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Operating Instructions

Raman fiber-optic cables KFOC1 and KFOC1B

Commissioning, operation, and maintenance details for Raman fiber-optic cables

Endress+Hauser
People for Process Automation

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1 About this document

This manual provides information about the KFOC1 Raman fiber-optic cables and KFOC1B Raman fiber-optic cables.

1.1 Warnings

Structure of Information	Meaning
⚠ WARNING **Causes (/consequences)** Consequences of noncompliance (if applicable) ▸ Corrective action	This symbol alerts you to a dangerous situation. Failure to avoid the dangerous situation can result in a fatal or serious injury.
⚠ CAUTION **Causes (/consequences)** Consequences of noncompliance (if applicable) ▸ Corrective action	This symbol alerts you to a dangerous situation. Failure to avoid this situation can result in minor or more serious injuries.
NOTICE **Cause/situation** Consequences of noncompliance (if applicable) ▸ Action/note	This symbol alerts you to situations which may result in damage to property.

1.2 U.S. export compliance

The policy of Endress+Hauser is strict compliance with U.S. export control laws as detailed in the website of the Bureau of Industry and Security at the U.S. Department of Commerce.

1.3 List of abbreviations

Term	Description
°C	Celsius
cm	centimeter
e	absorptivity
EEA	European economic area
EO	electro-optical
°F	Fahrenheit
FC	fiber channel
FOCA	Fiber-optic cable assembly
IPA	isopropyl alcohol
m	meter
NIR	near infrared
nm	nanometer
PVC	polyvinyl chloride
SSCS	stainless steel connector shell
T	transmission
UV	ultraviolet
WEEE	waste electrical and electronic equipment

2 Basic safety instructions

The safety information in this section is specific to the Raman fiber-optic cables. Refer to the Raman Rxn2, Raman Rxn4, and Raman Rxn5 Operating Instructions for additional analyzer-related safety information about working with lasers.

It is the responsibility of the user to understand and comply with all applicable safety regulations. These will vary based on the installation location of the instrument. Endress+Hauser takes no responsibility for determining the safe use of the instrument based on this qualification procedure.

2.1 Requirements for personnel

- Installation, commissioning, operation, and maintenance of the Raman fiber-optic cables may be carried out only by specially trained technical personnel.
- Technical personnel must be authorized by the plant operator to carry out the specified activities.
- Technical personnel must have read and understood these Operating Instructions and must follow the instructions contained herein.
- Faults at the measuring point may only be rectified by authorized trained personnel. Repairs not described in this document must be carried out only directly at the manufacturer's site or by the service organization.

2.2 Intended use

Use Raman fiber-optic cables in analytical Raman applications to position the analyzer base unit remotely from the sampling probe.

2.3 Electrical safety

As the user, you are responsible for complying with the following safety conditions:

- Installation guidelines
- Local standards and regulations for electromagnetic compatibility

2.4 Operational safety

Before commissioning the entire measuring point:

1. Verify that all connections are correct.
2. Ensure that electrical cables and optical fiber connections are undamaged.
3. Do not operate damaged products. Protect them against unintentional operation.
4. Label damaged products as defective.

If faults cannot be rectified during operation, products must be taken out of service and protected against unintentional operation.

⚠ CAUTION

Activities while the Raman fiber-optic cables are in operation introduce risk of exposure to measured materials.

- ▶ Follow standard procedures for limiting exposure to chemical or biological materials.
- ▶ Follow workplace policies on personal protective equipment including wearing protective clothing, goggles, and gloves and limiting physical access to analyzer location.
- ▶ Clean any spills using the appropriate site policies on cleaning procedures.

2.5 Product safety

The product is designed to meet local safety requirements for the intended application, and has been tested accordingly, leaving the factory in a condition in which it is safe to operate. All applicable regulations and international standards have been observed. Devices connected to Raman Rxn analyzers must comply with the applicable safety standards.

