## FBI-Gauge unit

## Specifications

| General performance | | |
|---|---|---|
| Model | **A50** | **B10** |
| Maximum measurement length (*1) | 50[m] | 10[m] |
| Data sampling ratio | 2.5[Hz] | 100[Hz] |
| Minimum sensor spacing | 0.4[mm] | 5[mm] |
| Minimum gauge length | 1[mm] | 5[mm] |
| Stress measurement: | | |
| Measurement range | ±10,000(μStrain) | ±10,000[μStrain] |
| Repeat accuracy | ±2[μStrain] | ±5[μStrain] |
| Temperature measurement (*2) | | |
| Measurement range | −50 ~ 300℃(Polyimide coated fiber) | |
| | −200 ~ 800℃(Gold coated fiber) | |
| Repeat accuracy | ±0.2[℃] | ±0.4[℃] |
| Main unit | | |
| Exterior dimensions and weight | 36[cm]×32 [cm]×17[cm] /8[kg] | |
| Power consumption | 50 [W] | |

(*1) Inquire about different fiber lengths
(*2) Displayed temperature is relative to the reference temperature.


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# Optic fiber sensing system

# FBI-Gauge

## Fiber Beam Investigation

FTR
Fuji Technical Research

# Strain and temperature measurement in point, line and plane formats!!

The FBI-Gauge sensing system is designed to measure strain and temperature via optic fiber attached to the surface of the test piece. Continuous measurement along the optic fiber supports both point and continuous line and surface observation. FBI-Gauge does not require large numbers of strain gauges, and is easy to set up and inexpensive.

## Measurement procedure

1. Optic fiber sensor
2. Sensor initialization
3. Strain and temperature measurement
4. Processing of measurement data
5. 3-D evaluation

## ODiSI hardware

The ODiSI, developed by Luna Technologies in the United States, is an optical distributed sensor interrogator for strain and temperature measurement which uses Optical Frequency Domain Reflectometry (OFDR)* to detect microscopic-level Rayleigh scattering within optic fiber for monitoring displacement at millimeter-level precision.

※Optical Frequency Domain Reflectometory

### Features

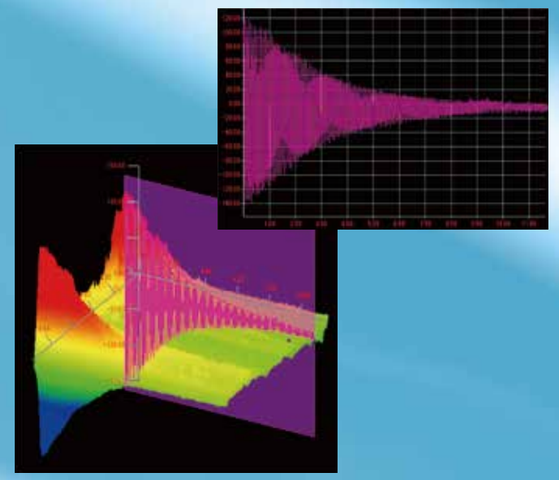
- Sensor length: 1～50 meters
- Smallest increments: 1mm
- Measurement cycle: A-Type ～5Hz
  B-Type 100Hz
- Minimum resolution: ±2μStrain ±0.2℃
- Measurement range: ±10,000μStrain
  -50～300℃
  (Polyimide coated fiber)
  -200～800℃
  (Gold coated fiber)

## 3-D analysis

The advanced and powerful 3-D analysis system processes sensor data and generates shape and measurement results for display in intuitive format.

### Key functions

- 3-D analysis
  (typically displayed as 3-D color contours)
- 3-D shape mapping
- 3-D dimensional measurement
- 2-D graphing
- 3-D graphing
- FFT
- Other analysis and evaluation tools



## FBI-Gauge can be used in a wide range of industries.


Railways


Building construction


Industrial facilities


Automobiles


Dams

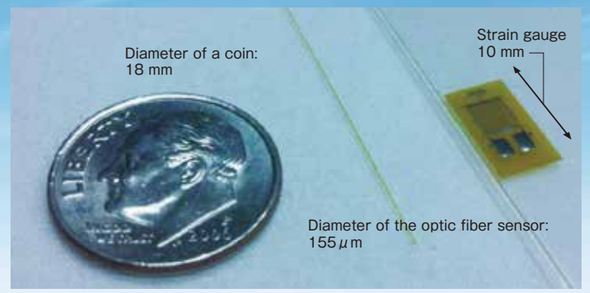

Bridges

# FBI-Gauge Features

## Advantages of FBI-Gauge

■Supports line and surface observation, as well as point observation.
■Extremely lightweight sensor
■Can be used in electromagnetic environments and places where fire is strictly prohibited
■Sensor can be freely attached to fit different measurement conditions
■Single sensor capable of performing strain, temperature, and a variety of other measurements.

