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Operating Instructions
Fiber Optic Cables

Endress+Hauser
People for Process Automation

Table of Contents

1 About this document

1.2 Warnings

Structure of Information	Meaning
⚠ WARNING **Causes (/consequences)** If necessary, consequences of non-compliance (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)** If necessary, consequences of non-compliance (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** If necessary, consequences of non-compliance (if applicable) ▸ Action/note	This symbol alerts you to situations which may result in damage to property.

Table 1. Warnings

1.3 Symbols on the device

Symbol	Description
	The Laser Radiation symbol is used to alert the user to the danger of exposure to hazardous visible laser radiation when using the system.
	The High Voltage symbol that alerts people to the presence of electric potential large enough to cause injury or damage. In certain industries, high voltage refers to voltage above a certain threshold. Equipment and conductors that carry high voltage warrant special safety requirements and procedures.
	The WEEE symbol indicates that the product should not be discarded as unsorted waste but must be sent to separate collection facilities for recovery and recycling.
CE	The CE Marking indicates conformity with health, safety, and environmental protection standards for products sold within the European Economic Area (EEA).

Table 2. Symbols

1.4 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.

1.5 Glossary

Term	Description
°C	Celsius
cm	Centimeter
e	Absorptivity
EEA	European Economic Area
EO	Electro-optical
FC	Fiber channel
IPA	Isopropyl alcohol
m	Meter
NIR	Near infrared
nm	Nanometer
PVC	Polyvinyl chloride
T	Transmission
UV	Ultraviolet
WEEE	Waste Electrical and Electronic Equipment

Table 3. Glossary

2 Basic safety instruction

NOTICE

- The safety information in this section is specific to the 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.

2.1 Requirements for the personnel

- Installation, commissioning, operation, and maintenance of the fiber optic cables may be carried out only by specially trained technical personnel.
- The technical personnel must be authorized by the plant operator to carry out the specified activities.
- The technical personnel must have read and understood these Operating Instructions and must follow the instructions contained therein.
- 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 Designated use

The fiber optic cables are frequently used in analytical Raman applications to allow the analyzer base unit to be located 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 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, and protect them against unintentional operation.
4. Label damaged products as defective.

During operation:

1. If faults cannot be rectified: products must be taken out of service and protected against unintentional operation.
2. Keep the door closed when not carrying out service and maintenance work.

⚠ CAUTION

Activities while the 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

Each fiber optic cable is designed to meet state-of-the-art safety requirements, has been tested, and left the factory in a condition in which it is safe to operate. The relevant regulations and international standards have been observed. Devices connected to Raman Rxn analyzers must comply with the applicable safety standards.

2.6 Important safeguards

- Do not use the fiber optic cable for anything other than its intended use.
- Do not look directly into the laser beam.
- Do not stare or focus a laser in a diffused direction.
- Do not point a laser at a mirrored surface.
- Do not leave attached and unused probes uncapped or unblocked.
- Always use a laser beam block.

2.7 Health and safety considerations

It is the user's responsibility 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.

3 Product description

Fiber optic technology revolutionized Raman spectroscopy by allowing Raman sampling probes to be located remote 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 and/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.

3.1 Laboratory cables

In the laboratory, it is particularly critical to handle fiber optic cables properly to prevent damage. This is important from both a cost as well as a safety perspective. Damaged cables may disperse laser light into the laboratory environment, presenting an optical hazard to personnel in the area. Cables must be handled properly, inspected regularly, and replaced when damage is identified.

3.2 Process cables

In the process environment, fiber optic cables are subjected to additional conditions that require consideration. The cable may need to be run through areas such as plenums, indoor ducts, conduits, or open cable trays, where temperatures along the length of the cable can range from as low as −40 °C to 80 °C or greater. Outdoor cables may be exposed to harsh weather conditions, including rain, snow, and ice, and prolonged exposure to ultraviolet (UV) rays from the sun.

Fiber optic cables for the process environment come in three basic cable ratings: indoor, outdoor, and combined indoor/outdoor use. Indoor rated cables are flame resistant and are typically able to be installed in plenums and to be run through walls. Outdoor-rated cables are resistant to degradation by UV light and can survive in a broad temperature range. Indoor–outdoor rated cables combine the features of both indoor and outdoor cables.

