for fitting various types of connectors, male as well as female types. You focus the microscope manually by turning the knurled ring.

After the microscope has seen and assessed the connector, the software outputs a result report in PDF form containing a classification of the damages. It should be studied and if required, saved for future reference as a quality archive.



FAILED. This connector was scratched against a metallic surface and abused in general. It is so dirty and damaged that the software rejects it immediately.

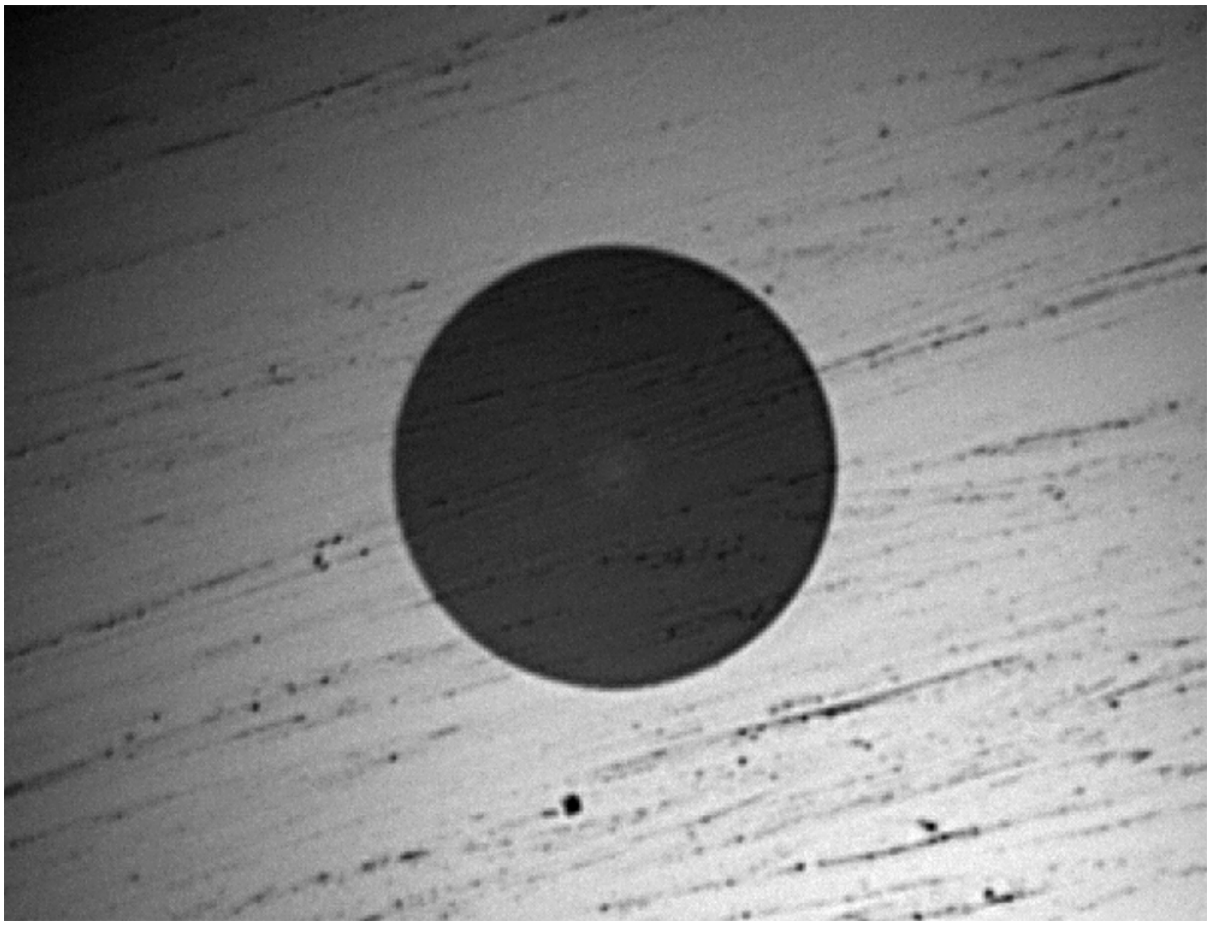


PASSED. This is a properly cleaned connector. And if it doesn't look like this, there is no hope for the cable. It has to be discarded. Minor damage outside the outer grey ring may be acceptable.

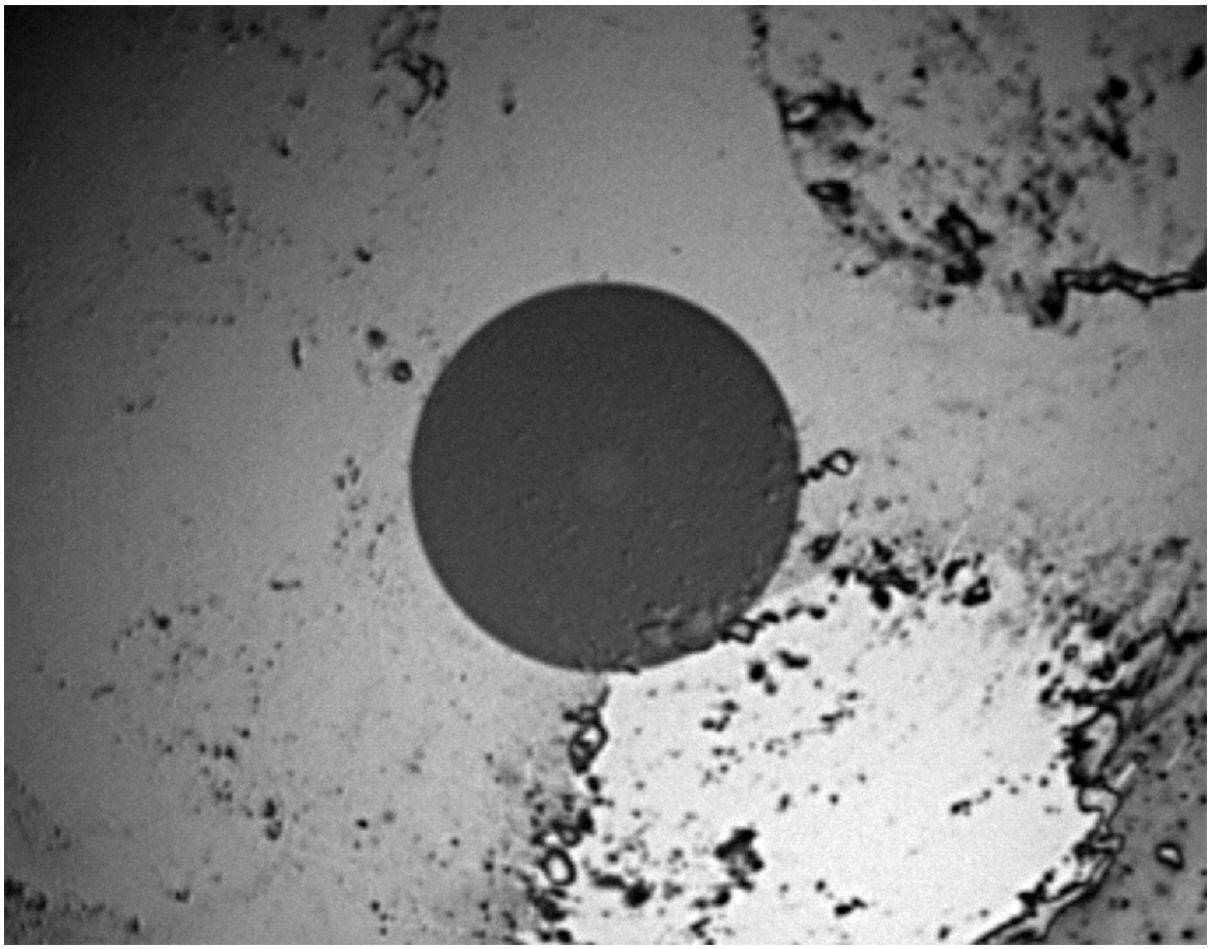
MICROGRAPH EXAMPLES

What might the microscope disclose? The below micrographs are examples of the most common situations, displaying both treatable, and untreatable damages. Note that he fibre core is only visible in some cases, as a faint dot in the middle of the grey area, as the fibre is not transmitting any light.