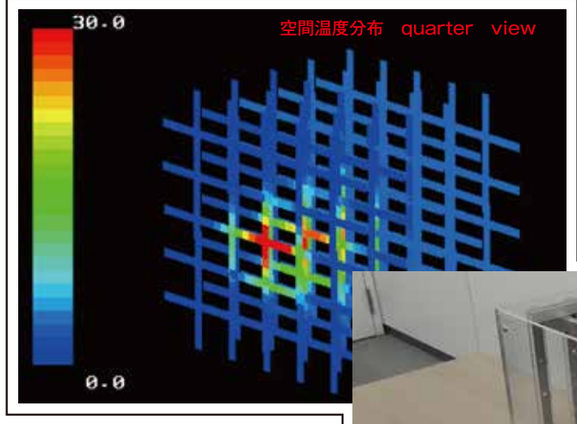
Thin optic fibers with a diameter of 155μm can be set in extremely narrow gaps.
They are also ideal for measuring the strain of curved surfaces. (Minimum bending radius=10mm)




## Uses of FBI-Gauge

■Measuring the strain or temperature in an electromagnetic environment
■Measuring an object with multiple measurement points that make it difficult to install the gauge
■Checking the temperature distribution of a tower that is tens of meters in height
■Measuring the inside of narrow gaps
■Conducting measurements when the weight of the connection cable for the strain gauge is too heavy

As the photo to the left shows, there is a problem with point measurement -- Tons of connection cables are needed when there is a large number of gauge channels. The use of lightweight optic fibers is the perfect solution for conducting measurements across numerous channels.



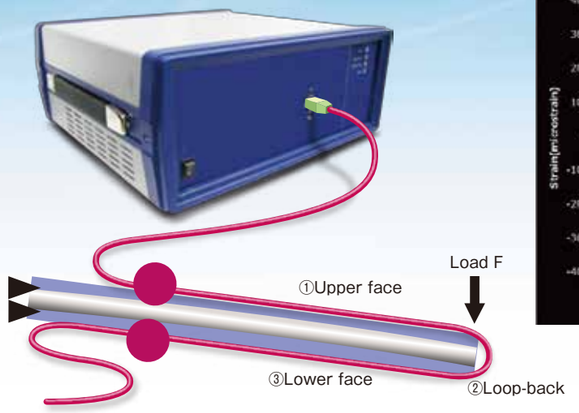

Optic fibers are thin and lightweight, allowing you to freely design a layout that fits your installation needs. As the figure to right shows, installation in the air makes it possible to visualize the temperature distribution in space.

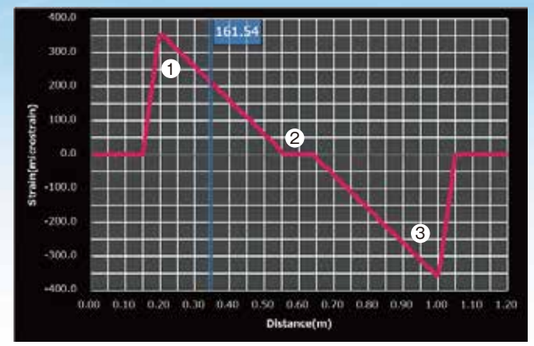
# Distributed strain measurement

## Example of strain measurement with FBI-Gauge

### Reduce man-hours and cost of settings

Optic fibers attached to the upper and lower faces of an aluminum cantilever are used to measure strain distribution. The results are presented in graphical form in 5 mm increments. The optic fiber, which is the red line, is mounted on the upper and lower faces of the cantilever . A standoff cable is used to connect the left-hand end of the optic fiber on the upper face to the FBI-Gauge unit.
(The loop-back at the right-hand end is not attached.)