3 Incoming product acceptance and product identification

3.1 Delivery

The scope of delivery comprises:

- Raman fiber-optic cables in the configuration ordered
- *Raman fiber-optic cable Operating Instructions (BA02177C)*
- Raman fiber-optic cable Certificate of Product Performance
- Local declarations of conformity, if applicable
- Certificates for hazardous zone use, if applicable
- Raman fiber-optic cable optional accessories, if applicable

If you have any questions, contact your supplier or local sales center.

3.2 Supplementary documentation

All documentation is available:

- On the Endress+Hauser mobile app: www.endress.com/supporting-tools
- In the Downloads area of the Endress+Hauser website: www.endress.com/downloads

This document is an integral part of the document package, which includes:

Part Number	Document Type	Document Title
TI01641C	Technical Information	Raman fiber-optic cables Technical Information

3.3 Incoming acceptance

1. Verify that the packaging is undamaged. Notify the supplier of any damage to the packaging. Keep the damaged packaging until the issue has been resolved.
2. Verify that the contents are undamaged. Notify the supplier of any damage to the delivery contents. Keep the damaged goods until the issue has been resolved.
3. Check that the delivery is complete by comparing the shipping documents with your order. Notify the supplier if there are any missing items.
4. Pack the product for storage and transportation in such a way that it is protected against impact and moisture. The original packaging offers the best protection. Make sure to comply with the permitted ambient conditions.

If you have any questions, refer to our website (https://endress.com/contact) for the list of local sales channels in your area.

3.3.1 Product identification

The order code and serial number of your product can be found in one or more of the following locations:

- On the product
- In the delivery papers

3.3.2 Manufacturer address

Endress+Hauser
371 Parkland Plaza
Ann Arbor, MI 48103 USA

3.4 Installation

Raman fiber-optic cables are frequently used in analytical Raman applications to allow the analyzer base unit to be positioned remotely from the sampling probe.

This is most commonly found in *in situ* monitoring areas in the laboratory and in process environments. The ability to position the analyzer base unit remotely from the sampling point can be very beneficial when installing a Endress+Hauser Raman analyzer in an designated plant environment. This flexibility allows the analyzer base unit to be located in a control room or designated analyzer sheds.

Raman fiber-optic cables meet IEC 60079-14 requirements for use in hazardous zones as defined by the IEC. These cables are marked as either:

Cable type	***Zone code***
KFOC1 Raman fiber-optic cable	*Endress+Hauser – Raman Fiber Cable Part#20111635 X5-CSA-C/US 180789 FT-4 AWM Class I/II A/B 80C 30V.*
KFOC1B Raman fiber-optic cable	*Endress+Hauser – Raman Fiber Cable Part#2021982 X1 E177515 c(UL)us Type CMR-OF FT4 75C or E523128-FO AWM 20276 AWM Class I/II A/B 80C 30V.*

These markings appears at 24-inch intervals on each cable type. These cables are specified as components in the hazardous area installation documentation and form an intrinsic safety part of the probe assembly.

Consult local laws and regulations to ensure compliance with cable installation requirements for your division or zone.

3.5 Operation

Optical fibers provide excellent transmission media, however, they are not loss-free. These transmission losses are not significant for standard laboratory cable lengths of 1.9 or 5 m (6.2 or 16.4 ft), but become significant with longer cable lengths ranging from 50 to 300 m (164 to 984 ft), which are not uncommon for process locations.

Optical fibers exhibit a small signal loss for each meter of cable length that the signal travels. In addition, the transmission of optical fibers is wavelength dependent, which means that the transmission loss per meter increases as the excitation wavelength moves to a shorter wavelength. Therefore, losses using a Raman laser of 532 nm are greater per meter than those using a laser of 785 nm.

3.5.1 Signal loss

When developing a method in the laboratory for transfer to production, it is important to evaluate the impact of potential fiber losses. With a 785 nm laser, cable lengths as long as 227 m (744 ft) can be used with only a 25 % loss in signal. Note that the percentage transmission (%T) shown in Figure 1 accounts for the cumulative loss over the whole cable and includes excitation signal losses in the 227 m (744 ft) excitation fiber and Raman signal loss in the 227 m (744 ft) collection fiber. A 25 % signal loss is relatively small and can be compensated for by optimizing the spectral acquisition parameters in a production method to acquire more signal at the expense of time per measurement.