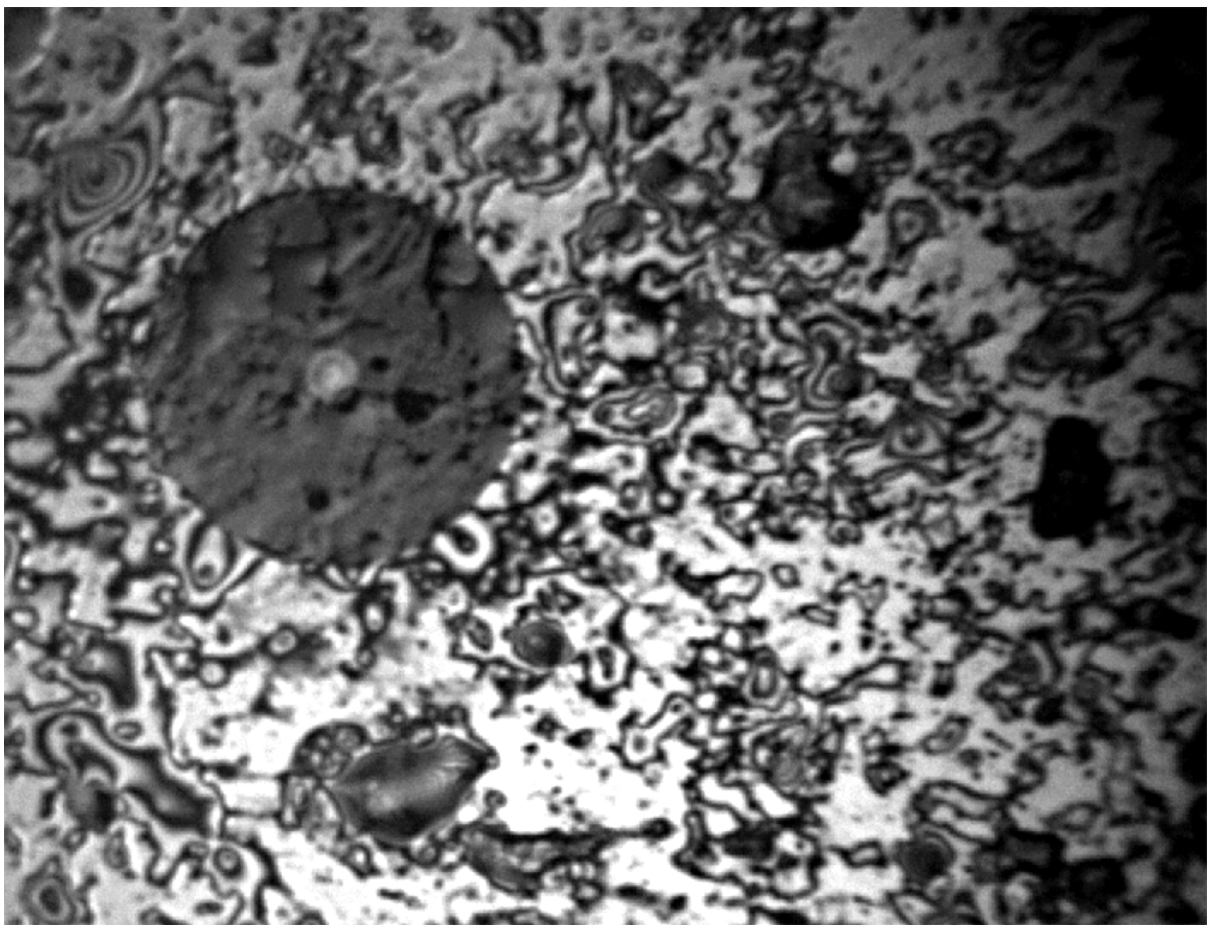
Typical Damages



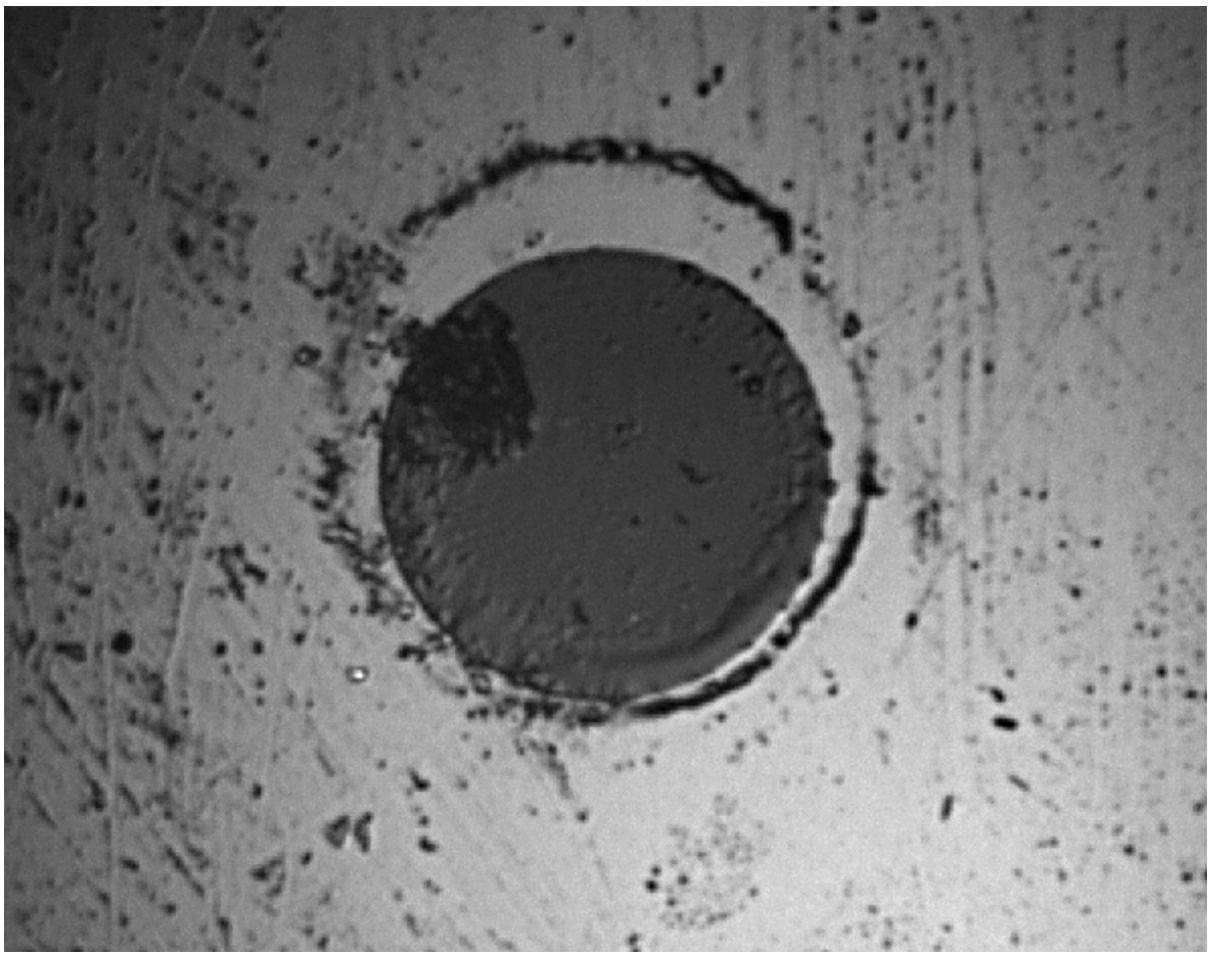
After rubbing the connector against a pair of jeans, streaks of fat accumulated on the connector face. This connector should be able to be saved using a click-type cleaning pen.



A failed attempt of a cleaning heavily soiled contact has left traces of propanol on the surface. Let dry and re-clean.