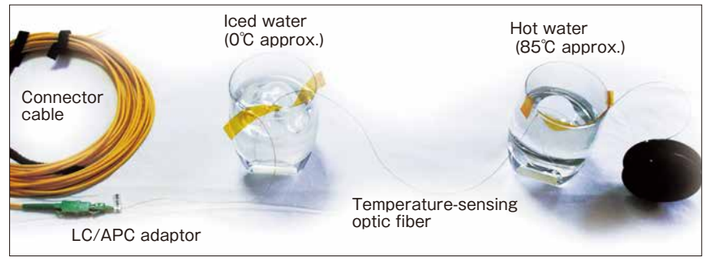



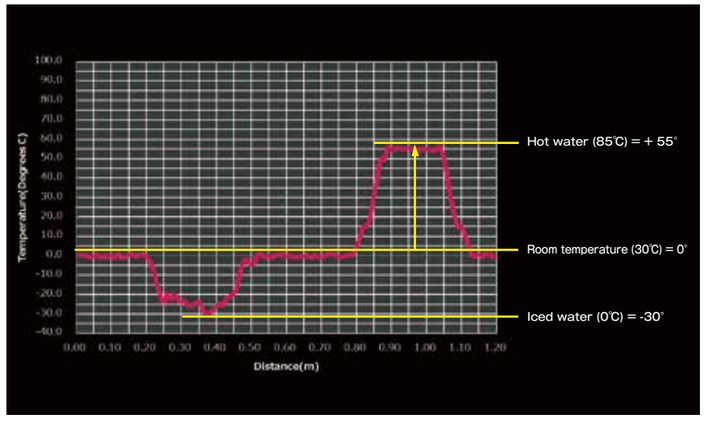

Static load strain

①Upper face: positive strain associated with tension
②Loop-back section: no load, no strain
③Lower face: negative strain associated with compression

# Distributed temperature measurement

FBI-Gauge uses a single optic fiber to measure temperature, eliminating the hassle of having to synchronize the time across multiple measurement positions. The optic fiber can also be installed in narrow spaces or stretched across a wide space, thereby offering a high degree of freedom for installation in places that pose problems for conventional systems.