For the same experiment using a 532 nm laser as the excitation source, the loss for a cable length of 227 m (744 ft) is 85 %. Visible wavelength lasers, such those producing light at 532 nm, typically produce less laser power per unit volume of space than their near infrared (NIR) diode laser counterparts operating at 785 nm. The combination of greater cable losses and lower laser power from visible lasers are some of the Endress+Hauser often recommends NIR lasers (and 785 nm excitation) for solid and liquid process applications.

3.5.2 Results

The absorptivity (e) values provided are based on the difference in transmission between a 1.9 m (6.2 ft) and a 50 m (164 ft) fiber. Fiber cable connection variations have been averaged out and injection losses are assumed to be equivalent for both cables.

Emission absorptivities are based on the average value for the entire Raman spectrum window (transmission is slightly less for lower Raman shifts and slightly greater for higher Raman shifts).

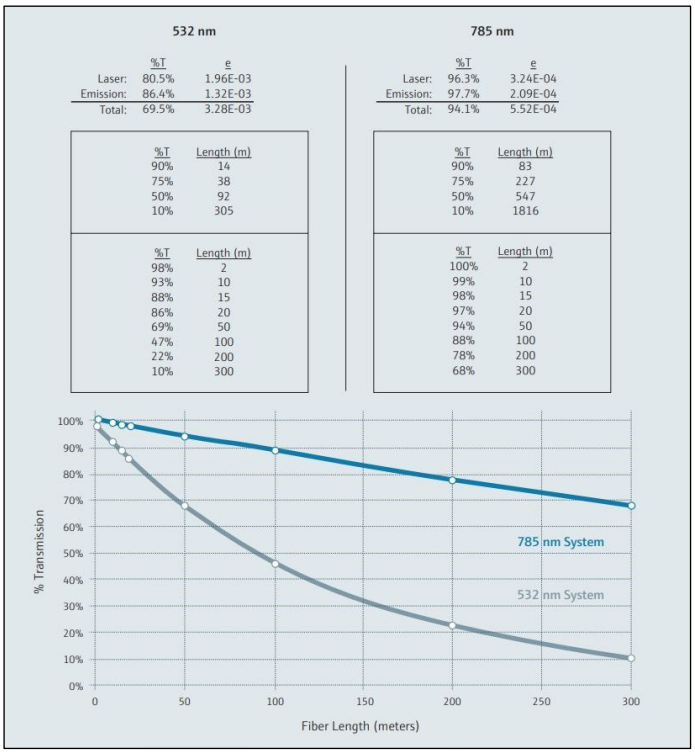

Figure 1. Measured fiber transmission (%T) vs. fiber length

3.6 Maintenance

3.6.1 Cleaning a Raman fiber-optic cable

To ensure optimal performance, it is recommended that you follow the steps below to properly clean and install a Raman fiber-optic cable assembly. EO connections are the same for both KFOC1 and KFOC1B cable types.

1. Remove the cover from the probe fiber cable-side connector.

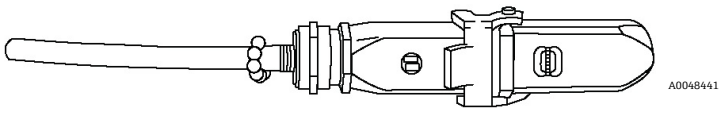

Figure 2. Electro-optical fiber connection cover

2. Clean the fiber tips of the cable-side connector prior to installation if cleanliness of fiber tips is unknown.
   - First use a lens wipe very lightly saturated with a solvent, such as 100 % isopropyl alcohol (IPA), followed by a final cleaning with a 1.25 mm fiber cleaning tool. Do not use the same wipe for both fiber tips.