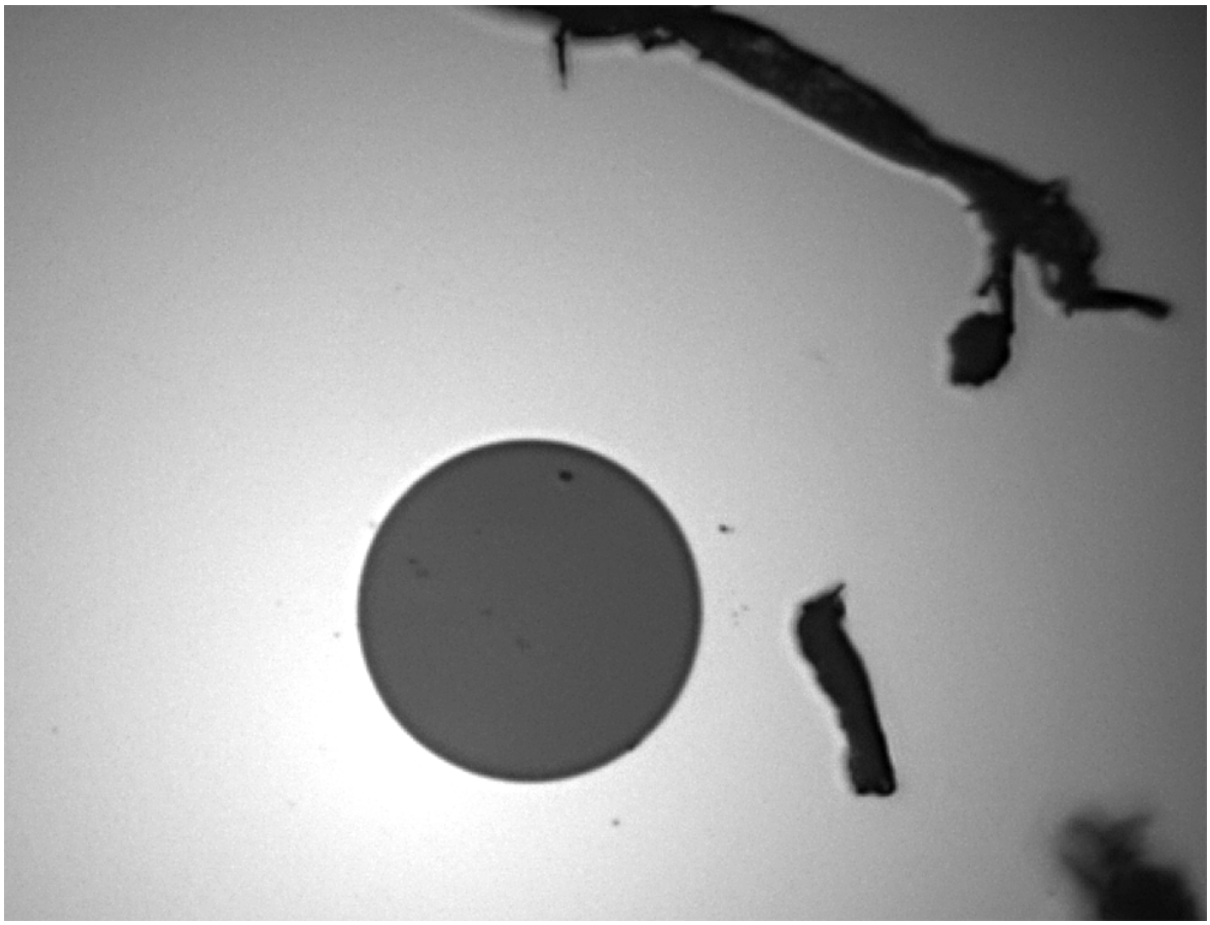


Never drag a fibre cable along the floor, as this may be the result. Lots of dust and scratches. It is doubtful if this connector can be saved. Damages in this range will probably result in an attenuation of some 4-5 decibels.



Ring of fat. The round ring in the image is caused by one contact surface being fatty when pressed against the other contact. This causes the fat to be squeezed out from the centre, forming a ring. Note that the surfaces have been in contact and that there is now a fat ring on the other connector, too. If this is inside a port on a patch panel, you must dismantle the patch panel.

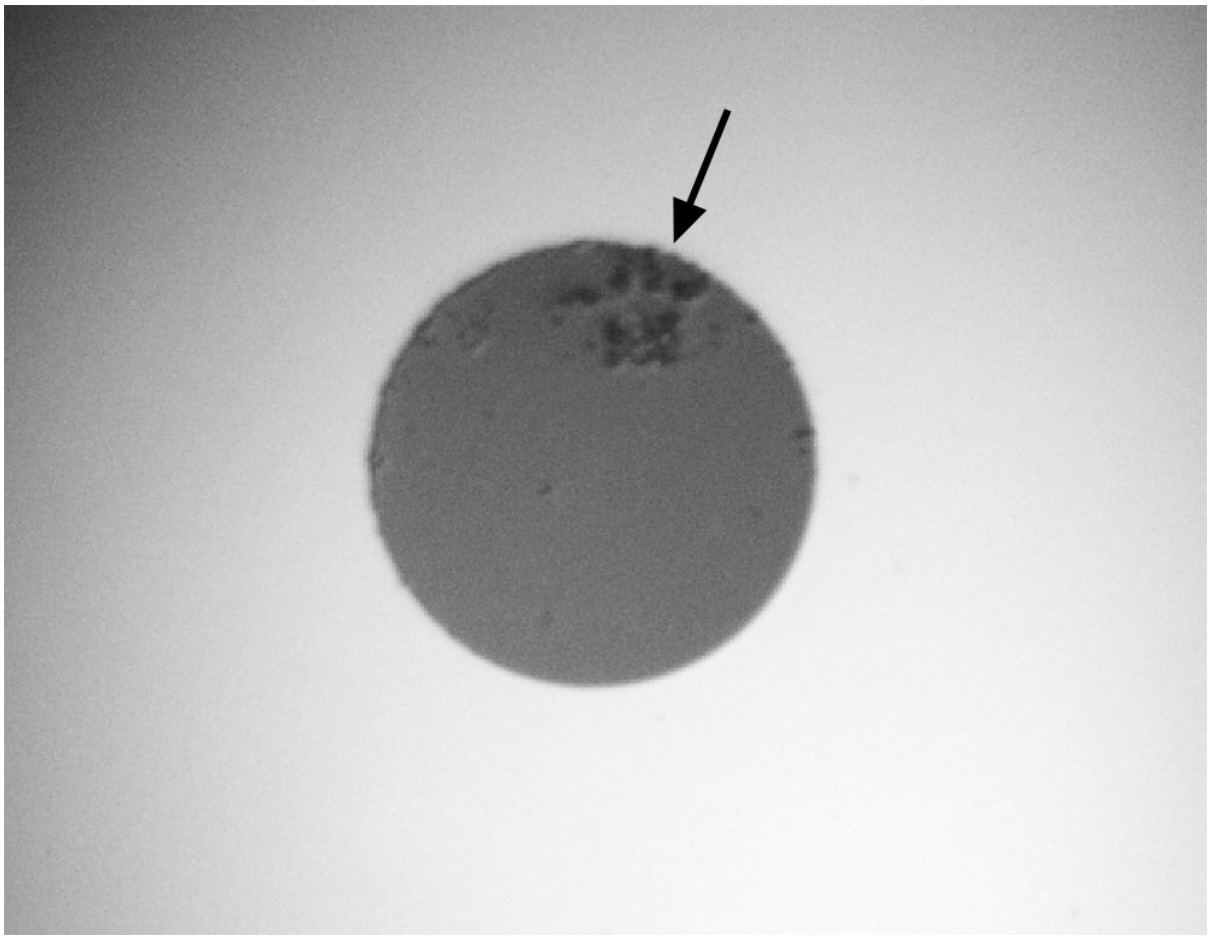
Fat can move around inside the connector thanks to the capillary effect, especially when the equipment is hot.



