Application Note AN136

How to Decouple and Mount Fiber Bragg Grating (FBG) Sensor Chains

1. Objective

Fiber Bragg Grating (FBG) sensor chains are innovative, multipoint sensors that use optics to detect the presence of a shift in temperature or strain. This application note describes currently known best practices on how to isolate a temperature or strain measurement and for mounting a fiber with FBGs.

2. How FBGs Work

An FBG is a periodic structure that reflects only one wavelength of the light guided within an optical fiber. Each FBG is composed of many gratings and the wavelength it reflects is proportional to the distance between the gratings and their refractive index. So, as the fiber is stretched or compressed (due to strain and partially due to temperature) or the refractive index changes (due to temperature), the FBG reflects a slightly different wavelength. This wavelength shift is then measured to determine the temperature or strain the FBG is experiencing.

In cases where the FBG sensor chain experiences a change in either only temperature or only strain, the wavelength shift can be attributed to the isolated parameter. However, in the presence of both temperature and strain variations, the unwanted parameter must be compensated for or removed from the measurement. It should be noted that FBGs are up to 10 times more reactive to strain changes than to temperature changes. As a result, it is imperative to remove the possibility of strain effects on a thermometry system while minor temperature fluctuations may be ignored in a high magnitude strain system (greater than ±100 με).

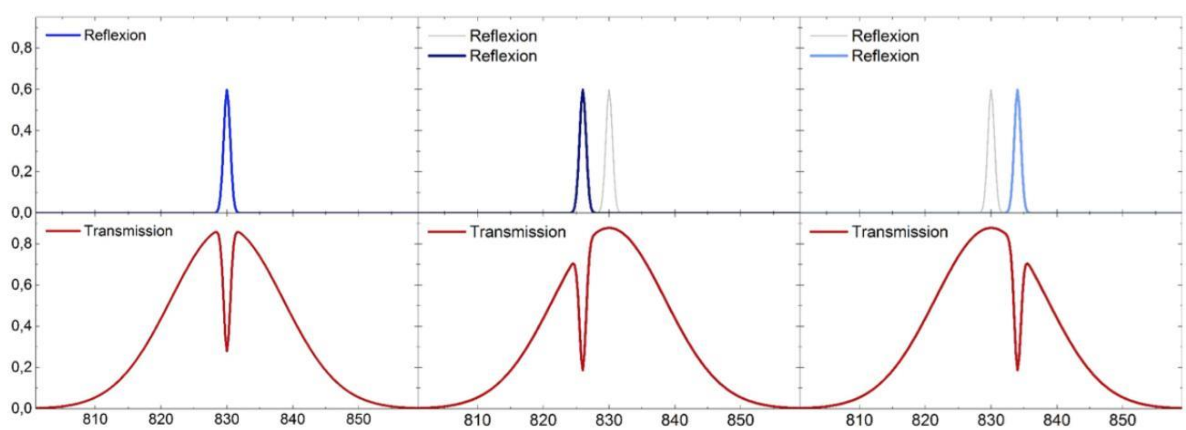

Figure 1. Reflection and Transmission Spectrum of FBGs: Static (left), Compressed (middle), and Stretched (right)

3. Decoupling and Mounting FBGs

FBGs are inscribed within a traditional fiber optic cable which is then adhered to the surface of the object to be monitored. There are different ways to mount the fiber depending on the targeted parameter (temperature or strain) and if decoupling is required.

3.1. Temperature Capillaries for Decoupling

The best method to isolate temperature is to enclose the bare fiber with a capillary. A capillary is a tube with an extremely small internal diameter affixed to the fiber at the beginning of the sensing region and left unattached at the end of the fiber. The capillary acts as a barrier between the surface and the FBGs, allowing the flow of temperature while reducing strain effects. Large bends in the capillary will transfer some strain to the FBGs while smaller bends are suppressed. And, since the capillary is attached at only one end, the fiber and FBGs remain free to expand and contract as temperature fluctuates.

The most prevalent off-the-shelf capillary options are silica, stainless steel, and PEEK tubing. The table below describes the specifications for each material where the time constant refers to the approximate transient temperature response. Bare fiber is included as a reference.