- Swipe the fiber tip once with the damp portion of the wipe, then swipe once more with a dry portion of the same wipe. Repeat for both fiber tips.

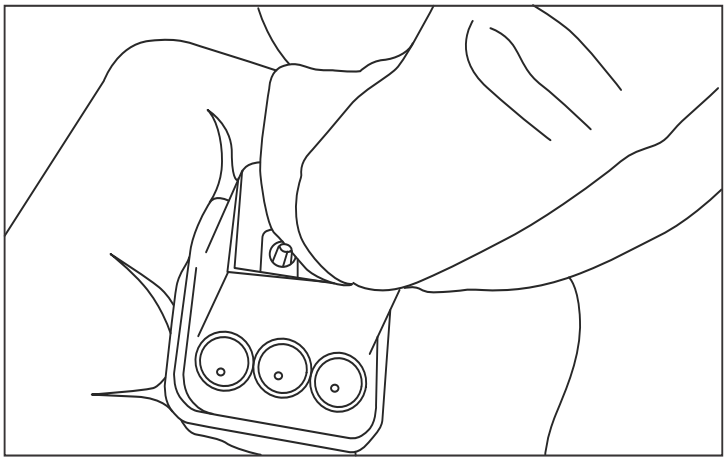

Figure 3. Cleaning electro-optical fiber connection

3. Next, use an IBC or equivalent 1.25 mm ferrule cleaner with the bulkhead adapter attached to do a final clean of the center of the ferrule where the fiber resides. Press together until a click is heard and repeat once.

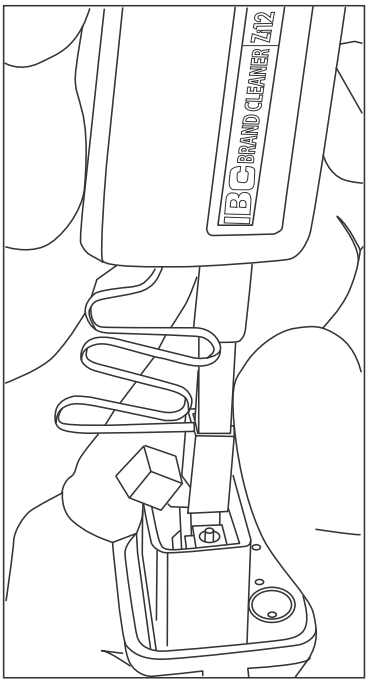

Figure 4. Final clean of electro-optical fiber connector fiber tips

4. Connect to the analyzer.
5. Repeat for any additional probes.

4 Product description

Raman fiber-optic cables revolutionized Raman spectroscopy by enabling remote location of Raman sampling probes from a base unit. This enabled Raman spectra to be acquired in hazardous environments from samples that cannot be easily transported to a sampling chamber. Consequently, Raman spectroscopy entered several new arenas including the industrial process line, where the base unit is placed in a control room or other protected environment while the Raman probe is placed in the process line for real-time, *in situ* process monitoring and control.

In the majority of state-of-the-art remote dispersive Raman systems, the excitation radiation is delivered from the laser to the Raman probe through a single excitation fiber. The scattered radiation that is collected from the sample is delivered to the spectrograph through a single collection fiber.

Optical fibers are constructed of a low-hydroxyl silica core surrounded by a flourine-doped silica cladding and a protective acrylate buffer coating. This 3-layer fiber is typically formed in a single “draw” manufacturing operation. The outer packaging of the cable may vary depending on the application. Fibers intended for industrial and laboratory applications often place a tight polymer buffer on the fiber or run through a loose polymer tube. Such fiber subassemblies can then be packaged into a composite industrial grade cable with a robust polymer outer jacket containing other such optical fiber subassemblies, electrical wires, and a rigid strength member.

4.1 Raman fiber-optic cable types

Raman fiber-optic cables with different connectors are available to connect various Raman probes and Raman Rxn analyzers. A list of commonly used fiber cables is provided below.

