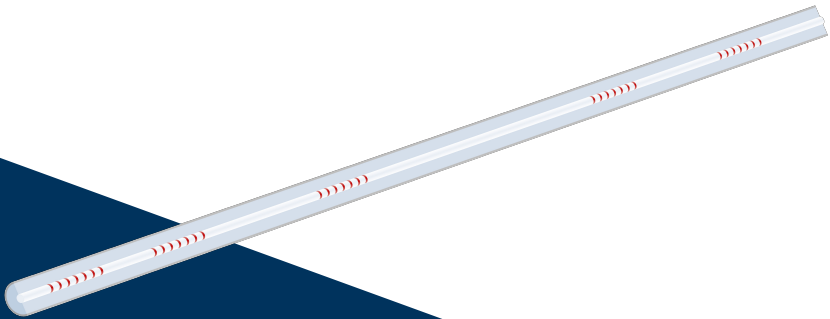


ENGLISH

## Mounting Instructions



# FS70FBG

Array of bare FBG

HBK FiberSensing, S.A.  
Via José Régio, 256  
4485-860 Vilar do Pinheiro  
Portugal  
Tel. +351 229 613 010  
support.fs@hbkworld.com  
www.hbkworld.com

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All product descriptions are for general information  
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quality or durability.

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# 1 GENERAL INFORMATION

The following instructions refer to the installation procedure of the FS70FBG Array of bare FBGs.

Material Numbers
K-FS70FBG

## 1.1 Environment Considerations

### 1.1.1 Packaging Disposal

The packaging of this equipment is designed to protect it from damage during transportation and storage. It is also made of materials that can be recycled or reused, in accordance with the European Union’s waste management regulations to minimize its environmental impact.

If you plan to move your equipment to different locations it is advisable that you keep the original package for reuse. This will not only grant proper protection for transportation, but also ensure the reduction of waste creation.

Packing boxes include a label with information on the materials used on that specific package.



Fig. 1.1 Packing label example

Please follow the instructions below to dispose of the packaging properly and responsibly and contribute to the preservation of our planet. Thank you!

To dispose of packaging, you should:

- Remove any labels, adhesives, nails, staplers or caps that are not part of the same material.
- Rinse the packaging with water to remove any residues or dirt.

- Flatten or fold the packaging to reduce its volume and save space (except for glass that should not be crushed).
- Separate the packaging by material and place it in the appropriate recycling bin or bag.

Most of our packing are made of paper and plastic and aimed to be reused or recycled, but they are not appropriate for food containing. Please consult the chapter “Packing Symbols” for more detailed information about the packing materials used by HBK FiberSensing, marked in the packing label of each product delivered to customers.

### Packaging Symbols

Packing materials are marked with the correspondent symbol for guidance.



Not appropriate for food



Recyclable

The recycling symbols for the different materials include numbers and letters that identify the material type. For example, PET (polyethylene terephthalate) is marked also with the number 1, and PE-HD (high-density polyethylene) is marked with the number 2. For paper (PAP) 20 corresponds to corrugated cardboard and 22 to paper as seen in newspapers, books,...

























































PLASTICS													
BATTERIES													
PAPER													
METALS													
ORGANIC													
GLASS													
COMPOSITES													

Fig. 1.2 Recycling symbols

**Plastics**

Plastic packaging materials are commonly bags, films, trays, blisters or containers.

**Batteries**

Batteries are not part of the packaging, but they may be included in the equipment or its accessories. Please refer to section 2.1.1 Disposal of your old appliance for more information.

**Paper**

Paper packaging materials are commonly boxes, cartons, envelopes, or labels.

**Metals**

Metal packaging materials are commonly cans, foils, caps, or wires.

**Organic**

Organic packaging materials could be wood, cork, or cotton and are made of natural or biodegradable materials that can be composted or reused.

**Glass**

Glass packaging materials are bottles, jars, or vials.

**Composites**

Composite packaging materials are made of layers of different materials, such as paper, plastic, and aluminum. They are marked with a recycling symbol and a letter that indicates the composition of the packaging. For example, PAP is for paper and plastic, and ALU is for aluminum.

## 2      SENSOR INSTALLATION

---

The following instructions show guidelines for the installation of the FS70FBG Array of Bare FBG on smooth surfaces for measuring strain.

For embedding in composite materials or applying in non-uniform surfaces (where strain gradients over the FBG length occur), please contact HBK FiberSensing.

### 2.1      Introductory notes

When mounting FS70FBG sensors, please pay attention to the following:

- Handle with care. These are precision sensors and so their achievable accuracy highly depends on correct mounting.
- Do not bend the fiber beyond its minimum bend radius to prevent breakage.
- Ensure the fiber is clean and free from contaminants that could affect its performance.
- Avoid applying excessive tensile stress to the fiber.
- Keep the fiber away from sharp objects that could cause nicks or scratches.
- Use appropriate tools and techniques when handling the fiber to avoid crushing or damaging it.
- Handle the cables with care before fixing to avoid damage. Pay special attention to the fragile splice area where the interface between the cables and the fiber. The difference between rigidities is a fragile point.

### 2.2      List of materials

Included material
FS70FBG Array of FBG

Needed material
Sanding sheets.
Surface cleaning agents. Recommended HBK: 1-RMS1 or 1-RMS1-SPRAY
Tissues. Recommended HBK: 1-8402.0026
Drafting tape. Recommended HBK: 1-KLEBEBAND

Glue.

Recommended HBK: 1-EP310S, 1-X60

Recommended Third Party: DP490 from 3M

Protection.

