

# **Application Note 4, Reliable Operation of LSProbe 1.2 Laser-Powered Electric-Field Probes**

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## 1 Introduction

Electric-field probes fall into one of two categories – battery-powered and laser-powered. Laser-powered probes offer the significant advantage of unlimited continuous operation. They save both time and effort for recharging or exchanging batteries or field probes.

However, most laser-powered field probes face a common issue. Contamination of the fiber connector end-faces can result in burn-in defects and thus system failures. Fig. 1 shows the end-faces of a clean, a contaminated and a defective (burned-in) fiber connector.



Figure 1: End-faces of optical fiber connector, viewed through fiber microscope

To mitigate this issue and enable reliable operation, LUMILOOP has developed sacrificial cable kits that are included in every LSProbe 1.2 Field Probe delivery.

The sacrificial cable kits operate as connector savers for the FC/ST connectors of Field Probe, Computer Interface and extension cable. They provide two defined and convenient points for disconnecting the Field Probe from the Computer Interface using the E2000 connectors of the sacrificial cable kits.

Due to the integrated shutters, burn-in defects at the E2000 connectors are significantly less frequent. However, in the case of a burn-in defect at an E2000 connector, the sacrificial cable kit can easily be replaced with a spare kit. That means, the system is quickly ready for use again. A spare sacrificial cable kit is provided with each LSProbe 1.2 Field Probe. To avoid further progression of burn-in defects, the complete kit including both sacrificial cables and the E2000 coupler shall always be replaced.

This document gives detailed instructions on operating laser-powered field probes both reliably and effortlessly, it contains four more sections:

- Section 2, page 3, the mechanism of fiber failures,
- Section 3, page 4, purpose and application of sacrificial cables kits,
- Section 4, page 6, fiber connector cleaning instructions,
- Section 5, page 8, replacement of sacrificial cable kits,
- Section 6, page 9, fiber handling recommendations.

## 2 Fiber Failure Mechanism

LUMILOOP's statistics show that more than three quarters of the field probes that are turned-in for analysis have fiber issues caused by improper handling.

For transparency, LUMILOOP creates a detailed report for every returned field probe, containing failure analysis and corrective measures. Fig. 2 shows images taken out of a typical repair report. In the shown case, the user had plugged the optical fibers frequently without cleaning. Additionally, the sacrificial cables had been removed by mistake. Consequently, both faces of an FC fiber connector pair, which carries the optical power for the field probe, suffered a burn-in defect.

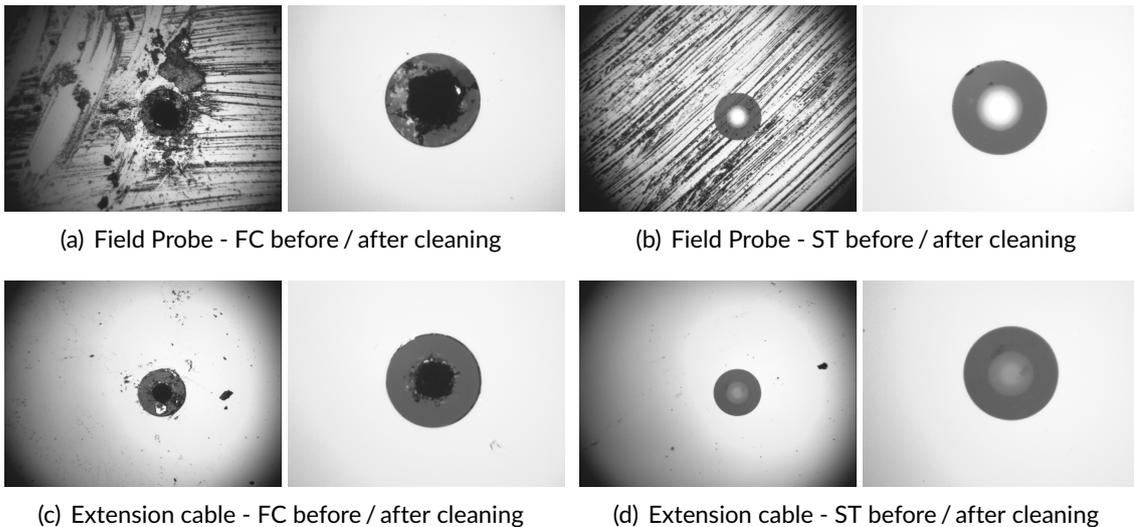


Figure 2: Example for contaminated FC (power) and ST (data) fiber connectors

As suggested by the name, burn-in defects are caused by excessive heating, leading to cracking and/or melting of the fiber core where two fibers interface. A sound optical fiber interface introduces less than 0.5 dB of attenuation. Contamination, e.g. by dust particles, will result in a higher attenuation, and thus a significant fraction of the optical power to be converted into heat.