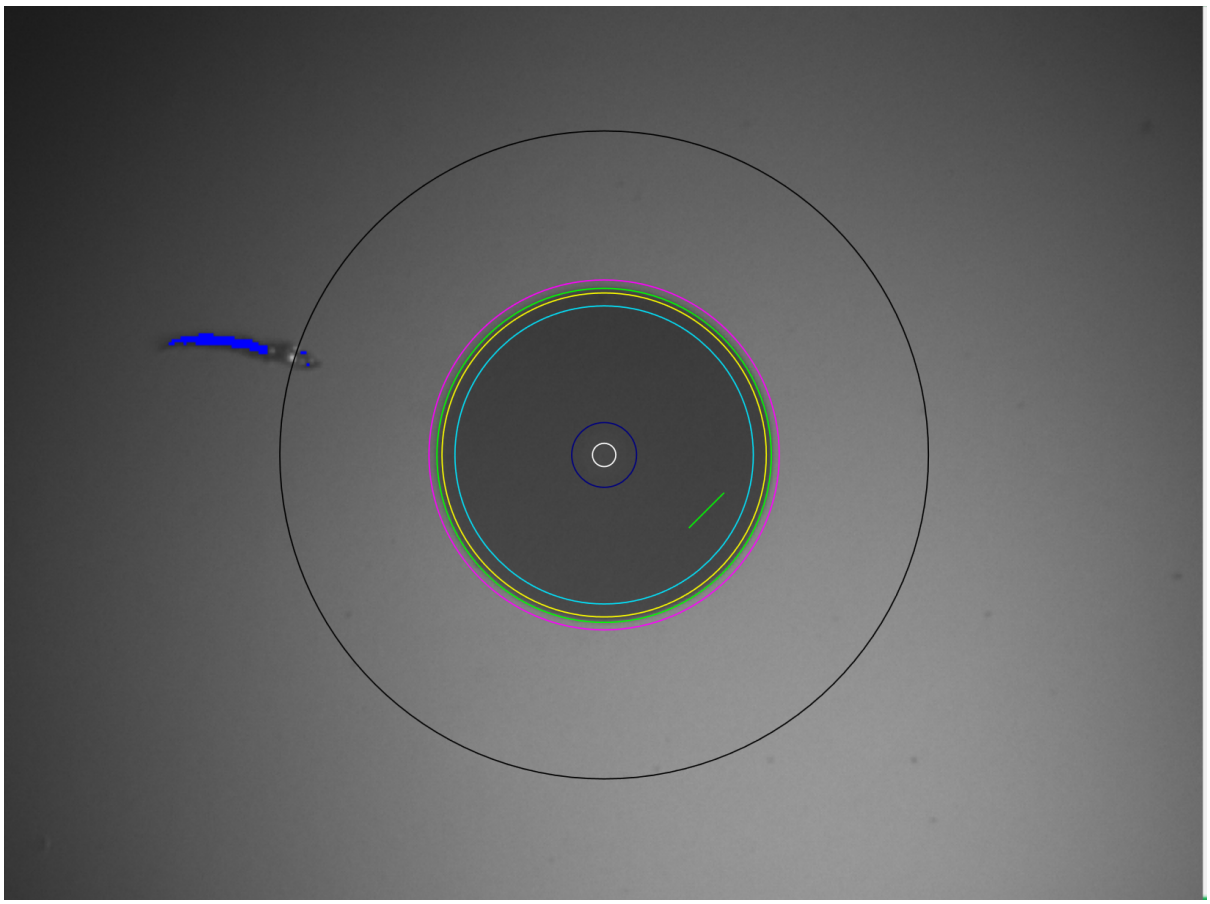
Dust inside a female receptacle in an optical transceiver. This kind of dirt is very difficult to remove because one has to clean inside a small hole, possibly using a cotton swab, if the cleaning pen cannot save the situation.

Cleaning Results

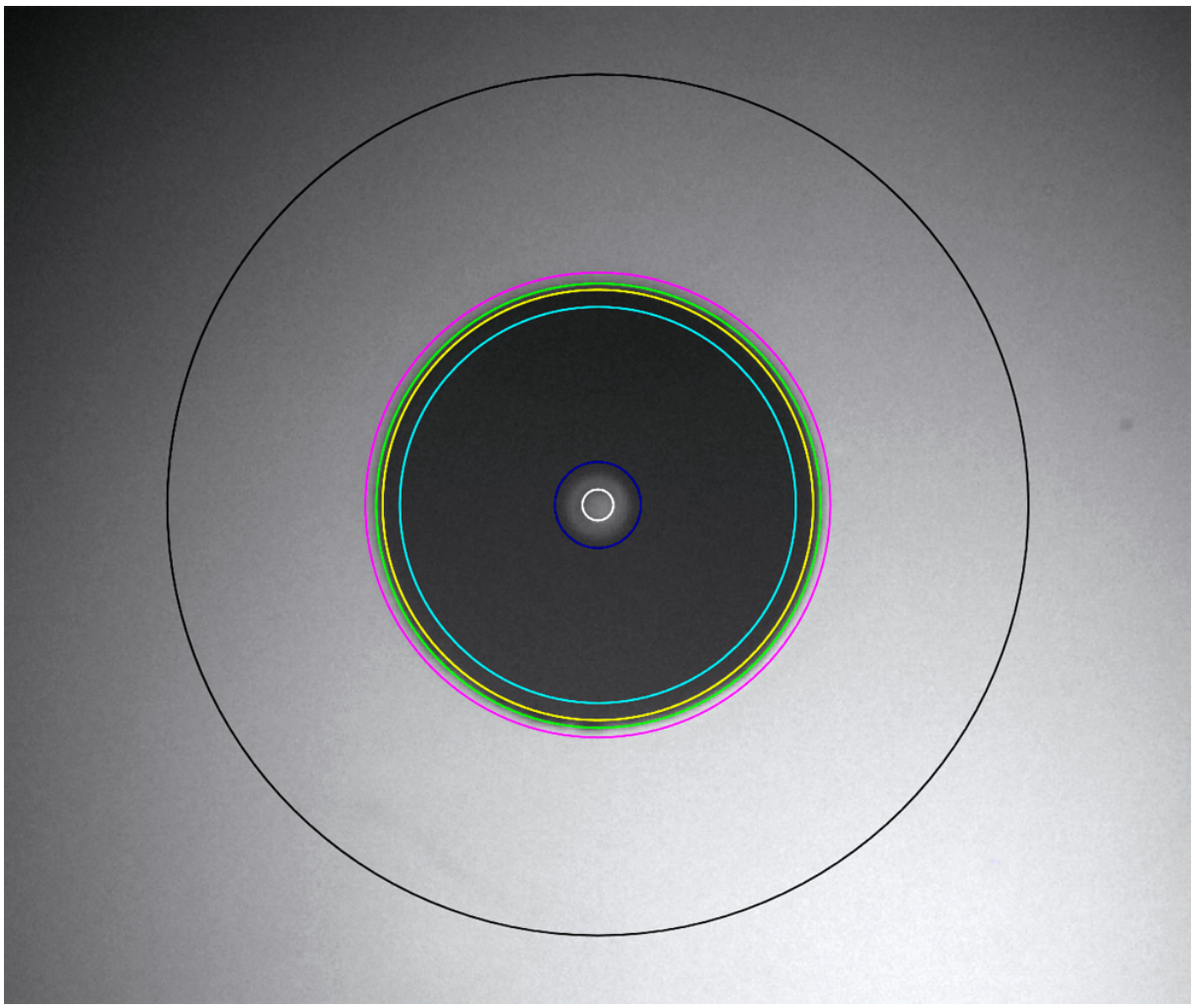
Although a connector has been cleaned repeatedly, some damage may remain.



Irremovable, permanent damage in the form of a notch in Zone A, as a result of the connector being scratched against metal. This connector can not be used further, since the damage occurred in an area critical to light transmission.



Acceptable damage (blue) in Zone C, which does not affect the transmission of light. The small green scratch in Zone A is also acceptable because it is not located at the core.