Recommended HBK: 1-ABM75 and/or 1-AK22

### 2.3 Preparation of the installation area

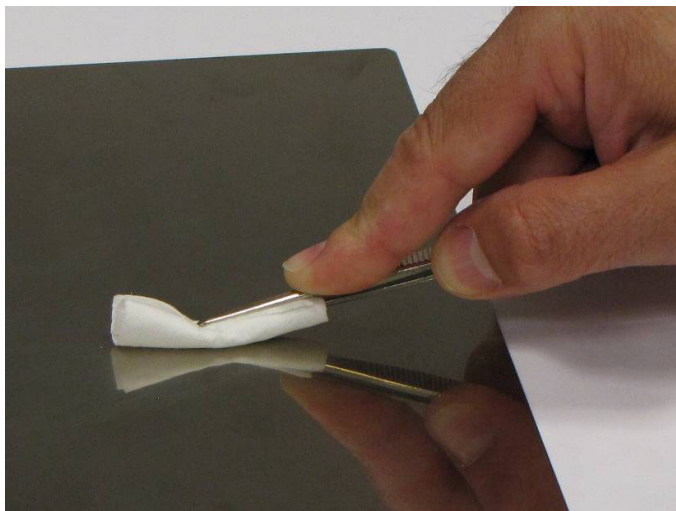
The surface of the material to instrument needs to be cleaned ensuring that no dust nor grease is present in gluing area.

Clean the surface using RMS1 cleaner (*Fig. 2.1*) and the non-woven tissues (*Fig. 2.2*), as recommended.



*Fig. 2.1 Spraying 1-RMS on specimen*

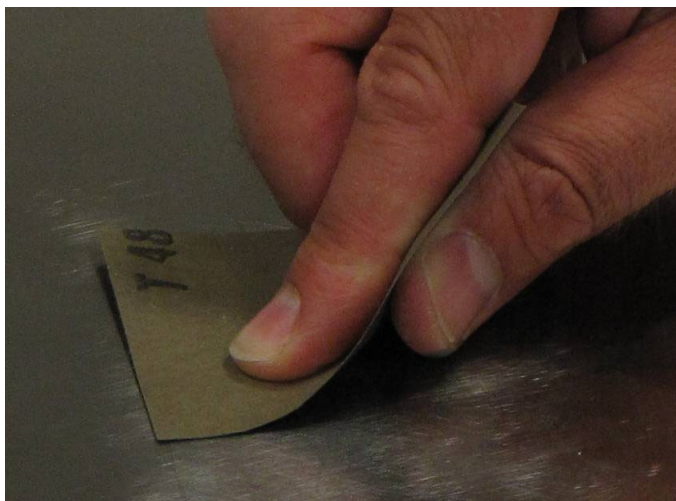




*Fig. 2.2      Cleaning with nonwoven pad*

The wiping movements should always be performed in the same direction until the last tissue comes out clean.

For installation with EP310S adhesive, the surface of the measuring point must be roughened using 220 grain emery cloth or finer emery cloth worked in circles (*Fig. 2.3*)



*Fig. 2.3      Roughening the surface using emery cloth*

Clean the roughened installation surface again with RMS1 and non-woven pads (Fig. 2.4)



Fig. 2.4      *Cleaning the roughened installation surface*

**2.4      Marking the measuring point**

Define the alignment of each FBG considering the measurement direction. The FBG is centered at the midpoint between the marking lines.

This step is particularly important as the fiber positioning dictates the measurement direction.

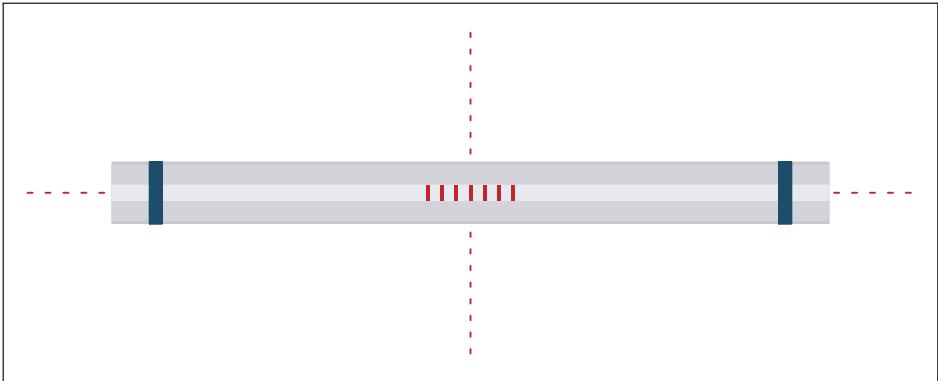


Fig. 2.5      *FBG alignment markings*

In the ideal case, an empty ball point pen cartridge is recommended for marking the installation point. The length of the marking line should be approx. 60 mm in the measure-

ment direction. A vertical marking line, approx. 40 mm long, must be drawn starting at the center of the installation point, see *Fig. 2.6*.



*Fig. 2.6*      *Marking the marking lines*

Once the area is marked out, the installation point must be cleaned very thoroughly, see *Fig. 2.7*. Please note that a new non-woven pad must be used each time the point is wiped. Repeat the cleaning process until no residues can be detected on the non-woven pad.



*Fig. 2.7 Final cleaning of the installation point*

Position the optical fiber with the FBG centered on the measuring point under small tension such that the fiber lies as straight as possible. Fix the fiber in this position with two polyimide adhesive stripes (order number 1-KLEBEBAND) outside the fiber markers (Fig. 2.8)



*Fig. 2.8 Fixing the optical fiber*

## 2.5 Gluing the sensor

The selection of adhesives and the gluing process determines the operation of the FS70FBG as a strain sensor in terms of measurement range and operating temperatures. Always refer to the installation instructions of the adhesive for details.



### Important

*Gluing process may lead to changes in the spectral response of the FBG, with impact on the quality of the measurement.*

#### 2.5.1 Using EP310 adhesive

EP310 bonding shows the optimal results with respect to creep at elevated temperature and elevated strain. EP310 is a hot curing adhesive. This means that it can be used only if heating can be easily applied to the measuring piece. The minimum temperature of curing EP310 is 80°C (with a curing time 8 h).

Apply EP310 adhesive (order number 1-EPS310) along the complete FBG bonding area. The bonding length should at least comprise the markers. Allow the adhesive to dry for 5 minutes at room temperature.

When bonding with EP310, it is important that the fiber directly touches the surface along the complete bonding length.