Figure 3: Power density comparison: 1 Watt fiber core vs. 1 Kilowatt hot plate

LSProbe 1.2 field probe systems can launch up to 1 Watts of optical power into a 62.5  $\mu\text{m}$  optical fiber core. The resulting power density is more than a thousand times greater than that of a typical hot plate.

### 3 Sacrificial Cable Kits for LSProbe 1.2 Field Probe Systems

The LSProbe 1.2 Field Probe System consists of a Field Probe and a Computer Interface, connected by duplex fiber optic cables. Any Field Probe can be operated by any Computer Interface, both are identified by separate serial numbers.

Sacrificial cable kits serve as connector savers for all FC/ST connectors. Sacrificial cable kits are easily recognizable by their blue fiber jackets. As suggested by their name, sacrificial cable kits are meant to be sacrificed, i.e., thrown away, in the event of an fiber connector burn-in.

In a typically busy lab environment fiber cleaning as outlined in Section 4 can be difficult to enforce – human error can never be ruled out completely. Sacrificial cable kits introduce an easy-to-use pair of E2000 connectors. E2000 connectors are significantly less prone to contamination and thus to burn-in defects because of their integrated automatic shutters. Consequently, E2000 connectors may be plugged without cleaning, consciously accepting that contamination will accumulate with each plugging cycle and lead to a burn-in defect eventually.

Once a burn-in defect has occurred, the complete sacrificial cable kit must be replaced, including the E2000 coupler. Failing to replace one half of the sacrificial cable kit will inevitably lead to the replacement cable's burn-in.

Every LSProbe 1.2 System comes with a fiber extension cable and three sacrificial cable kits: one connecting the Computer Interface and fiber extension cable, one connecting fiber extension cable and Field Probe and one spare sacrificial cable kit.

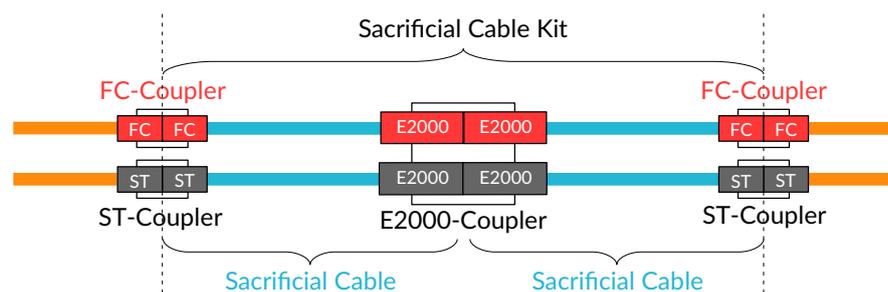


Figure 4: Sacrificial cable kit, consisting of two sacrificial cables, one E2000 coupler, one FC coupler and one ST coupler

The components of a connected sacrificial cable kit are shown in Fig. 4. A sacrificial cable kit consists of a pair of short fiber cables with FC/ST connectors at one end and E2000 con-

nectors at the other end. The two sacrificial cables are connected by an E2000 coupler. The FC/ST connectors at either end of the sacrificial cable kit connect to and protect the FC/ST connectors of the Field Probe, the Computer Interface and the fiber extension cable. Fig. 5 shows the fiber connections of a typical LSProbe 1.2 Field Probe System.