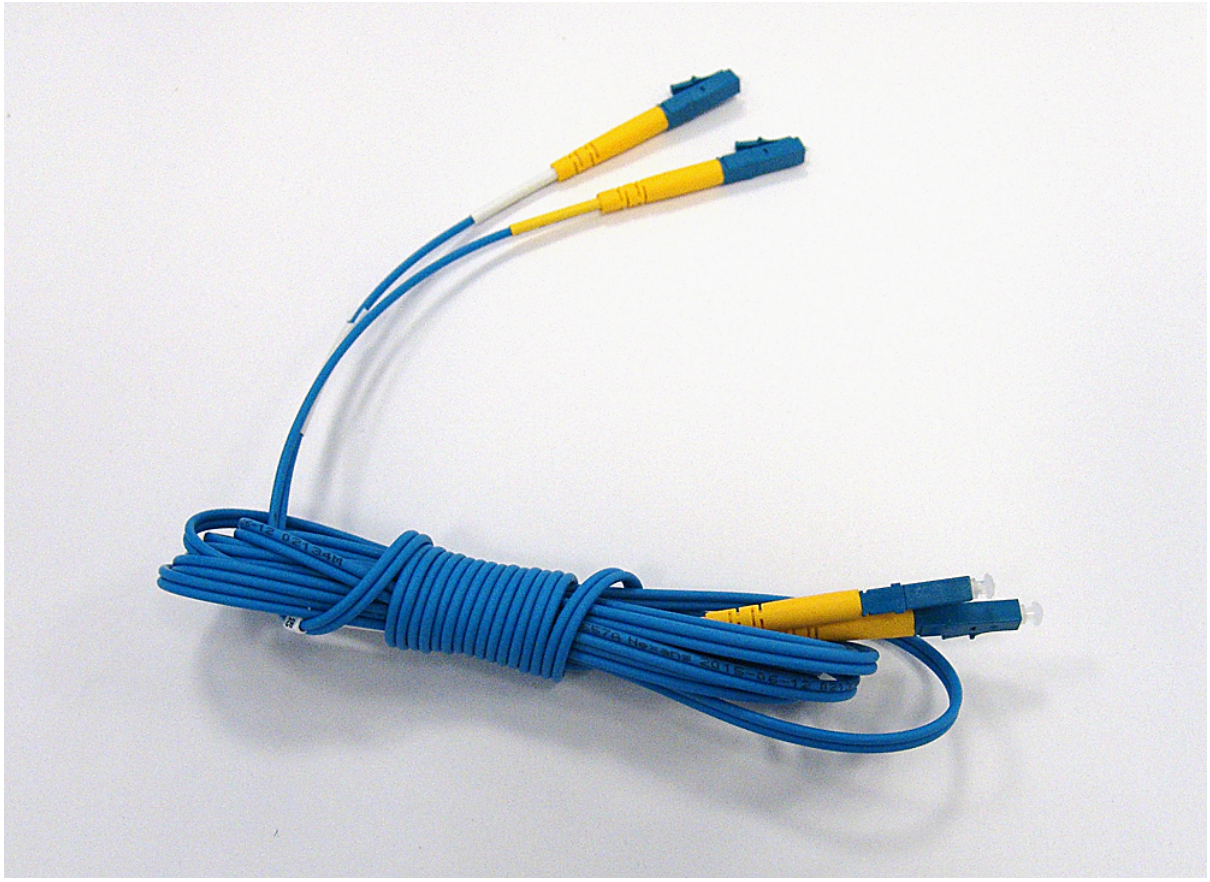


Perfect result after successful cleaning. The assessment software signals top scores for all connector surfaces. This is what you should aim for.

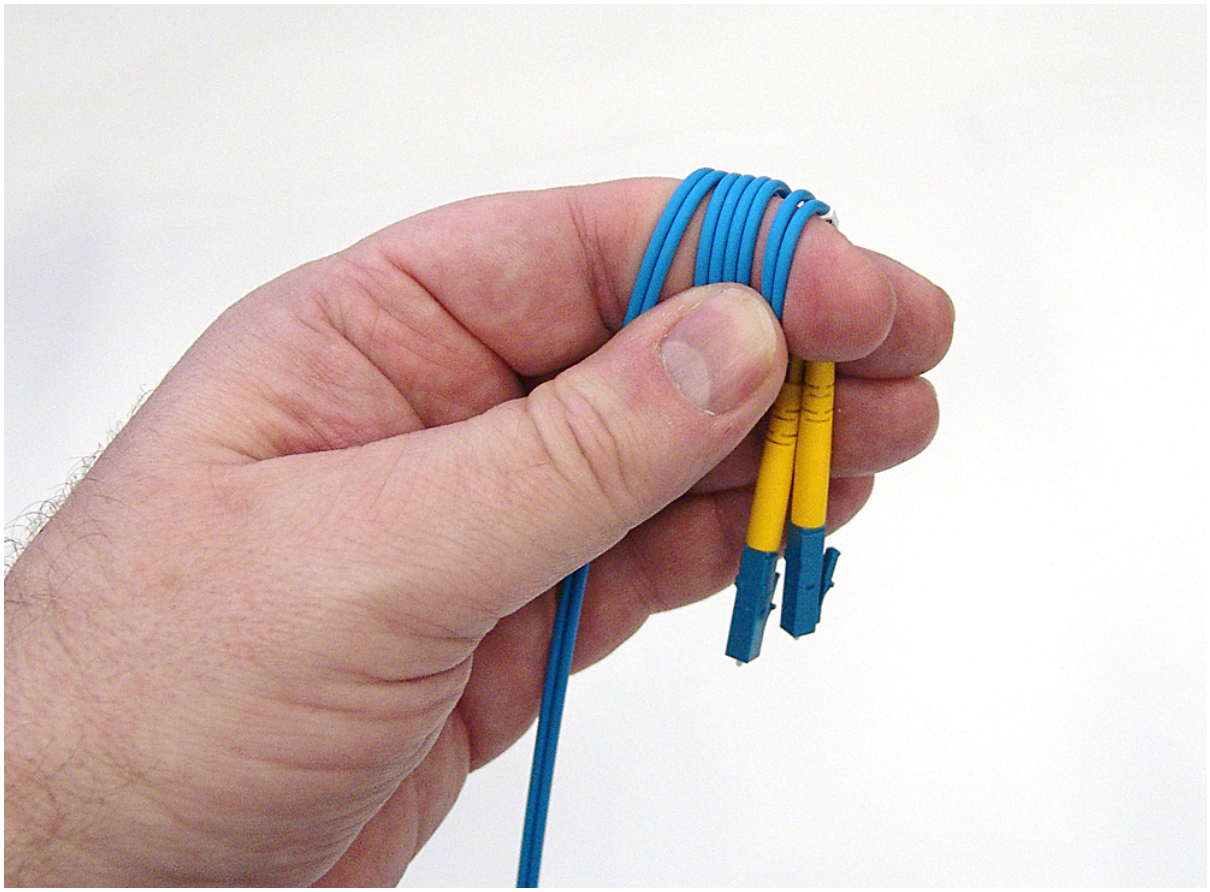
FIBRE CABLE HANDLING

Please be nice to the cable and connectors. If the glass core is stretched or bent more than a certain degree, it will break into two or more parts. One of two things can happen. At best, the core members are no longer aligned with each other and the laser light can not pass. In the worst case, they overlap each other slightly and part of the signal can pass. This may work, but is influenced by temperature, vibration or movement.

Fibre cables can not be handled like their copper equivalents. They are sensitive to bending, crushing and dirt. Damage that is not visible on the outside may well be catastrophic for the fibre inside. Since a new patch cable can cost around SEK 200, it is easy to quickly spoil a whole lot of money by cutting corners with management.



Sure, it may be convenient to roll up an unruly fibre like this, as any headphone cord? This cable is basically destroyed, as the bending radii are too small.