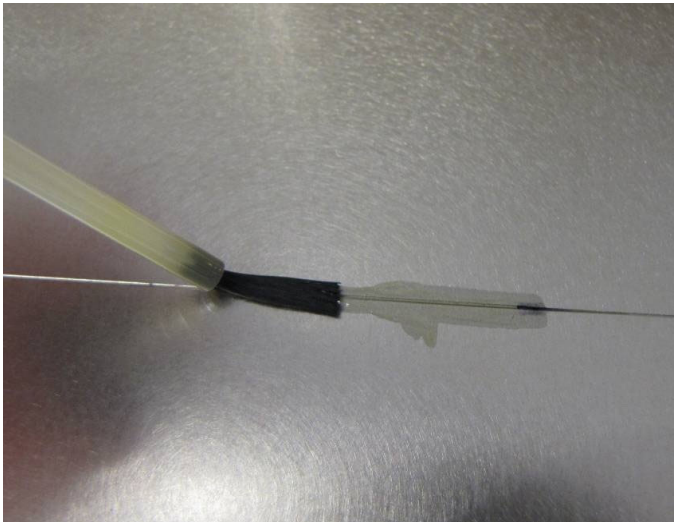
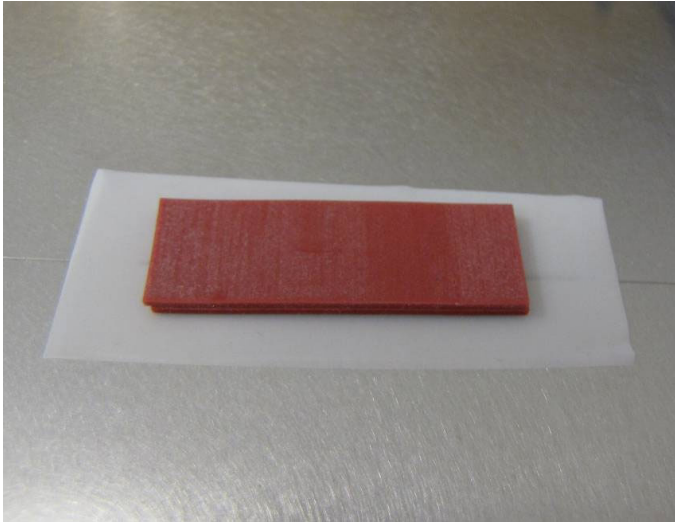


Fig. 2.9 Covering the FBG bonding area with EP310 adhesive

Place a piece of Teflon foil (order number 1-Teflon) and two stripes of silicone rubber (enclosed EP310) on top of the installation point. The silicone stripes should measure 2 cm x 4 cm.



*Fig. 2.10 Covering the optical fiber bonding area with Teflon foil and two stripes of silicone rubber*

Put a flat load of 1 kg on top. The load should be mounted symmetrically on top of the FBG bonding area.



*Fig. 2.11 Load on top of the optical fiber FBG bonding area*

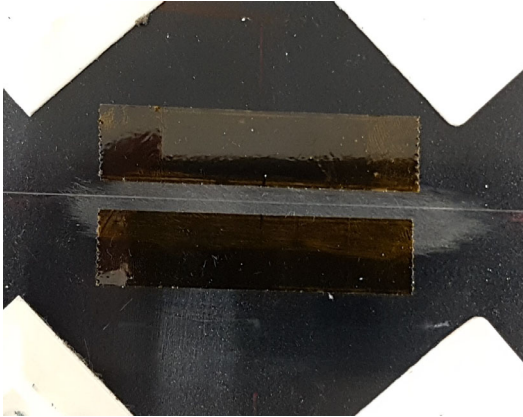
The EP310 adhesive must cure preferably for 2 h at 150°C, or at 80 °C for at least 8 h.



### 2.5.2 Installation with epoxy adhesive

When using a two component epoxy (for example the suggested DP490 from 3M) the bonding length of the FBG must be surrounded by the glue. Bonding length must be at least between the two markings (50mm centered at the FBG).

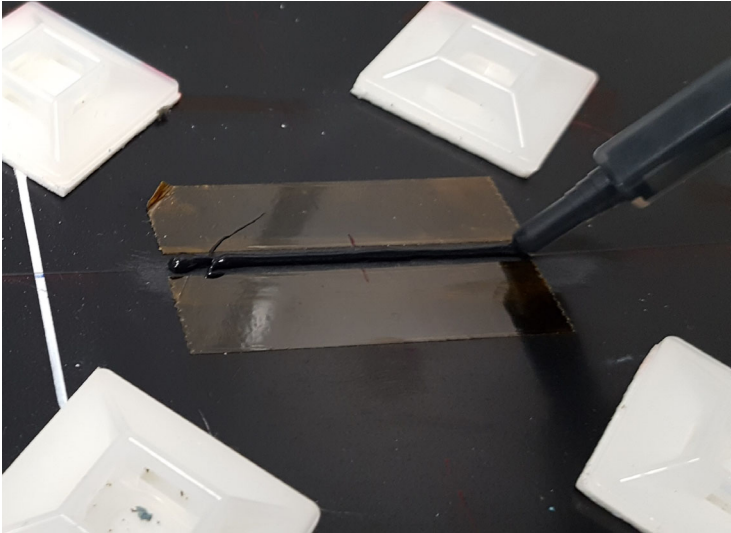
- Start by creating a groove using two polyimide tape stripes (order number 1-KLEBE-BAND), long enough to fit the bonding area, placed in parallel and symmetrically to the fiber.



*Fig. 2.12 Gluing groove.*



- Apply a very thin cord of epoxy glue along the bonding length.