Riser rated cables are a popular option for cables used in the process environment. These cables are designed to be mounted in any orientation (including vertically) so that they can be run up a wall to reach overhead ductwork.

For installation in hazardous locations in Canada and the United States, Endress+Hauser deploys a specialized hybrid cable containing both fiber-optic and electric members. This cable is marked as:

Endress+Hauser – Raman Fiber Cable Part#20111635 CSA-C/US FT-4 AWM Class I/II A/B 80C 30V <|> <Date>

This marking appears at 24 inch intervals. This cable is called out as a component of the North American hazard area installation documentation and forms an intrinsic component of the probe assembly. The use of these cables is required for all North American hazardous locations installations when an installation is to meet North American certification.

3.3 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 have integrated the laser interlock into the probe termination for improved laser safety. The laser switches off within milliseconds, preventing laser light from being dispersed into the environment if the cable is severed.

Endress+Hauser Raman’s standard fiber cables are indoor/outdoor, riser-rated fiber optic cables. These cables are also fully rated for flame/UV resistance and pull strength, maximizing their safety in the process environment.

Endress+Hauser Raman fiber 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.

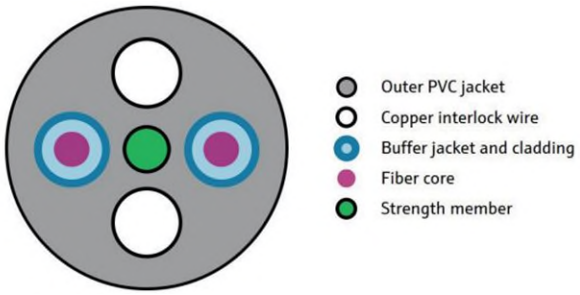

Figure 1. Cross section of a Raman fiber optic cable

The cable contains a rigid strength member, copper interlock wires, and a protective outer PVC jacket. 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.

4 Incoming product acceptance and product identification

4.1 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 and nothing is missing. Compare the shipping documents with your order. Notify the supplier of 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, please contact your supplier or your local sales center.

4.1.1 Identifying the product

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.

4.1.2 Manufacturer address

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

4.2 Scope of delivery

The scope of delivery comprises:

- Fiber optic cables in the configuration ordered
- Fiber optic cable Operating Instructions
- Fiber optic cable Certificate of Product Performance
- Local declarations of conformity, if applicable
- Certificates for hazardous zone use, if applicable
- Fiber optic cable optional accessories, if applicable

If you have any queries: Please contact your supplier or local sales center.

5 Installation and maintenance

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

Nowhere is this more commonly found than in the areas of *in situ* monitoring 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 an Endress+Hauser Raman analyzer in an existing plant environment. This flexibility allows the analyzer base unit to be located in a control room or existing analyzer sheds.

5.1 Cleaning a fiber optic cable

To ensure optimal performance, it is recommended that you follow the steps below to properly clean and install a fiberoptic cable assembly.

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

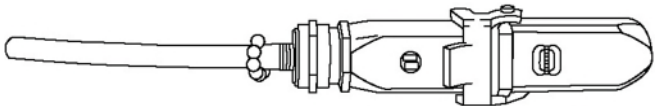

Figure 2. Electro-optical fiber connection cover

2. Clean fiber tips of 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 reagent grade acetone or 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.

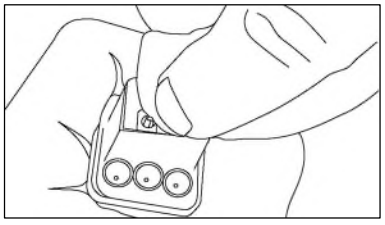

Figure 3. Cleaning electro-optical fiber connection

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.

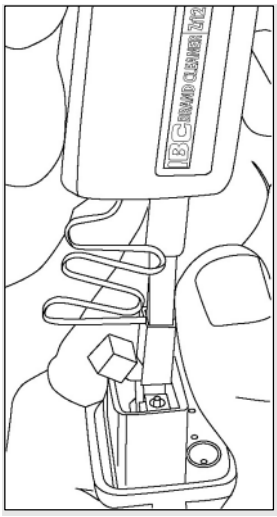

Figure 4. Final clean of electro-optical fiber connector fiber tips

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

6 Operation

Optical fibers provide excellent transmission media but they are not loss free. These transmission losses are not significant for standard laboratory cable lengths of 1.9 or 5 meters. But they would come into play with longer cable lengths ranging from 50 to 300 meters, 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.