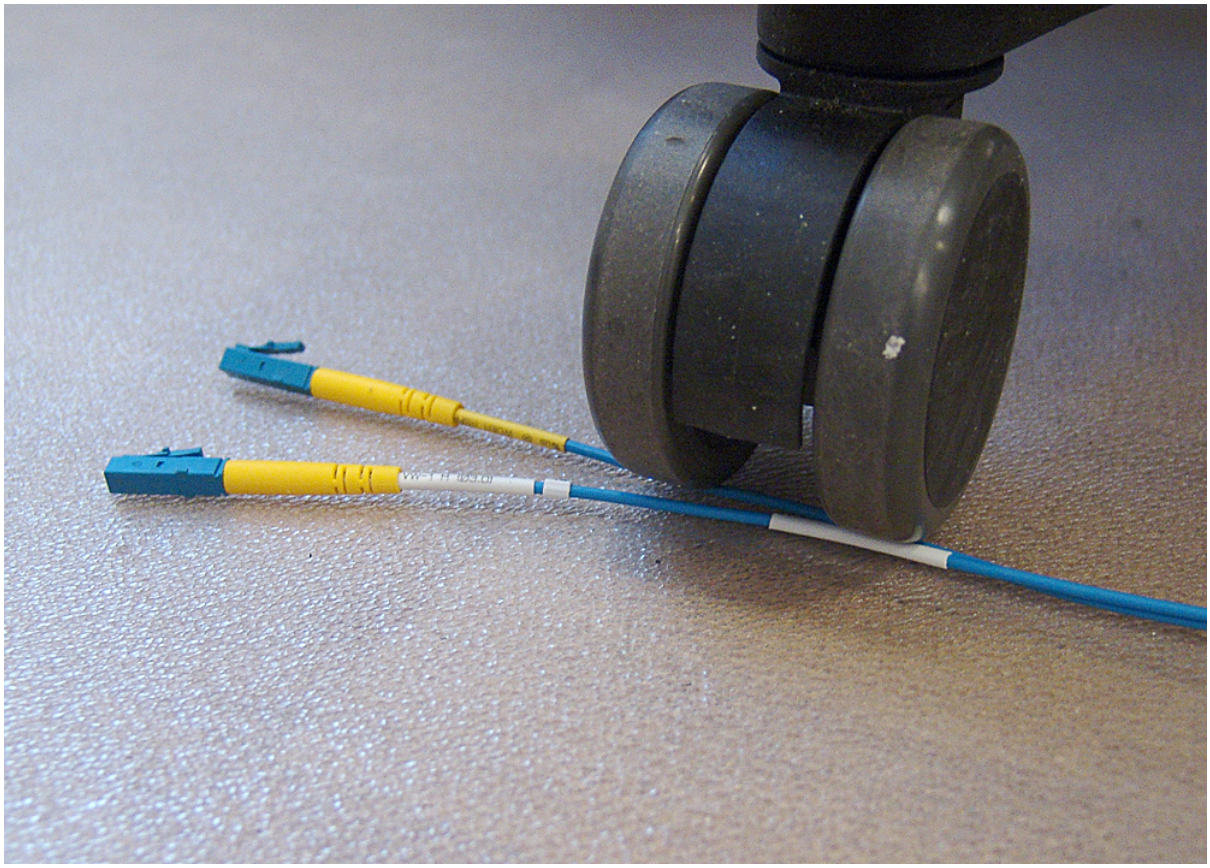


An innocent pastime during a coffee break? This cable is not likely to be usable. The glass core is probably ruptured, and dust and grease has accumulated on the connector surfaces.

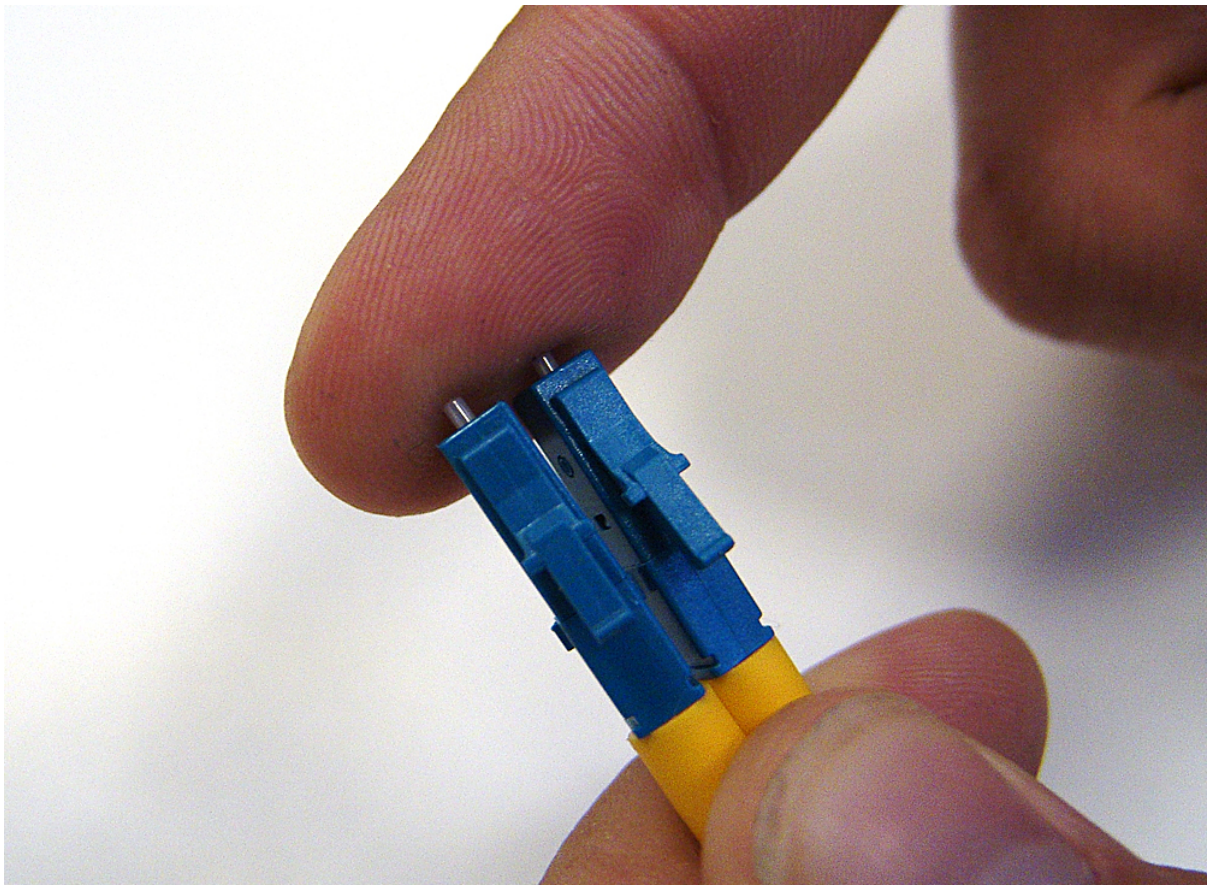
Fibre cables should not be lying around on the floor. Cable removed from equipment should not be put on the floor, not even temporarily. It becomes dirty, and someone may step on it and crush it internally.

Murphy's Law states that when dragging a cable behind you on the floor it will get caught in a door or similar. Again, it becomes dirty and the pull will probably destroy the core. For the same reason, a cable may not be permanently deployed through a doorway.

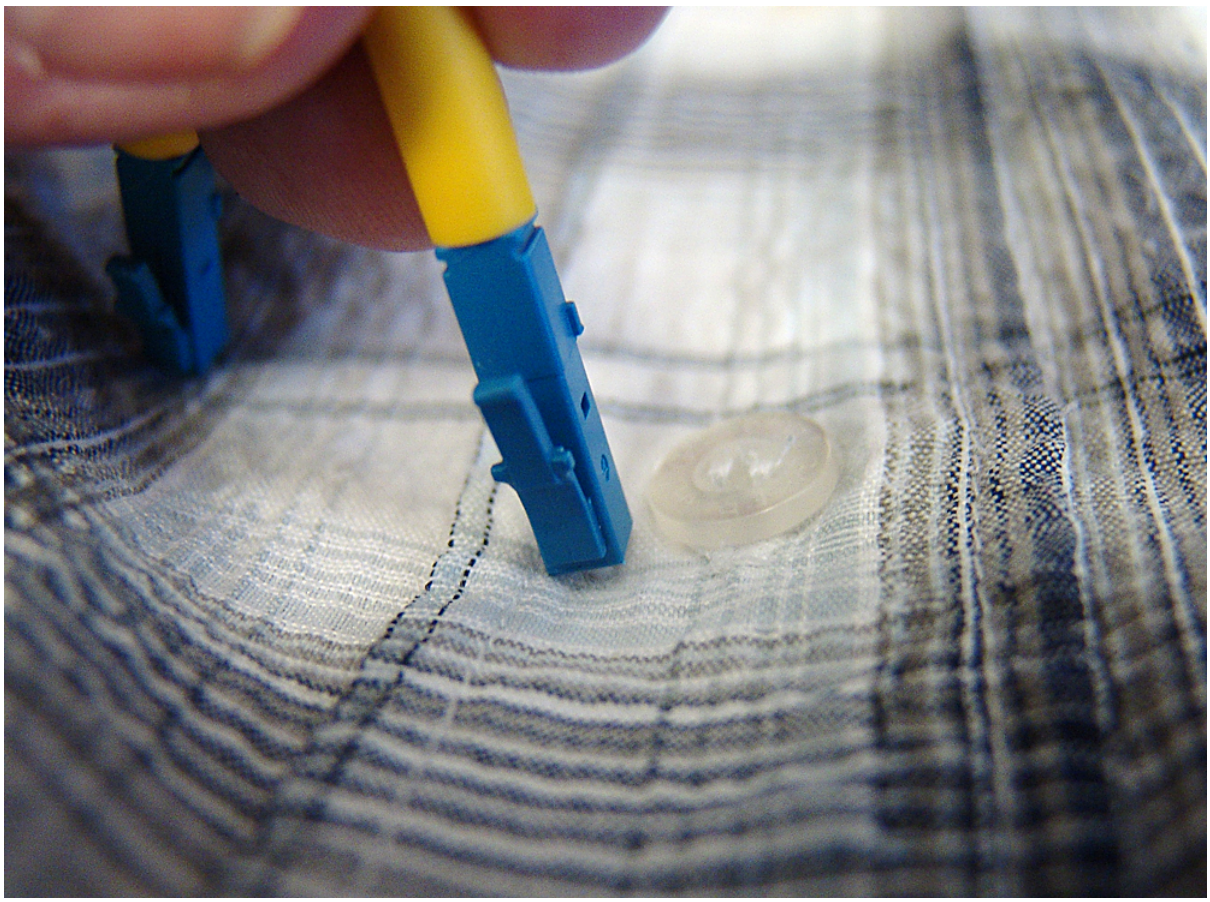
To mount a cable with staples using a staple gun is to promptly destroy it.