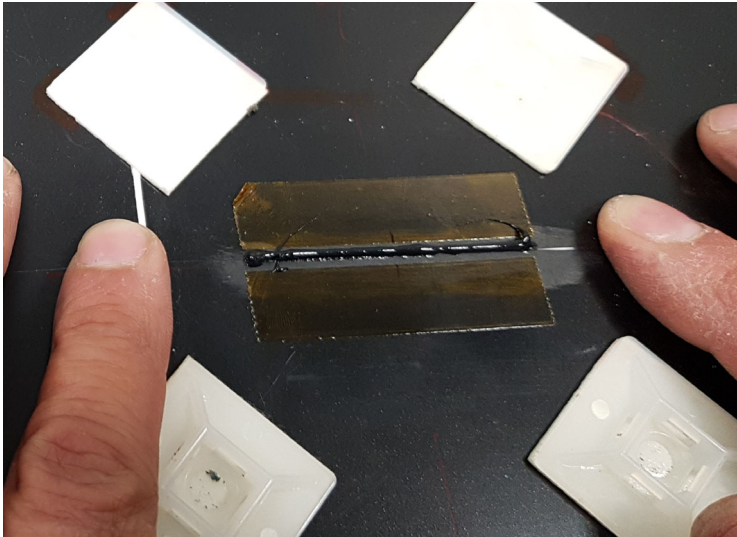
*Fig. 2.13 Applying the epoxy glue.*

- Very gently slightly twist the fiber from one side to the other, ending on the initial position. This will ensure that the fiber is fully involved in glue, while it is kept as close as possible to the surface.



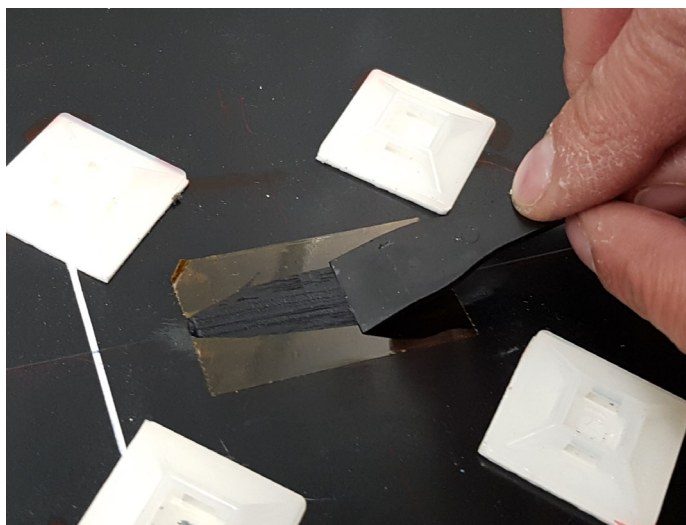
### **Information**

*The position of the fiber, in the end, should remain in a straight line and aligned to the desired measuring direction.*



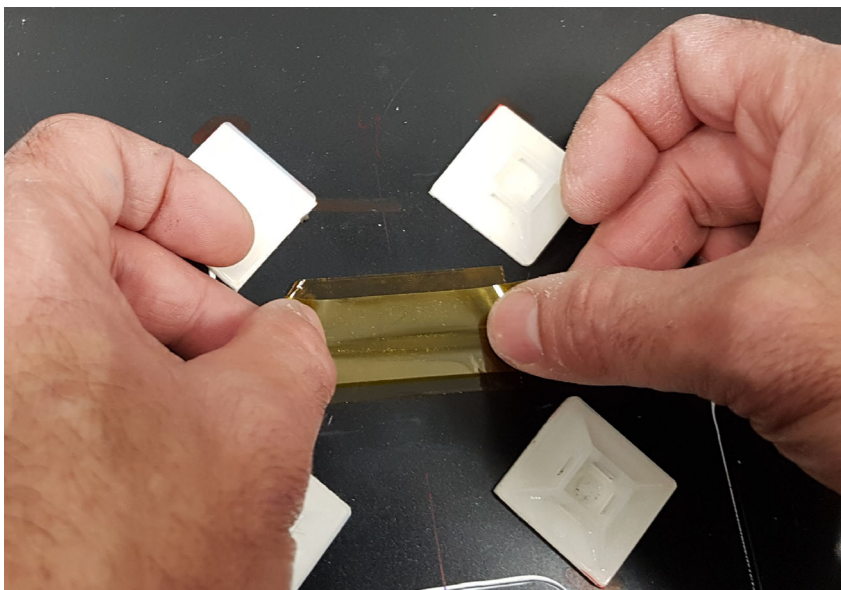
*Fig. 2.14 Twisting the fiber.*

- Using a non-metallic spatula or any similar flat tool, spread the glue along the groove making a continuous movement on a single direction. The movement should not be interrupted, meaning that it should start from one end until the other. This step will spread the glue over the full area of the groove and remove the excess of glue to the sides.



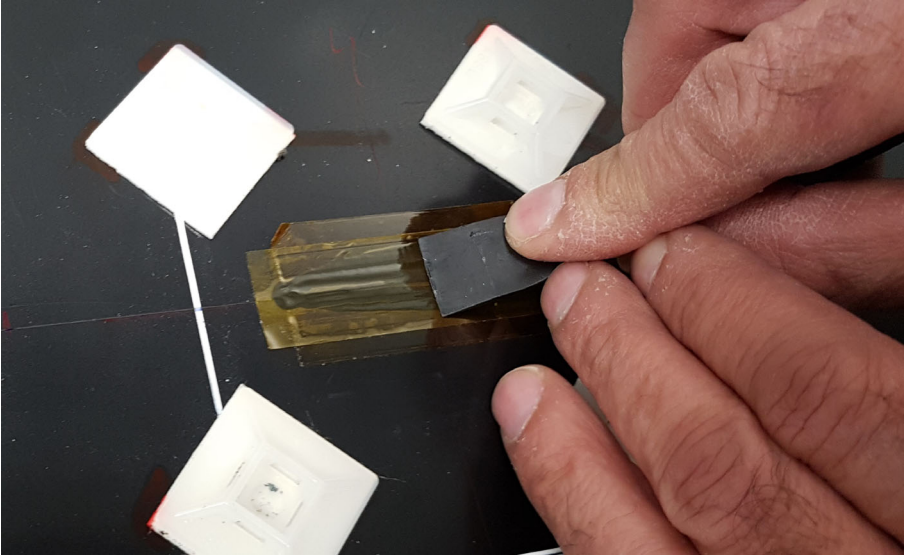
*Fig. 2.15 Spreading the glue with a spatula.*

► Apply a piece of polyimide tape on top of the FBG and the glue.



*Fig. 2.16 Applying a new piece of polyimide tape.*

- Repeat the process of spreading the glue with a spatula, this time over the polyimide tape.