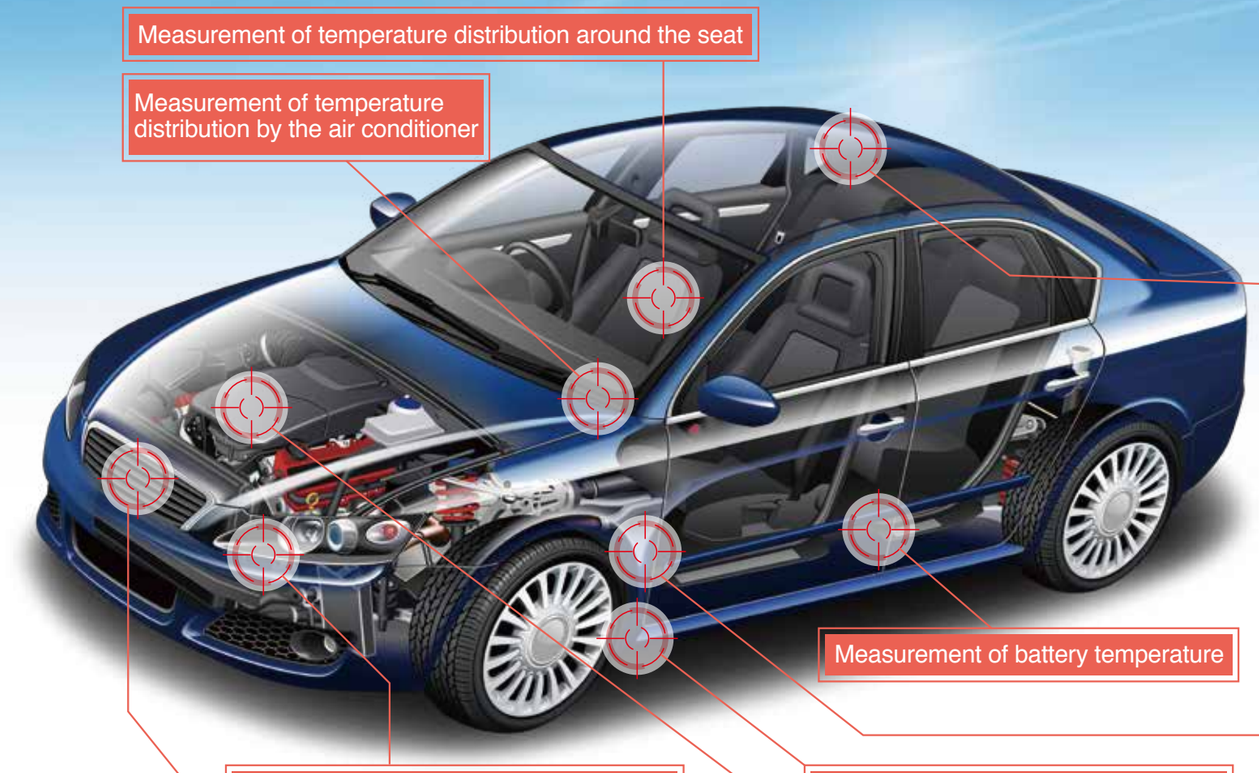

Change in temperature

FBI-Gauge measures temperature by monitoring constriction of the optic fiber due to heat.
The starting temperature is recorded as a baseline, and changes in temperature are determined relative to the baseline.

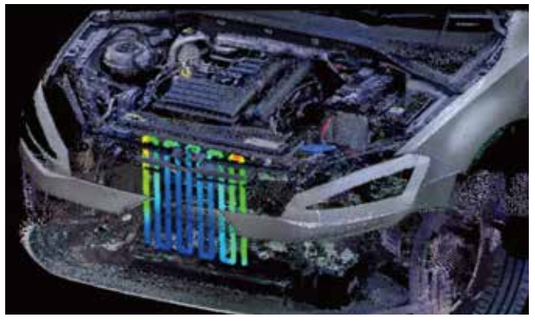
Temperatures relative to baseline room temperature (= 0° )

# Use of FBI-Gauge in the automotive industry

FBI-Gauge is a strain and temperature sensing system that uses optic fibers for the sensors. Measurements can performed continuously along the optic fiber, allowing for continuous line and surface observation over a wide area, as well as point observation. The sensor part of the FBI-Gauge does not use electricity, which means the system can also be used in an electromagnetic environment.

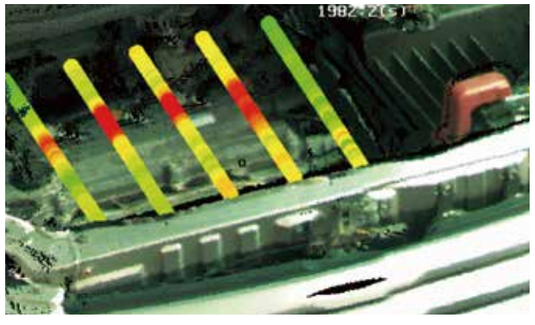



## Measurement of temperature distribution on the radiator



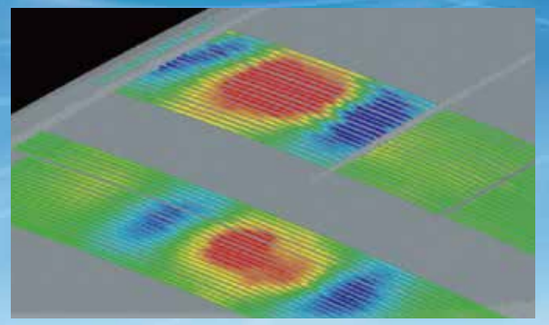
The use of a single optical fiber sensor for measurements makes it possible to visualize heat accumulation, temperature gradient, and other conditions. It allows for the measurement of localized distribution, which cannot be measured through the point observation of multiple parts. This provides for a more detailed examination of the cooling efficiency.

## Measurement of temperature distribution inside the engine room



The sensor can also be set up to measure temperature distribution in space. Unlike thermography, which only shows temperature distribution on a surface, the FBI-Gauge shows distribution in space.