6.1 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 meters can be used with only a 25% loss in signal. Note that the percentage transmission (%T) shown in Figure 5 accounts for the cumulative loss over the whole cable and includes excitation signal losses in the 227 meter excitation fiber and Raman signal loss in the 227-meter 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 meters is approximately 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 laser are some of the factors behind why Endress+Hauser often recommends NIR lasers (and 785 nm excitation) for solid and liquid process applications.

6.2 Results

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

Emission absorbtivities are based on the average value for the entire Raman spectrum window (i.e., transmission will be slightly less for lower Raman shifts and slightly greater for higher Raman shifts).

Figure 5. Measured fiber transmission (%T) vs. fiber length

7 Fiber optic cable types

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.

7.1 2011654-XXX

Figure 6. 2011654-XXX

Analyzer	Probe	Description	Standard Length
Raman Rxn5	Rxn-30	FOCA, EO(M)/SSCS, XXXM-----Specification: Electro/Optical Cable; Length = XXX Meters; Connectors = EO (M) to SSCS	No standard length (limited by application)

Table 4. 2011654-XXX

7.2 2018150-XXX

Figure 7. 2018150-XXX

Analyzer	Probe	Description	Standard Length
Raman Rxn2, Raman Rxn4, Raman Rxn5, Legacy Rxn products	Probes that accept EO connectors; Probes that accept FC connectors	FOCA, EO(M)/FC, XXXM---- Specification: Electro/Optical Cable; Length = XXX Meters; Connectors = EO (M) to FC	5-200 meters in 5-meter increments (limited by application)

Table 5. 2018150-XXX

NOTICE

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

7.3 2017161-XXX

Figure 8. 2017161-XXX

Analyzer	Probe	Description	Standard Length
Raman Rxn2, Raman Rxn4, Raman Rxn5	Probes that accept EO connectors	FOCA, EO(M)/EO(M), XXXM----Specification: Electro/Optical Cable; Length = XXX Meters; Connectors = EO (M) to EO (M)	5-200 meters in 5-meter increments (limited by application)

Table 6. 2017161-XXX (used as an extension cable for 2012936)

7.4 2012936-XXX

Figure 9. 2012936-XXX

Analyzer	Probe	Description	Standard Length
Raman Rxn2, Raman Rxn4, Raman Rxn5	Probes that accept EO connectors	FOCA, EO(M)/EO(M), XXXM----Specification: Electro/Optical Cable; Length = XXX Meters; Connectors = EO (M) to EO (M)	5-200 meters in 5-meter increments (limited by application)

Table 7. 2012936-XXX

7.5 2018539-XXX

Figure 10. 2018539-XXX

Analyzer	Probe	Description	Standard Length
Legacy Rxn platforms	Probes that accept FC connectors	FOCA, EXT, FC/FC, XXXM----Specification: Electro/Optical Cable; Length = XXX Meters; Connectors = FC to FC	5-200 meters in 5-meter increments (limited by application)

Table 8. 2018539-XXX

NOTICE

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

7.6 2018540-XXX

Figure 11. 2018540-XXX

Analyzer	Probe	Description	Standard Length
Legacy Rxn platforms	Probes that accept FC connectors	FOCA, FC/FC, CSA, XXXM----Specification: Electro/Optical Cable; Length = XXX Meters; CSA-Rated; Connectors = FC to FC	5-200 meters in 5-meter increments (limited by application)

Table 9. 2018540-XXX

NOTICE

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

8 Technical data

8.1 Specifications

Structure of Information	Meaning
General Features	Integrated copper conductor wire for interlock capability Kevlar internal strength members Flame retardant Fungus resistant
Cable Rating	Operating temperature: -40°C to +80°C Storage temperature: -55°C to +80°C Indoor/outdoor UV Riser-rated Cable tray–rated 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	Installation: 6.3” (16.00 cm) Operation: 3.2” (8.13 cm)
Crush Resistance	1700-2200 N/cm
Termination	Proprietary electro-optic

Table 10. Specifications

9 Index

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