	SM800P Polyimide Coated Bare Fiber	Silica	Stainless Steel	PEEK
Max. Temperature	350°C	350°C	600°C	200°C
Thickness	0.15 mm	0.44 mm	1.00 mm	1.60 mm
Min. Bend Radius	7 mm	20 mm	100 mm	40 mm
Max. Length	500 m	2 m	3 m	10 m
Time Constant	~400 ms	~775 ms	~745 ms	~530 ms

The silica capillary provides the smallest diameter and minimum bend radius but has the slowest transient response. Meanwhile, stainless steel offers the highest maximum temperature but is relatively inflexible and slow to react. It should be noted here that the maximum temperature of the FBG system is still limited by the bare fiber. Finally, PEEK displays the fastest transient response and best maximum fiber length but is the thickest of the capillaries. PEEK provides further benefits as an electrical insulator and is chemically inert to most solvents.

3.2. Temperature Mounting

While mounting FBGs for temperature sensing, the most important consideration is to maintain good thermal contact. While there are many adhesive options, Kapton tape is a common preference due to its wide temperature ranges (-269°C to +260°C) and strong adhesive qualities. It is also easy to remove without damaging the fiber or capillary.

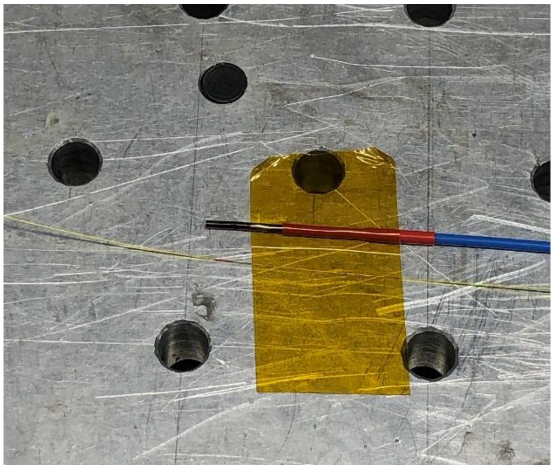

Figure 2. FBG Fiber and Temperature Sensor Mounted with Kapton Tape

3.3. Strain Decoupling

In cases where temperature can affect strain measurements, the best way to decouple temperature responses is by using an independent temperature FBG encapsulated in a capillary at a static location. This FBG only monitors the wavelength shift caused by temperature fluctuations since it is statically mounted. The temperature-dependent wavelength shift is then removed from the rest of the FBGs, leaving only strain measurements.

3.4. Strain Mounting

When mounting FBGs for strain sensing, it is essential to choose an adhesive that is compatible with the surface material. For most applications, a cyanoacrylate glue (i.e., superglue) can be used. Two useful adhesives are Loctite 496 for metal surfaces and Loctite 401 for plastic surfaces. To apply the glue, completely coat the surface and then attach the fiber. Primers can also be helpful for proper adhesion.

The glue stretches/compresses along with the surface, allowing the FBGs to properly measure strain. It should be noted that the FBGs only measure strain in the direction in which the fiber is lying. And, excessive pulling on the fiber, especially out of the strain plane, can ruin the quality of the cure.

In other cases, it may be necessary to protect the fiber from extreme compressive forces such as if the fiber is installed in concrete. The pressure can damage the fiber and prevent proper signal transmission. To prevent this, a channel can be created or milled out to lay the sensor fiber while still allowing strain monitoring. Then, a flat plate or series of clamps can be installed along the length of the fiber to hold the FBGs in place.

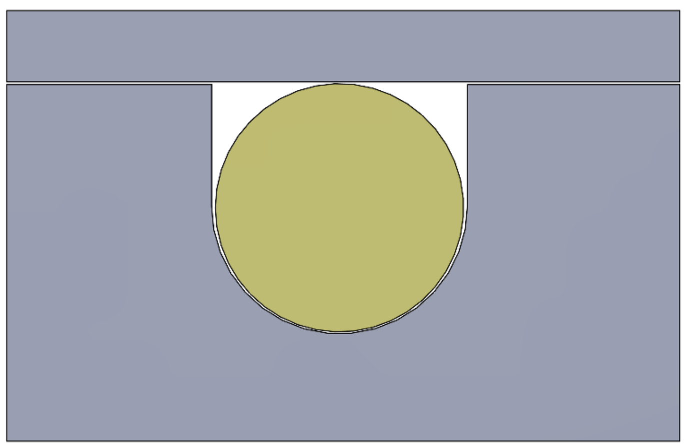

Figure 3. Cross-Section of an FBG Fiber in a Channel