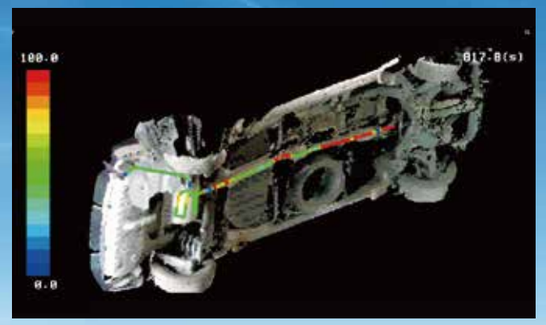
## Rigidity test of outer panel



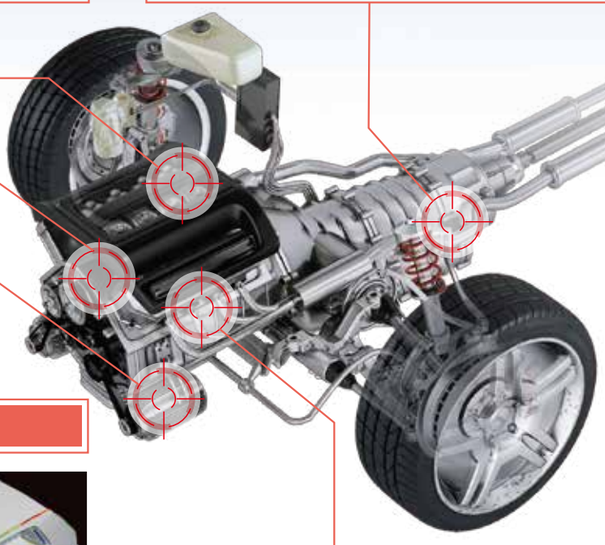
Provided by Honda R&D Co., LTD.

When optic fibers are densely attached at intervals of several centimeters, the FBI-Gauge can output distributed results just like a CAE tool.
This setup is ideal for comparing the results of an outer panel rigidity test with the CAE results.

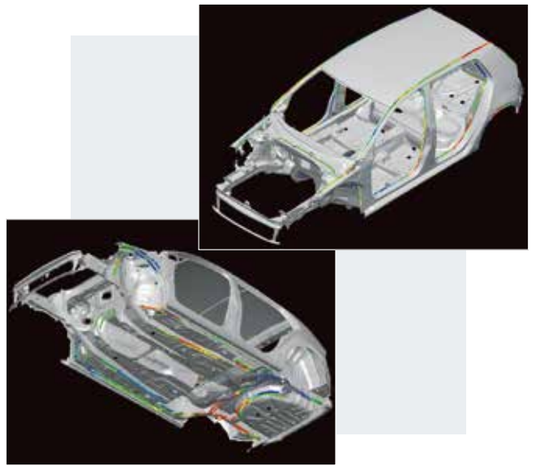
## Measurement of exhaust temperature distribution




A single optic fiber sensor allows for the simultaneous measurement of various parts.
The use of a single fiber eliminates the need for time synchronization and other tasks. Thus, the FBI-Gauge can also be used to compare the timing of multiple parts.

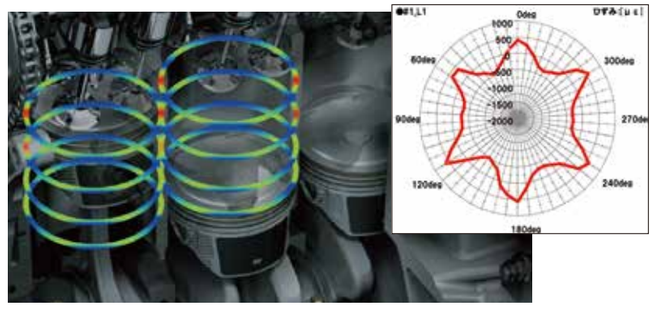



## Rigidity test of white bodies



With the traditional point observation, there was an unavoidable gap in skill between skilled workers and inexperienced workers. There was also the troublesome of task of checking whether the sensor was attached to the position where the strain is at its peak. Distribution measurement with the FBI-Gauge allows you to not only locate the peak strain afterwards, but also confirm the strain gradient.

## Measurement of bore deformation during bolt tightening process



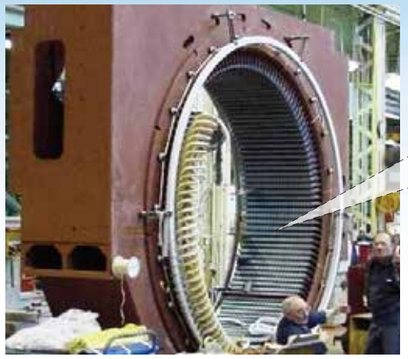

The FBI-Gauge is ideal for measuring strain of precision parts, such as the bore and bearing at the time of bolt tightening. The extremely thin size of the optic fiber sensor (155 $\mu$m) allows it be installed in many different places.
In addition the use of a single fiber sensor to perform measurements also allows for time synchronization, making it possible to check changes in strain while the bolt is being tightened.