Bump! Oh, I have this problem rolling the office chair. The small bumping sound is the sign of a broken cable. It just takes a second to destroy a fibre optic cable.

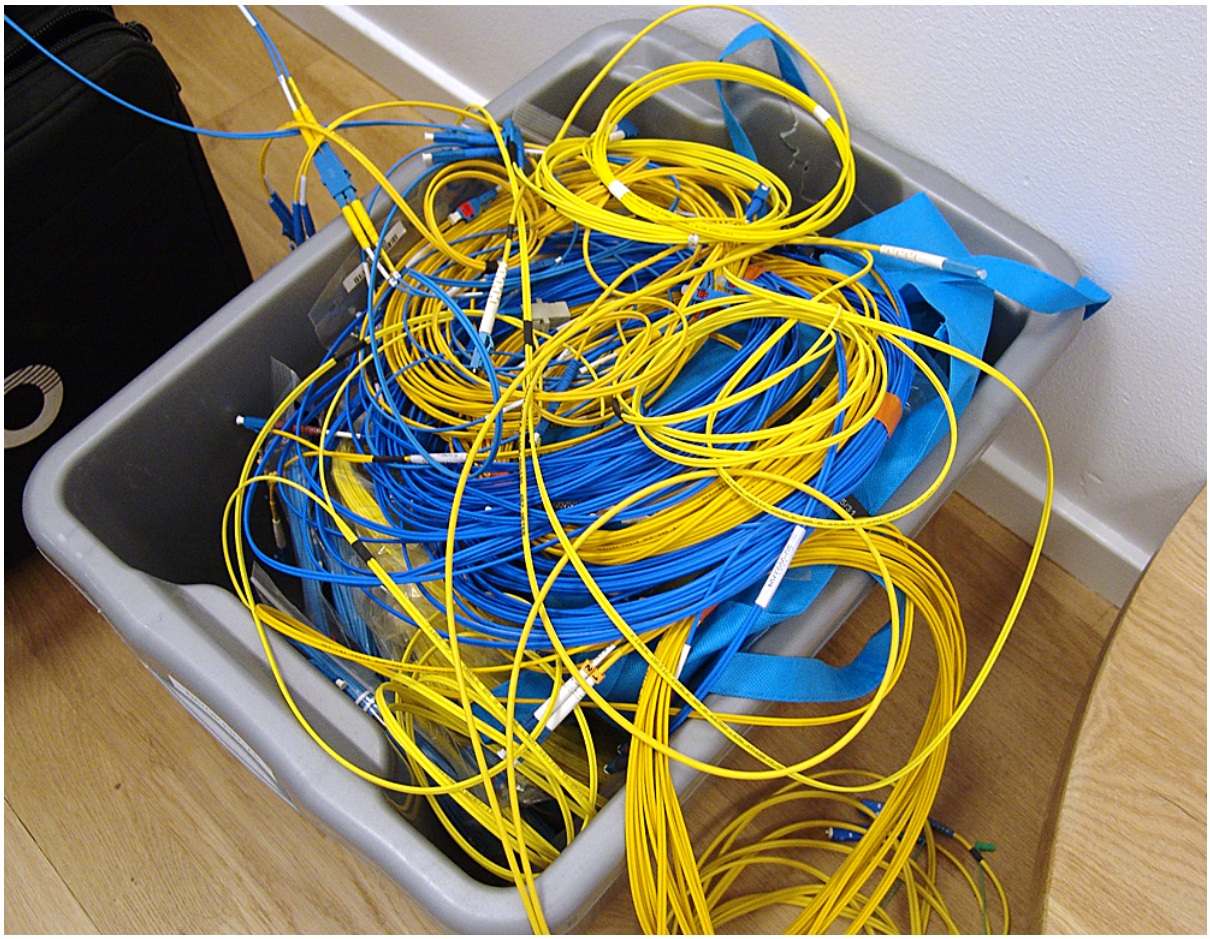


Do you have any idea of how dirty your fingers are? Have you seen them under a microscope? Avoid it. The fingertips are fat and full of loose dander, pollen and dust, what we commonly refer to as “dirt”. And it doesn’t matter how much you wash your hands. These connectors can hopefully be rescued by cleaning, but there is no guarantee.



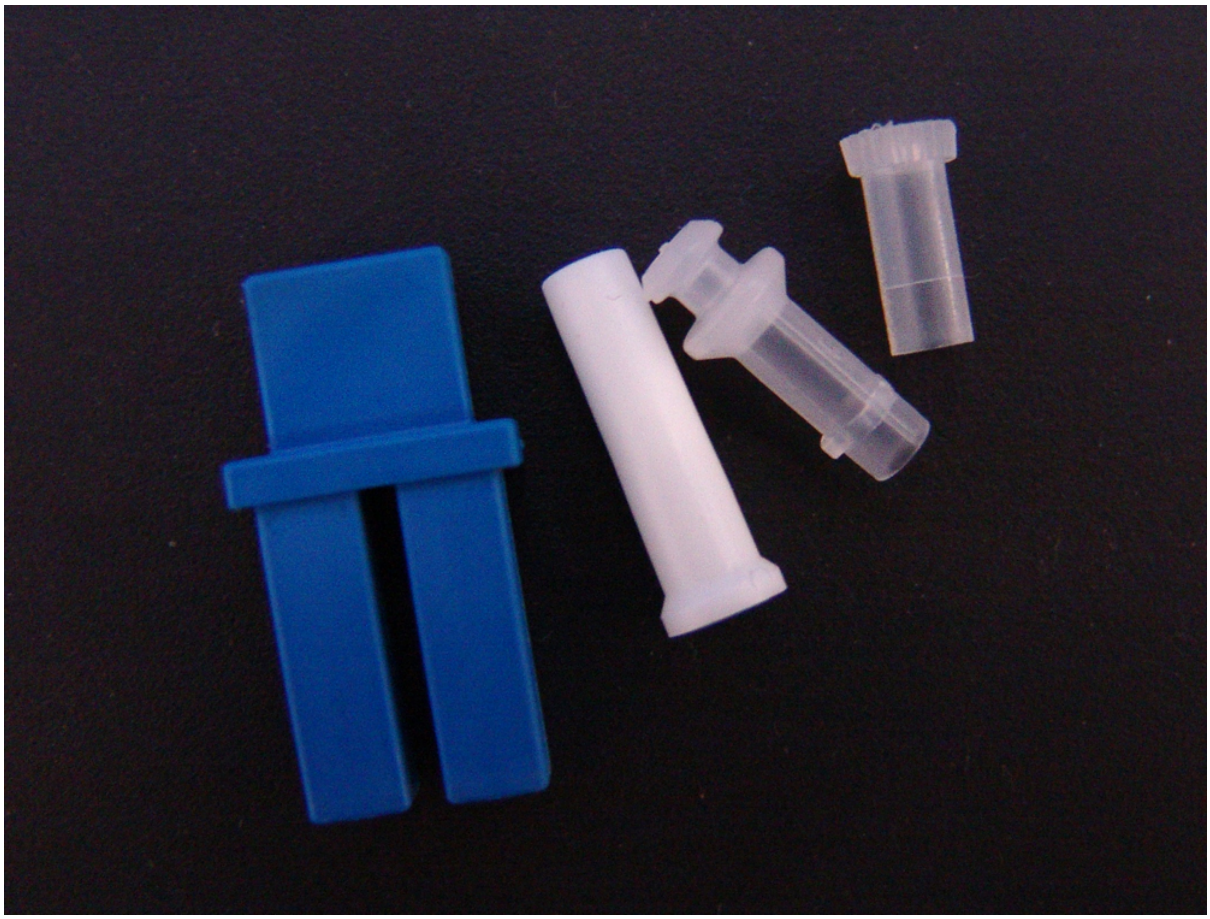
Do you usually rub your glasses against your sweater to get them clean? You might polish on a towel, or your sleeve, and they will be shiny clear. And all optics is the same? No, not really. Sweaters, towels and jeans all act as a junkyard or as coarse sandpaper on the nanometre level. The result is both scratches and fatty deposits on the connector surface.