*Fig. 2.17 Spreading the glue with a spatula.*

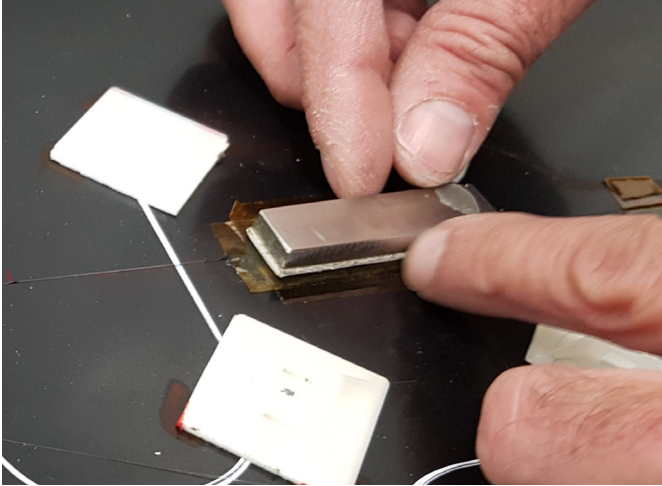
- Reapply stress on the fiber, if needed adjusting the fixation tape.



### **Information**

*The position of the fiber, in the end, should remain in a straight line and aligned to the desired measuring direction.*

- Place a piece of rubber on top of the gluing area and with the support of a stiff material apply continuous pressure.



*Fig. 2.18 Aligning the rubber and stiff auxiliary piece.*

- Keep pressuring for 1 to 2 minutes.



*Fig. 2.19 Applying uniform pressure over the FBG.*

- ▶ After this, remove the auxiliary piece and the rubber and pull the fiber on both extremes to ensure the correct alignment of the FBG. Reapply the initially applied tapes to secure the fiber in this tensioned position.
- ▶ Repeat the steps of spreading the glue with a spatula and pressure again for 1 to 2 minutes using the layered rubber and block.
- ▶ Wait for a total hardening of the epoxy glue and remove the polyimide tapes used during the gluing process.



### Information

*At room temperature the suggested DP490 glue needs 24 h to cure. For other curing temperatures please refer to the supplier instructions.*

## 2.6 Protecting the fiber path

In between FBG or between the FBG and the transition to the cable, it might be important to protect the fiber path. The need and exact solution will mostly depend on the application and on the environmental conditions.

### 2.6.1 Using epoxy adhesive

One possibility for protecting the fiber is using the suggested DP490 glue. The following suggests the use of a foam tape which provides a better-looking finishing.

- ▶ Create a groove around the fiber path using foam tape with approx. 1 mm thickness (recommended TESA Powerbond).



Fig. 2.20 Groove along the fiber using foam tape (optional).

- ▶ Apply the epoxy glue along the path.



- Use a spatula to smoothen the glue surface and fill the full width of the groove by gently pressing it against the foam tape making a continuous movement on a single direction.



Fig. 2.21 Spreading the glue with a spatula.

Wait for approx. 2 hours.

- Remove the red protection film of the tapes (optional). This will ensure a better-looking finish.

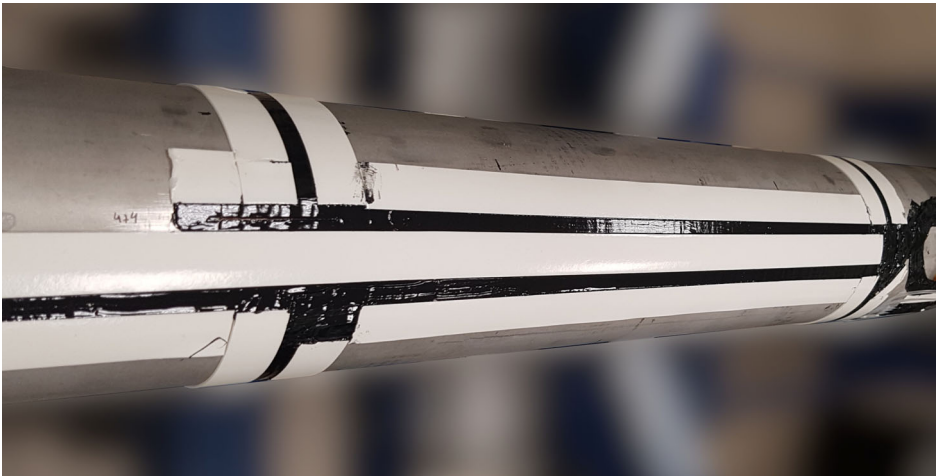
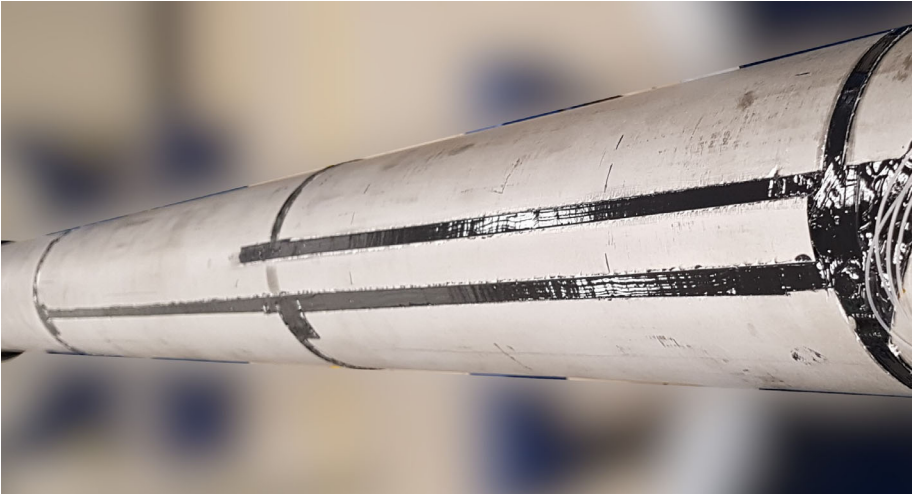


Fig. 2.22 Removing the red protection film.