# Use of FBI-Gauge in industrial facilities and in the construction industry

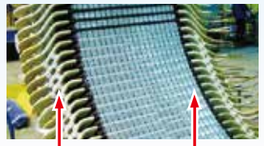
Introduction of optical fiber sensing advances in field of plant, because it does not affected by outside electromagnetic noise. Especially, FBI-Gauge excels in high-resolution measurement and be applied in wide range of the field that was not able to measure by the conventional electricity-style measurement technique and thermography.

## Measuring surface hot spots on generator stator

### FBI-Gauge for hot spots

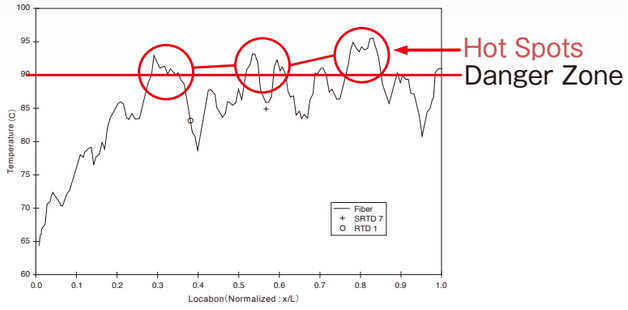


Optic fiber is attached to stator surface




Optic fiber can be deployed over a wide area, allowing line and plane measurement not supported with conventional thermocouples.
Temperature data can be generated in chronological form, and used to detect abnormalities relative to a defined steady state.

A single strand of optic fiber can identify multiple hot spots per millimeter.
Continuous measurement along the length of the optic fiber allows more sophisticated detection of abnormalities such as rapid changes in temperature distribution, as well as abnormalities in absolute temperature values.

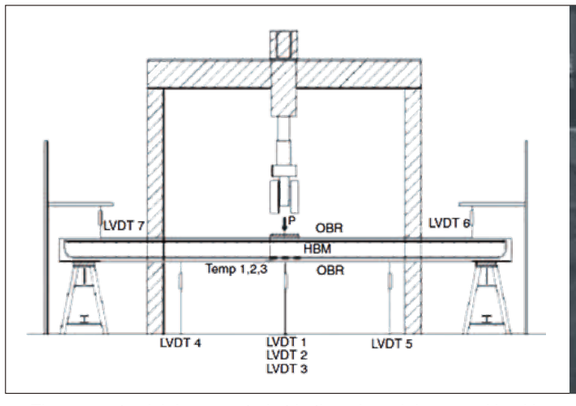



Hot spot measurements

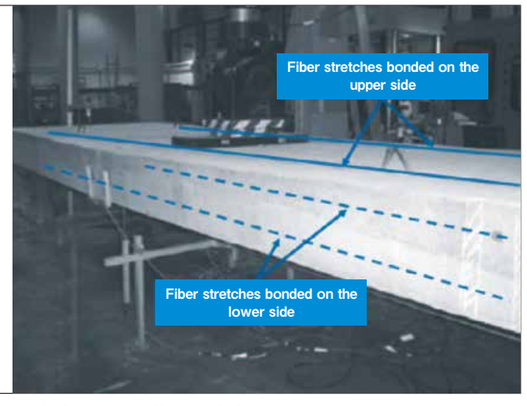
## Crack elongation in concrete

### Using FBI-Gauge for concrete load testing

Optic fiber on the upper and lower surfaces of the concrete slab is used to measure crack elongation under repeated load. A single optic fiber generates measurements along a line and can therefore measure multiple cracks at the same time.



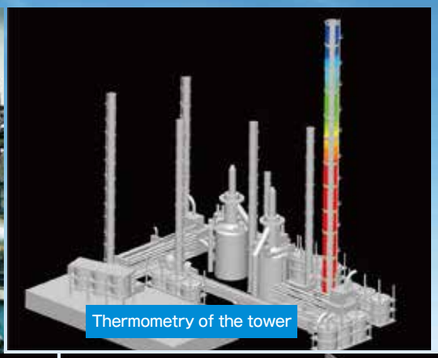

The concrete slab is supported at both ends and downward load is applied to the center section