4.2 KFOC1B-AAC? (KFOC1B) and KFOC1-BD? (KFOC1)

The question mark in KFOC1B-AAC? and KFOC1-BD**?** represents the configuration length that is customizable in 5 m (16.4 ft) increments.

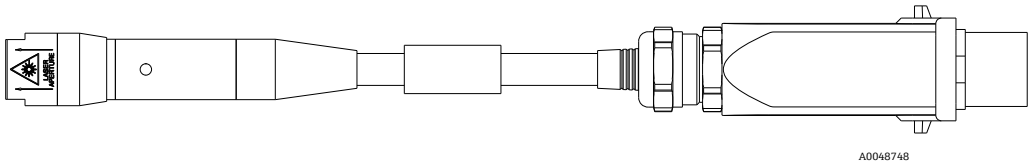

Figure 5. KFOC1-BD?

Analyzer	Probe	Description	Standard Length
Raman Rxn2 Raman Rxn4, Raman Rxn5,	Raman Rxn-10 Raman Rxn-30, Raman Rxn-40,	Base unit: EO (M) Probe connection: stainless steel connector shell Length: specify in meters	No standard length (limited by application)

NOTICE

- This Raman fiber-optic cable is compatible with some legacy Rxn products.

4.3 KFOC1B-AAB? (KFOC1B) and KFOC1-BC? (KFOC1)

The question mark in KFOC1B-AAB? and KFOC1-BC? represents the configuration length that is customizable in 5 m (16.4 ft) increments.

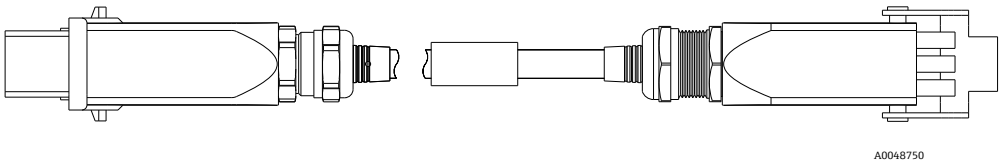

Figure 6. KFOC1-BC?

Analyzer	Probe	Description	Standard Length
Raman Rxn2, Raman Rxn4, Raman Rxn5	Probes that accept EO connectors	Base unit: EO (M) Probe connection: EO (F) Length: specify in meters	5 to 200 m (16.4 to 656.17 ft) in 5 m increments (limited by application)

4.4 KFOC1B-AAA? (KFOC1B) and KFOC1-BB? (KFOC1)

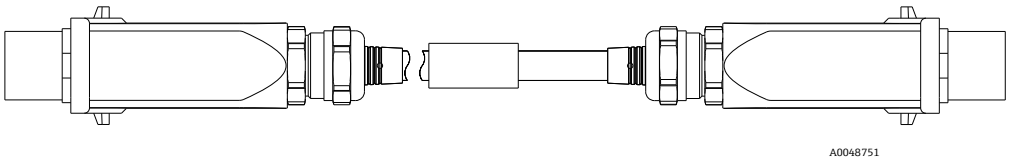

Figure 7. KFOC1-BB?

Analyzer	Probe	Description	Standard Length
Raman Rxn2, Raman Rxn4, Raman Rxn5	Probes that accept EO connectors	Base unit: EO (M) Probe connection: EO (M) Length: specify in meters	5 to 200 m (16.4 to 656.17 ft) in 5 m increments (limited by application)

NOTICE

- This Raman fiber-optic cable is compatible with some legacy Rxn products.

5 Technical data

5.1 Specifications

KFOC1 Raman fiber-optic cable	
Structure of Information	Meaning
General features	Integrated copper conductor wire for interlock capability Aramid (Kevlar) internal strength members Flame retardant Fungus resistant
Cable rating (cable only)	Operating temperature: –40 °C to 70 °C (–40 °F to 158 °F) Storage temperature: –55 °C to 70 °C (–67 °F to 158 °F) Certified: CSA-C/US AWM I/II, A/B, 80C, 30V, FTI, FT2, VW-1, FT4 Rated: AWM I/II A/B 80C 30V FT4
Bend radius	152.4 mm (6 in)
Termination	Electro-optic (EO) with connectors

The KFOC1B Raman fiber-optic cable features an improved rating, CMR-certification, ensuring easier compliance with local laws and regulations. This certification supports smoother implementation in process environments. Independently tested and certified by a third party, these cables offer enhanced protection against the spread of fire.