Wait for the glue to harden.

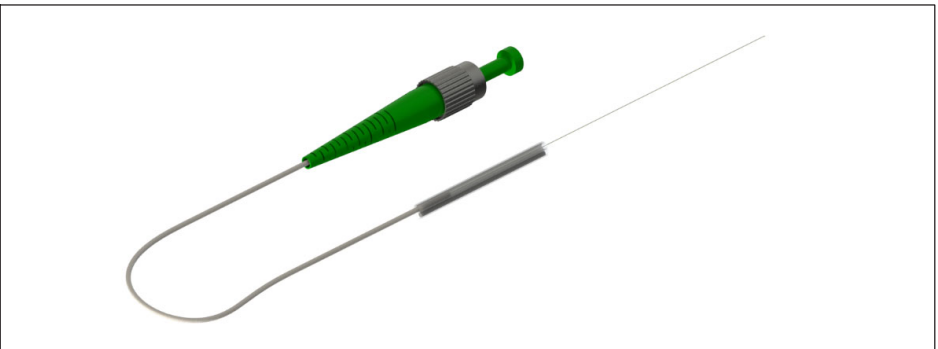
► Remove the tapes.



*Fig. 2.23 Finished protection.*

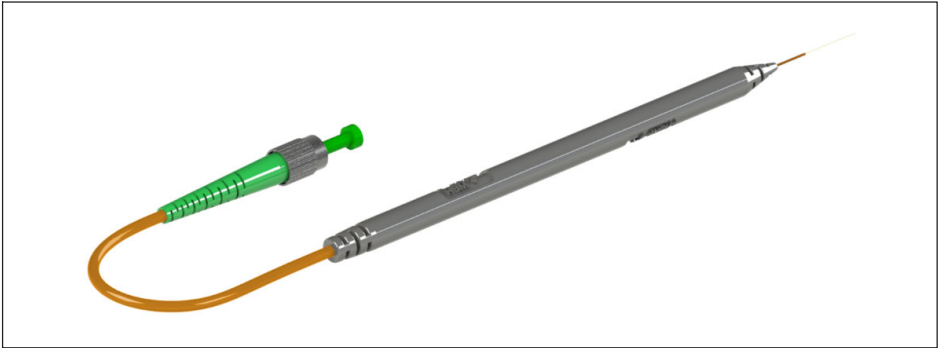
## **2.7 Routing and protecting the cables**

FS70FBG sensor can be delivered with or without cable, and with different types of cables.

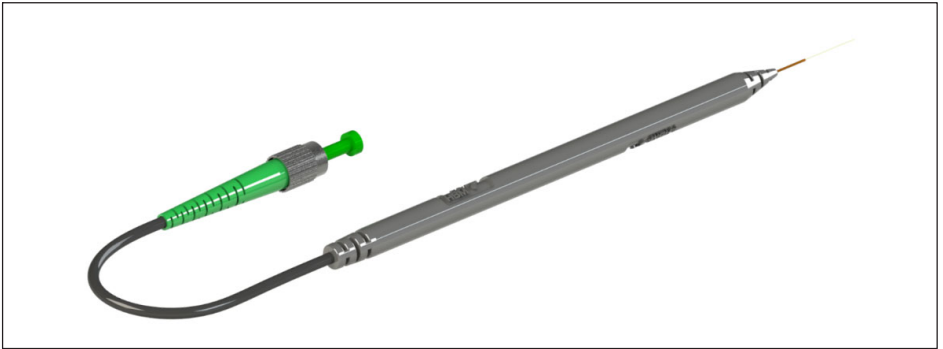


*Fig. 2.24 Braided cable termination*





*Fig. 2.25 Aramid cable termination*



*Fig. 2.26 Armor cable termination*

Sensor cable should be routed ensuring that cables are not hanging and curvatures are kept within the limits for the used cable. The cable should be fixed by means of clamps or strong tape. Splice protections must also be well fixed. The splice interface on the FS70FBG is a fragile location due to the difference of rigidities. This is especially true when considering the 3mm cables (aramid or armor).

## 3 SENSOR CONFIGURATION

### 3.1 Strain

Strain sensors are not calibrated sensors. The characteristic sheet delivered with the sensor presents the sensor data for correct strain computation.

For the fiber Bragg grating strain sensors, wavelength variation including the effect of temperature is given by the equation as shown in Fig. 3.1.

$$\frac{(\lambda - \lambda_0)}{\lambda_0} = k \cdot (\varepsilon_{Load} + (TCS + CTE) \cdot (T - T_0)) \cdot 10^{-6}$$

Fig. 3.1 Wavelength variation of a strain FBG due to strain and temperature effects

Where

- $\lambda$  is the measured Bragg wavelength of the strain sensor in nm
- $\lambda_0$  is the Bragg wavelength of the strain sensor at the reference instant in nm
- $k$  is the strain k factor of the strain sensor, dimensionless
- $\varepsilon_{Load}$  is the mechanical strain applied to the structure in  $\mu\text{m/m}$
- $TCS$  is the temperature cross sensitivity of the strain sensor in  $(\mu\text{m/m})/^{\circ}\text{C}$
- $CTE$  is the thermal expansion of the material of the specimen the strain sensor is attached to in  $(\mu\text{m/m})/^{\circ}\text{C}$
- $T - T_0$  is the temperature variation since the reference instant to the measurement instant in  $^{\circ}\text{C}$

#### Measurement with no compensation

If no temperature compensation is required the strain computation can be done as shown in Fig. 3.2.

$$\varepsilon = \frac{(\lambda - \lambda_0)}{k \cdot \lambda_0} \cdot 10^6$$

Fig. 3.2 Strain without temperature compensation computation formula

Where

- $\varepsilon$  is the measured strain in  $\mu\text{m/m}$
- $\lambda$  is the measured Bragg wavelength of the strain sensor in nm
- $\lambda_0$  is the Bragg wavelength of the strain sensor at the reference instant in nm
- $k$  is the strain k factor of the strain sensor, dimensionless