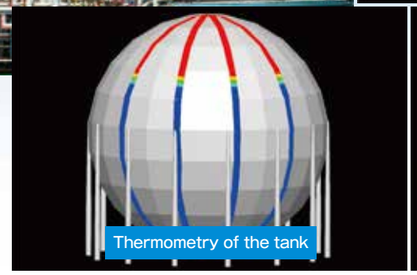


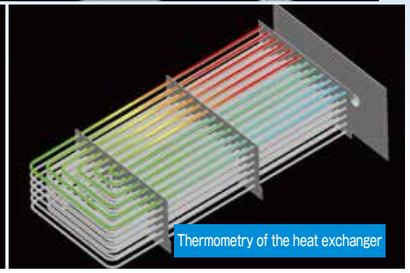

Optic fiber is attached to the upper and lower surfaces of the concrete slab

## Measuring temperature distribution of the plant

It is effective for a heat excess change measurement since a startup to the driving state of the plant.




The optical fiber is most suitable for long-term monitoring because the service life is relatively and never rust.

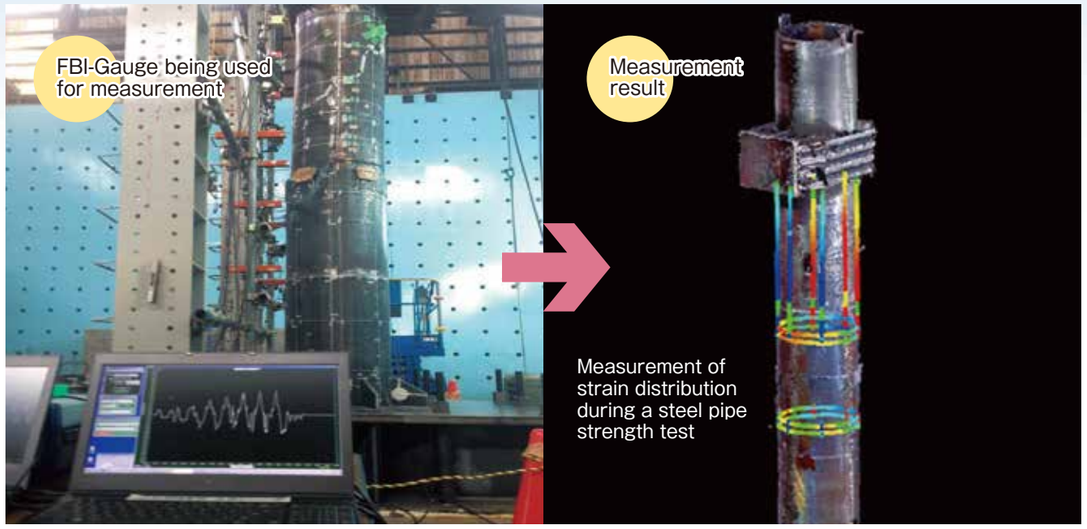
- Checking the aging deterioration attributed to strain caused by installation of the equipment
- Measurement of crack growth in concrete
- Testing strain during repeated loading
- Measurement of temperature distribution in a heat exchanger
- Measurement of temperature distribution in a building
- Measurement of temperature distribution in large equipment

# Post software

The FBI-Gauge comes with software that processes vast amount of measurement data obtained from the measuring equipment.
Normally, measurement data is output in three axes: values for longitudinal directions of the optic fiber, those for time, and those for strain and temperature. Accordingly, its processing is highly complicated with ordinary spreadsheet software.
The FBI-Gauge comes with powerful post software which is capable of processing three-axis data. This software permits quick processing for noise elimination, creation of 2D and 3D graphs, and handling of 3D visualization tool. This permits conversion of the data into intuitive output results and easy-to-understand graphs.

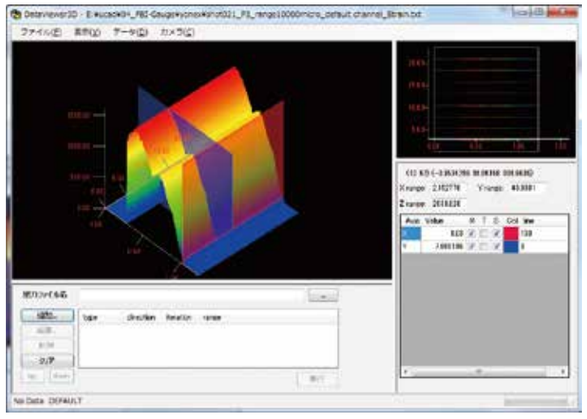
## 3D visualization tool

Set up the optic fiber sensor three-dimensionally as you like, measure temperature and/or strain, and use this tool to visualize the obtained data in 3D graphics. This will allow you to create a video showing the results, which makes you feel as if you were seeing the actual object on site. The tool uses point group obtained from 3D CAD of the object or 3D laser scanner to convert the strain and/or temperature into 3D contour graphics. This allows you to check intuitively where the peak is and what the gradient is like.