With the CMR rating, the KFOC1B Raman fiber-optic cable is ready for immediate installation in cable trays, risers, and all conduit types with no additional assessments required.

KFOC1B Raman fiber-optic cable	
Item	**Description**
General features	Integrated copper conductor wire for interlock capability Fiber-reinforced plastic (FRP) strength members Flame retardant Fungus resistant
Cable rating (cable only)	Operating temperature: –40 °C to 70 °C (–40 °F to 158 °F) Storage temperature: –55 °C to 70 °C (–67 °F to 158 °F) Certified: cULus AWM I/II, A/B, 80C, 30V, FTI, FT2, VW-1, FT4 Rated: CMR-FO, AWM I/II A/B 80C 30V FT4
Bend radius	152.4 mm (6 in)
Termination	Electro-optic (EO) connectors

6 Function and System Design

6.1 Endress+Hauser Raman cables

All Endress+Hauser Raman probes use standard cables comprised of an integrated fiber cable assembly containing an excitation fiber and a collection fiber packaged in a robust polyvinyl chloride (PVC) jacket to prevent breakage. Endress+Hauser Raman fiber-optic probes also integrate the laser interlock into the probe termination for improved laser safety. If the cable is severed, the laser switches off within milliseconds, preventing laser light from dispersal into the environment.

Endress+Hauser's Raman fiber-optic cables are rated for indoor/outdoor use, flame/UV resistance, and pull strength, maximizing their safety in the process environment. The cables are suitable for use in a variety of environments including direct burial, underground ducts, aerial installations, steam tunnels, building risers, cable trays, and harsh industrial settings. Consult your local laws and regulations to ensure compliance with cable installation requirements for your specific environment.

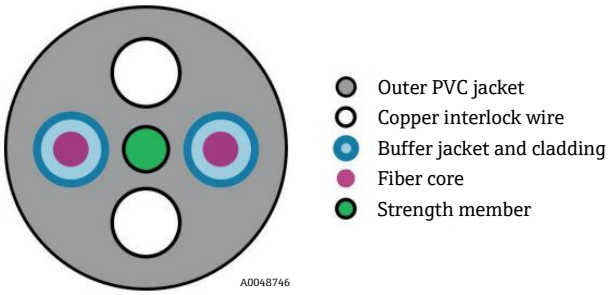

Figure 8. Cross section representation of a Raman fiber-optic cable

Endress+Hauser offers the strength member in both fiber-reinforced plastic (FRP) and aramid yarn. Aramid yarn (Kevlar) is a strong plastic made from tightly bonded organic molecules, while fiber reinforced polymer consists of fiberglass made from thin glass strands combined with plastic resin.

Normally, the fiber cable is installed into cable trays. However, should individual site engineering specifications require it, the cable may be further protected by the use of conduits. Some customers run cables in positively purged conduits to minimize the chance of flammable gas egress in explosive environment.

For long fiber assemblies, removable pulling socks are available as an option to help with installation. These allow complete tested assemblies to be installed *in situ* without the need for onsite termination.

It is recommended that cables being run outdoors, overhead, or any place where the cable jacket may come in contact with corrosive vapors are installed with an appropriately enclosed conduit. To install cables within a conduit, be sure to specify the cable with pulling eyes.

Component	**KFOC1 Raman fiber-optic**	**KFOC1B Raman fiber-optic**
Outer PVC jacket	Rigid PVC	Flexible PVC
Copper interlock wire	✔	✔
Buffer jacket and	✔	✔
Fiber core	✔	✔
Strength member	Aramid yarn	Fiber reinforced polymer

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