### Measurement with temperature compensation using a temperature sensor

Calculating compensated strain, in  $\mu\text{m}/\text{m}$ , using a temperature sensor is straightforward as the output of a temperature sensor is a temperature value in  $^{\circ}\text{C}$ . The calculation is the depicted in Fig. 3.3.

$$\varepsilon_{\text{Load}} = \frac{(\lambda - \lambda_0)}{k \cdot \lambda_0} \cdot 10^6 - (TCS + CTE)(T - T_0)$$

Fig. 3.3 Strain computation with temperature compensation using a temperature sensor

Where

- $\varepsilon_{\text{Load}}$  is the mechanical strain applied to the structure in  $\mu\text{m}/\text{m}$
- $\lambda$  is the measured Bragg wavelength of the strain sensor in nm
- $\lambda_0$  is the Bragg wavelength of the strain sensor at the reference instant in nm
- $k$  is the strain k factor of the strain sensor, dimensionless
- $TCS$  is the temperature cross sensitivity of the strain sensor in  $(\mu\text{m}/\text{m})/^{\circ}\text{C}$
- $CTE$  is the thermal expansion of the material of the specimen the strain sensor is attached to in  $(\mu\text{m}/\text{m})/^{\circ}\text{C}$
- $T$  is the measured temperature of the used temperature sensor in  $^{\circ}\text{C}$
- $T_0$  is the temperature from the temperature sensor at the reference instant in  $^{\circ}\text{C}$

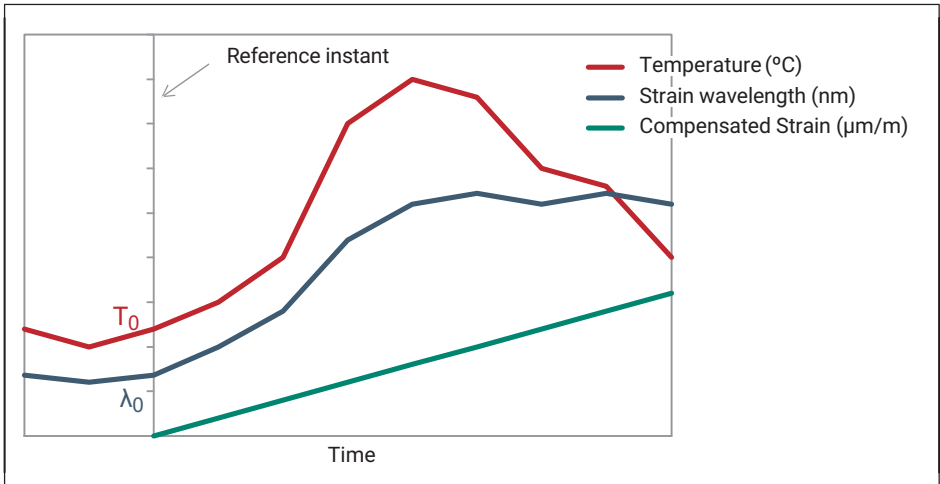


Fig. 3.4 Reference instant for temperature compensated strain measurement when using a temperature sensor for compensation

### Measurement with temperature compensation using a compensation element

Strain measurement can also be correctly compensated using a compensation element based on FBG technology. Different approaches can be used:

- a temperature sensor without calibration certificate
- a strain sensor installed on a strain-free area of the same material
- a strain sensor installed on a strain-free material with a known CTE

The computation of strain can then be performed using the equation from Fig. 3.5.

$$\varepsilon_{Load} = \frac{\lambda - \lambda_0}{k \cdot \lambda_0} \cdot 10^6 - \frac{\lambda_{TC} - \lambda_{0_{TC}} (TCS + CTE)}{\lambda_{0_{TC}} TCF} \cdot 10^6$$

Fig. 3.5 Strain computation with temperature compensation using an FBG compensation element

Where

- $\varepsilon_{Load}$  is the mechanical strain applied to the structure in  $\mu\text{m}/\text{m}$
- $\lambda$  is the measured Bragg wavelength of the strain sensor in nm
- $\lambda_0$  is the Bragg wavelength of the strain sensor at the reference instant in nm
- $k$  is the strain k factor of the strain sensor, dimensionless
- $\lambda_{TC}$  is the measured Bragg wavelength of the compensation element in nm
- $\lambda_{0_{TC}}$  is the Bragg wavelength of the compensation element at the reference instant in nm
- $TCS$  is the temperature cross sensitivity of the strain sensor in  $(\mu\text{m}/\text{m})/^{\circ}\text{C}$
- $CTE$  is the thermal expansion of the material of the specimen the strain sensor is attached to in  $(\mu\text{m}/\text{m})/^{\circ}\text{C}$
- $TCF$  is the temperature compensation factor of the compensation element in  $(\mu\text{m}/\text{m})/^{\circ}\text{C}$ . For an uncalibrated temperature sensor the value is given on the sensor's characteristics sheet. For a strain sensor attached to a specific material TCF can be calculated as shown in Fig. 3.6.

$$TCF = (5.7 + k \cdot CTE_{TC})$$

Fig. 3.6 Temperature compensation factor computation

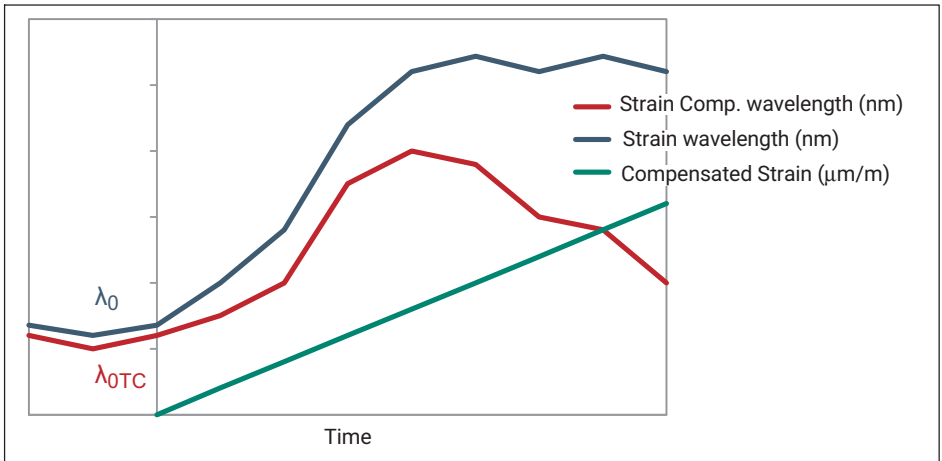


Fig. 3.7 Reference instant for temperature compensated strain measurement when using an FBG compensation element

### Measurement with bending moment correction

When measuring on an element using a sensor that is far away from the attachment surface there may be an “error” on the measurement because the distance between the measuring point/alignment and the neutral axis is different to the distance between the installation surface and the neutral axis.