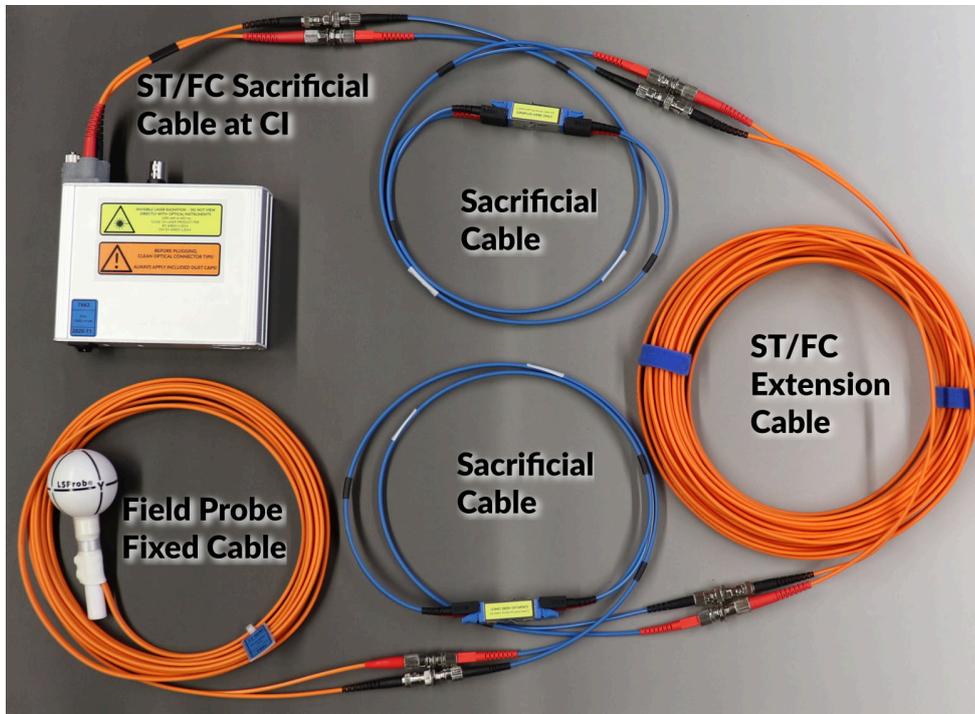


Figure 5: Typical LSProbe 1.2 Field Probe System with sacrificial cable kits

As highlighted in Fig. 6, the optical link should always be disconnected using E2000 connectors. Do not disconnect any FC/ST connectors unless absolutely necessary. When plugging FC/ST connectors make sure to observe the cleaning instructions in Section 4.

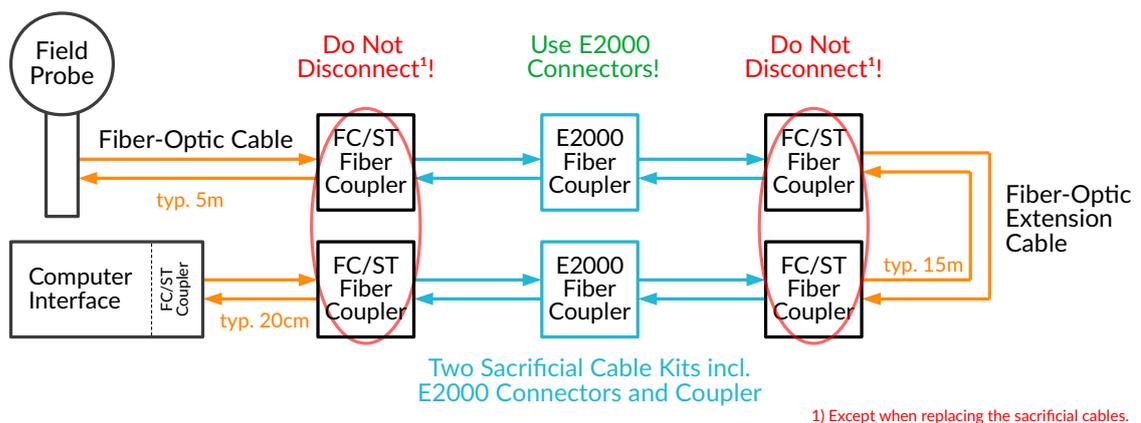


Figure 6: Fiber connections of a typical LSProbe 1.2 Field Probe System

## 4 Fiber Connector Cleaning Instructions

There are two methods for cleaning fiber-optic connectors: dry cleaning and wet-to-dry cleaning. Dry cleaning is suitable for minor contamination. Wet-to-dry cleaning is suitable for severe contamination caused by skin oils, skin flakes, dust particles, etc. Therefore, LUMILOOP recommends the wet-to-dry cleaning method, detailed in this section.