FIBRE CABLE STORAGE

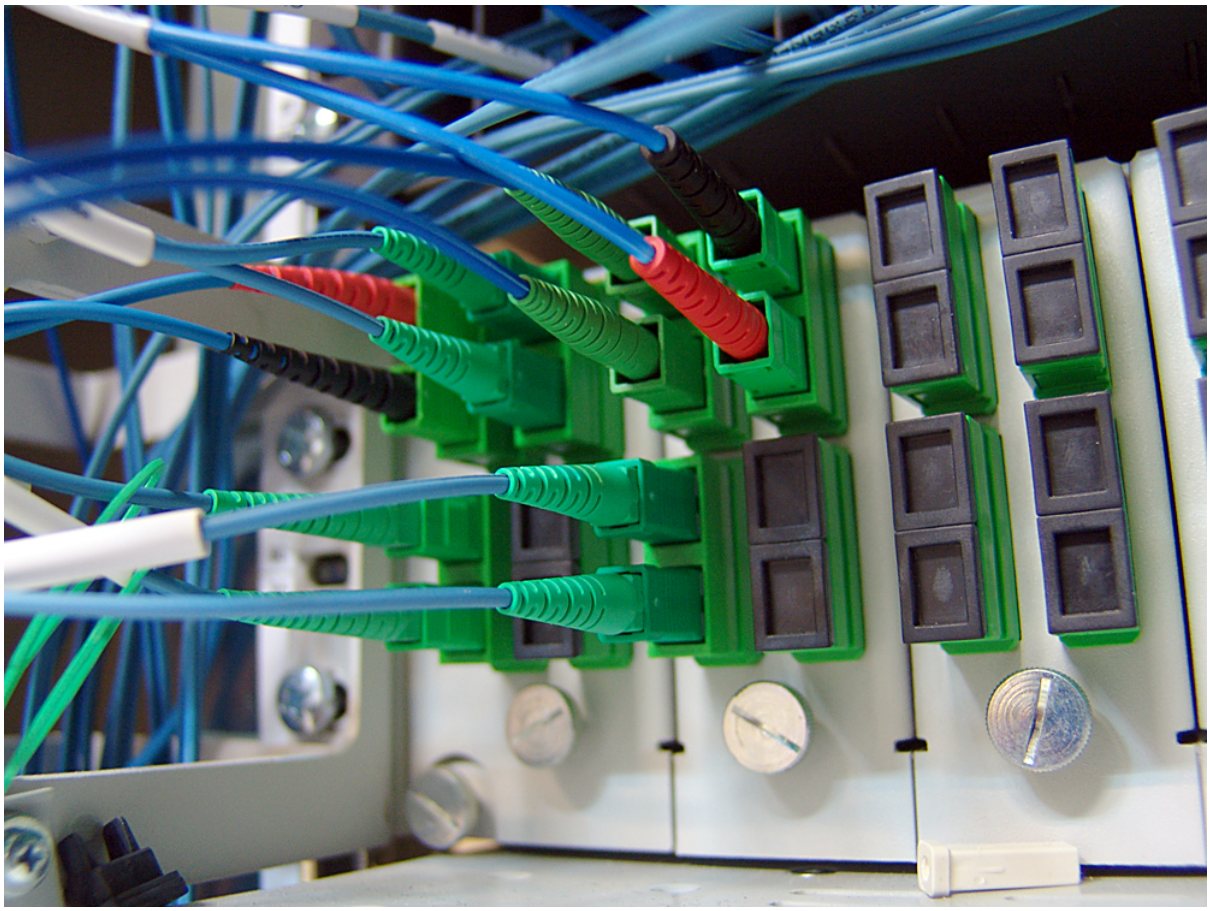


Lying around as a roll in a desk drawer, is definitely not the proper way to store fibre cables. The picture above shows another example of improper storage. The box contains disassembled cables removed from a data centre, stored temporarily in this way while awaiting investigation and cleaning. They certainly can not be re-used in this condition.

This is what proper storage looks like. Harnesses should be stored in their original packages in properly labelled boxes in a storeroom. Only then can you be sure that the cable you have is brand new and probably unharmed. But there is no guarantee. It must still be examined. See above.



The dust caps are among your best friends, those seemingly insignificant little plastic plugs that sit on new fibre connectors and on all patch panels and other optical equipment. Do not throw them away, but save and reuse. They are your insurance that the connectors are not contaminated by dust or invaded by cloth fibres, pollen and mites, when you plan to use them.



Here is a typical patch panel with black dust caps in the ports, which should remain there until the ports are to be used. To clean inside a port is considerably more difficult than cleaning a connector.

ATTENUATION EXAMPLES

A good mate between two connectors should not result in more than half a decibel's attenuation. A lousy joint with dirty connectors can attenuate up to some four decibels. Then you are in deep trouble.

Attenuation Examples
Two fibres spliced together: **0.01 dB**
Good joint with two clean connectors: **0.5 dB**
Poor joint with two dirty connectors: **2-4 dB**
Cable caught in door (damage to the core, useless): **10 dB**
SUNET between Stockholm and Uppsala (Odensala), 37 miles of fibre: **15 dB**
SUNET's requirement on Tele2's transmission network: **0.2 dB/km**

Having two or three bad connections in series could give as much attenuation as the entire route between Stockholm and Uppsala! You could cut your performance in half, jus' like that.

CONCLUSION

Cleanliness is a virtue. A dirty fibre connector can destroy the entire transmission or degrade performance significantly. Three dirty contacts in series could attenuate as much as the entire fibre route from Stockholm to Uppsala. A typical data centre could have upwards of a thousand patch cables, all potential sources of failure.

The most common mistake is reusing old cables without examining them with a microscope. Brand new connectors, being dirty anyway has caused a lot of problems in the expansion of SUNET, despite the explicit contractual obligation of connector cleaning.

SUNET is not giving away one-click fibre cleaning pens just because they have a nice logo, but because they should be used.

WORDS OF WISDOM

Clean all new fibres when they come out of the bag. You can't be sure they are clean.

Always clean in the same manner, to get repeatability.

When you have used a cotton swab, break it and discard it.

Scratched connectors can normally not be cleaned. Always protect connectors with a dust cover.

Retain all dust caps. Put them back immediately, when the port or connector is disconnected.

Always store transceivers with their dust caps on.

If a transceiver is not damaged, avoid trying to clean it.

Do not look into a fibre or a patch panel port. Normally, high power lasers in e.g. Raman and EDFA amplifiers decrease power if plug is pulled out, but you do not know. OTDR instruments also transmit high power, but have no similar safeguards. The eye is not protected by the blink reflex, because it is not activated by infrared light. Do not stare into beam with remaining eye!

FURTHER READING

Where to obtain fibre cleaning equipment:
https://www.aflglobal.com/Home.aspx
http://www.fujikura.com/
http://www.fs.com/

Where to obtain a fibre microscope:
http://www.viavisolutions.com/en-us
http://www.exfo.com/

All about various fibre connectors: **https://www.sunet.se/blogg/fiberkontakter-en-hel-massa-standarder/**
Various types of fibre: **https://www.sunet.se/blogg/sa-tillverkas-optisk-fiber/**
Watch your eyes and fingers: **http://www.thefoa.org/tech/ref/safety/safe.html**

Skriven av

JÖRGEN STÄDJE

Jag heter Jörgen Städje och har skrivit om teknik och vetenskap sedan 1984. Friskt kopplat, hälften brunnet!