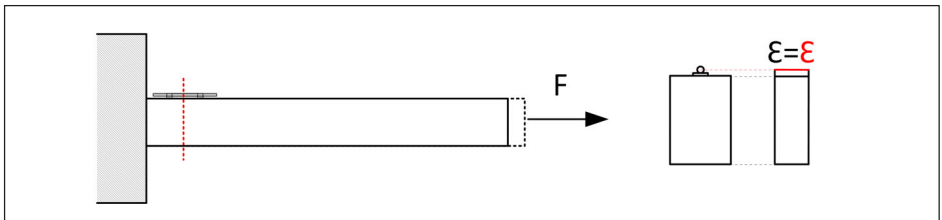


Fig. 3.8 Strain on pure axial deformation

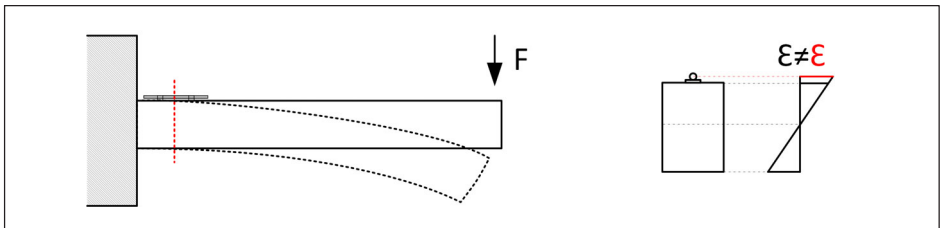


Fig. 3.9 Strain on pure bending moment

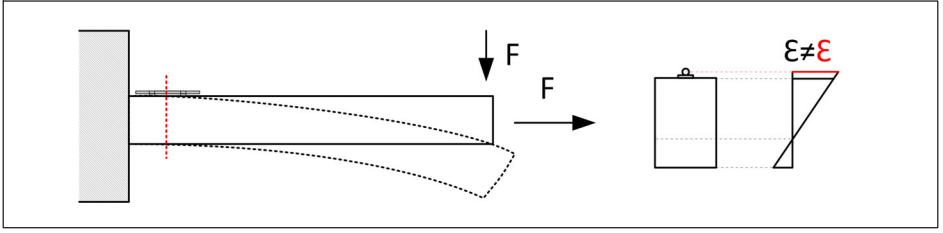


Fig. 3.10 Strain on axial load and bending moment

This becomes of high importance when the distance between the sensing element on the sensor to the attachment surface is relevant, or the measuring object is very thin. This distance on the FS70FBG Bare Fiber Bragg Grating is 0.095 mm ( $h_2$  on Fig. 3.11).

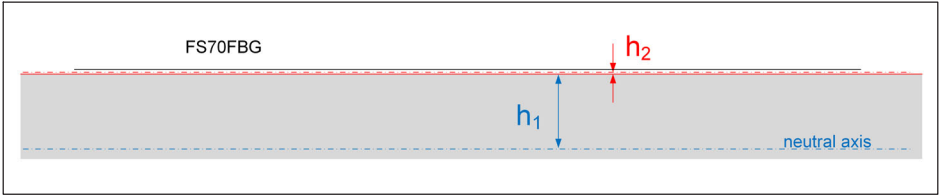


Fig. 3.11 Distance of the FBG to the mounting surface on the FS70FBG

However, knowing the distance to the neutral axis ( $h_1$ ) the measured strain from the sensor can be corrected into strain on the surface by a geometrical factor:

$$\varepsilon_{\text{surface}} = \frac{\lambda - \lambda_0}{k \cdot \lambda} \cdot \frac{h_1}{h_2 + h_1} \cdot 10^6$$

Fig. 3.12 Strain computation bending effect correction

Where

- $\varepsilon_{\text{surface}}$  is the mechanical strain on the measuring surface in  $\mu\text{m/m}$
- $\lambda$  is the measured Bragg wavelength of the strain sensor in nm
- $\lambda_0$  is the Bragg wavelength of the strain sensor at the reference instant in nm
- $k$  is the strain k factor of the strain sensor, dimensionless
- $h_1$  is the distance from the measuring surface to the neutral axis in mm
- $h_2$  is the distance from the measuring surface to the FBG in mm (0.095 mm for the FS70FBG)

## 4 SENSOR MAINTENANCE

---

### 4.1 Sensor

The FS70FBG comprises sensors that, after installation, cannot be repaired. However, the array can comprise several strain sensors in series. It might be possible to recuperate some signals when connection redundancy exists. If the fiber can be interrogated from both ends, ensure that at the location of the damage there is no light propagation (by fully cutting the fiber) and insert a splitter between the optical connector of the interrogator and the two ends of the FBG array.

Please contact HBK FiberSensing for further support if needed.

### 4.2 Cables

If a cable is damaged during installation or use, a local repair might be possible. However, the feasibility of the repair depends on the damage's location. If the damage is too close to the sensor, there may not be enough cable length available to use the splicing tools, making the repair unfeasible.

When a repair is feasible and there is sufficient cable length, you can cut the cable to remove the damaged section and perform a splice on the fiber cable. If there isn't enough cable length, you will need to insert an extension and perform two splices.

Please contact HBK FiberSensing for support on the splicing procedures.

### 4.3 Connectors

If a connector is damaged, it can be replaced either by performing a local splice or by returning the sensor for reconnection. Note that repairs performed by HBK FiberSensing may be subject to a fee.