Regardless of the method, the following sequence of steps should be observed:

1. Inspect the connector end-faces for contamination using a fiber microscope. Always ensure that the Computer Interface is switched off and cannot be turned on inadvertently during fiber inspection. Note that the focal plane for E2000 and ST/FC connectors differ and must thus be adjusted.
2. Clean the connector end-face.
3. Reinspect the connector end-face, go back to step two, if there is any contamination.
4. Connect the fiber connectors, do not put the connector down. Do not apply dust caps between cleaning and connecting.

LUMILOOP's cleaning kit shown in Fig. 7 includes:

- a 400x optical fiber microscope,
- two packs lint-free cassette cleaner wipes (Chemtronics, Foccus QbE Pleaning Platform, part no. QBE),
- a fiber-optic cleaning pen (Chemtronics, Foccus Fiber-Wash Precision Cleaner, part no. FW2170)
- an unfilled isopropyl alcohol (IPA) pipette/bottle,
- spare FC/ST dust caps and two E2000 locking caps.



Figure 7: LUMILOOP fiber-optic cleaning kit

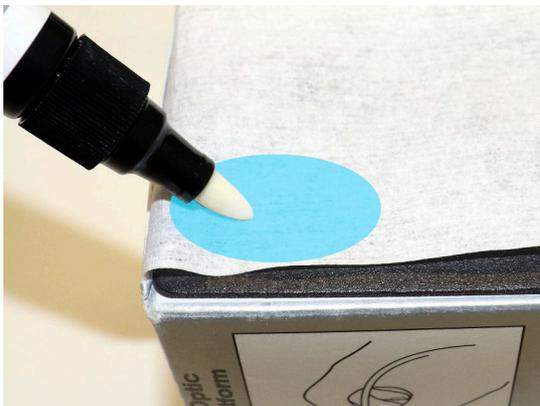
Fig. 8 shows how to clean the fiber connectr end-faces of ST/FC and E2000 connectors.



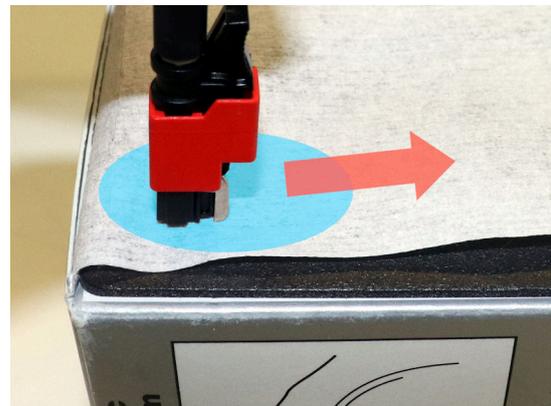
Step 1: Only for E2000 connectors, unclip the connector pair and apply an E2000 locking cap.



Step 2: Expose a fresh area of the lint-free fiber optic cleaning platform.



Step 3: Moisten one corner of the cleaning wipe using the fiber-optic cleaning pen or IPA pipette.



Step 4: Press the fiber end-face flatly against the moist area of the wipe and slide it into the dry area of the wipe.



Step 5: Only for E2000 connectors, remove the E2000 locking cap, re-clip the connector pair after cleaning both connectors.

Figure 8: FC/ST/E2000 fiber-optic connector wet-to-dry cleaning method

## 5 Replacing Sacrificial Cables

If a burn-in defect is observed at an E2000 connector, the complete sacrificial cable kit must be replaced. A step-by-step description of the recommended procedure is given below:

1. Prepare replacement
  - a) Disconnect the complete sacrificial cable kit including its E2000 coupler and dispose of it to prevent mix-up of cables or couplers.
  - b) Unpack a spare sacrificial cable kit. Skip step 2 for originally packed cables supplied by LUMILOOP.
2. Clean E2000 connectors
  - a) Unplug both E2000 connectors from the E2000 coupler.
  - b) Clean the connector pair of the first E2000 connector as described in Section 4 (Fig. 8) and plug it into the E2000 coupler.
  - c) Clean and connect the second E2000 connector.
3. Clean first end of sacrificial cable kit
  - a) Disconnect *both* FC connectors from the coupler.
  - b) Clean the first FC connector and connect it to the coupler.
  - c) Clean the second FC connector and connect it to the coupler.
  - d) Repeat steps a) through c) for the ST connectors.
4. Repeat step three for the second end of the sacrificial cable kit.
5. Consider ordering a new spare sacrificial cable kit.

**Fixing burned-in FC/ST connectors:** In case of a burn-in defect at a ST or FC connector due to improper handling, replacement is required. There are three distinct cases:

- In case of a burn-in defect at a fiber extension cable, the sacrificial cable kit and the extension cable can be replaced with spares. Please contact LUMILOOP for support.
- In case of a burn-in defect at the Computer Interface, experienced users may remove and replace the short orange fiber cable attached to the Computer Interface shown in Fig. 9. Please contact LUMILOOP for detailed instructions. Computer Interfaces without this short cable and associated cover can be refitted for improved system reliability. For older systems the sacrificial cable is attached directly to the Computer Interface. Please contact LUMILOOP support for more information.
- In case of a burn-in defect at the Field Probe, the system needs to be sent-in for repair. Please contact LUMILOOP for support.

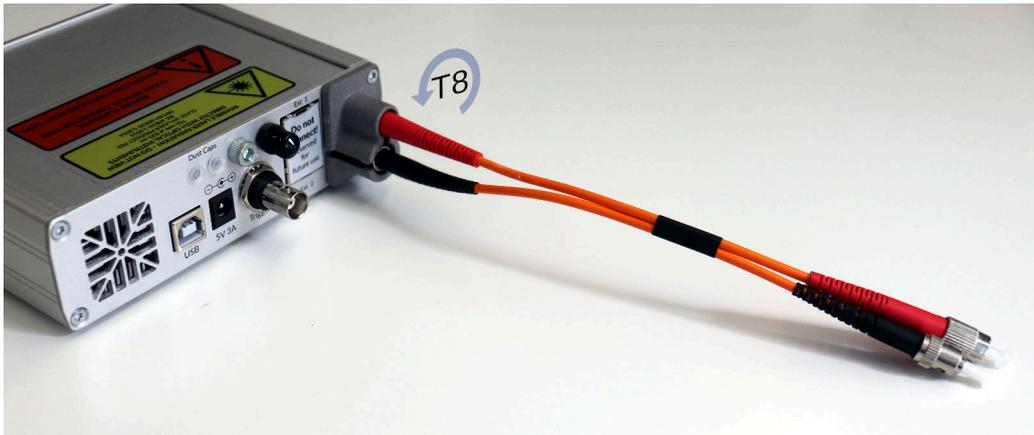


Figure 9: Rear view of Computer Interface with short fiber-optic cable fixed to its housing

## 6 Fiber Handling Recommendations

Observing the handling recommendations stated below will ensure the continuous, reliable operation of the LSProbe 1.2 Field Probe System. The recommendations should be brought to the attention of all staff operating the system. In general, always handle fiber-optic systems with care.

- Avoid bending of fiber optic cables more than the critical radius. For the fiber-optic cables supplied with the LSProbe 1.2 Field Probe, the critical bending radius can be given with 60 mm for short term and 100 mm long term bending.
- Avoid tensile strain on fiber-optic cables. Fiber-optic cables shall not carry the weight of the connectors.
- Always use two sacrificial cable kits – one between Computer Interface and extension cable and one between extension cable and Field Probe.
- Always disconnect the optical fiber connection using the E2000 connectors of the sacrificial cable kits.
- Do not open any FC/ST fiber connectors unless absolutely necessary.
- Cover all open fiber-optic connectors using the supplied dust caps.
- Before connecting any FC/ST connectors, e.g., when replacing a sacrificial cable kit, clean all connectors as described in Section 4. Use a fiber microscope to ensure that the connector end-faces are immaculate.
- When a sacrificial cable kit has burned-in at the E2000 coupler, replace the complete sacrificial cable kit including the E2000 coupler and clean all FC/ST connectors as described in Section 4.