FBI-Gauge can be used in combination with 3D laser measurement to produce photograph-like report of measurement results.

## Filtering functions



The FBI-Gauge comes with functions for processing noise, which is generated frequently in optical measurement, and detaching only necessary parts. This enables quick processing of 3-axis data, which is difficult with spreadsheet software.

Key functions
- ●3D analysis (typically displayed as 3D color contours)
- ●3D dimensional measurement
- ●2D graphing
- ●3D graphing
- ●Filtering functions
- ●Other analysis and evaluation tools



# How it works

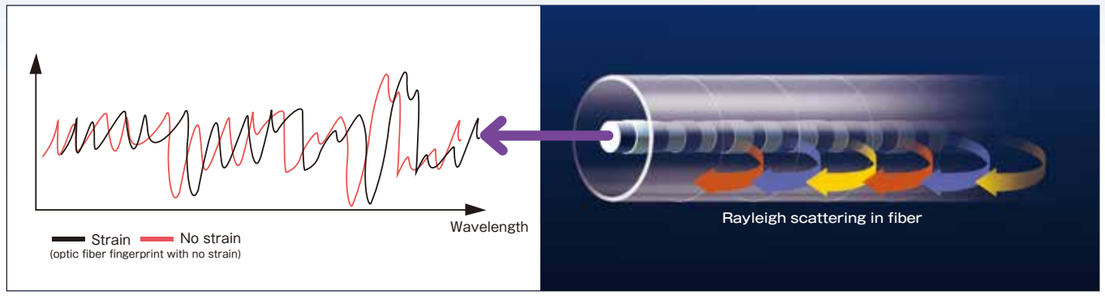
## Rayleigh scattering light distribution sensing system

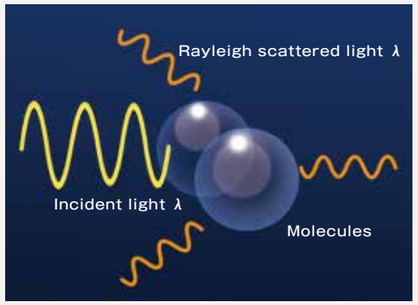
### About FBI-Gauge

FBI-Gauge is an optic sensing system that detects minute light reflections (known as Rayleigh scattering) produced by glass molecules in an optic fiber subject to a variable wavelength laser beam (1,510~1,570 nm).

### Unique optic fiber fingerprints and frequency offset due to strain

Minute density variations occur in the glass molecules in optic fiber. These are uniquely different for every optic fiber. The density variations cause discrepancies in the refractive index and these in turn govern the light wavelengths subject to Rayleigh scattering. The sum total of density variations along the length of an optic fiber is known as the optic fiber fingerprint, which effectively means that the same wavelength will always produce the same reflections provided that the optic fiber remains intact. In the event of strain occurring on the optic fiber, the reflected wavelengths will be offset at that particular point. FBI-Gauge uses a before and after comparison of reflected light patterns to determine the location and degree of strain at points along the optic fiber.



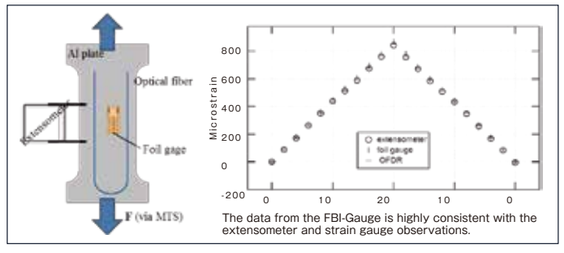

### Rayleigh scattering

FBI-Gauge detects reflected light in the form of Rayleigh scattering in the optic fiber.
Scattering normally refers to random dispersion of light caused by collisions with particles such as molecules in the air. The phenomenon known as Rayleigh scattering is associated with very small particles of the order of 10% of the light wavelength. A brilliant blue sky is the result of Rayleigh scattering of sunlight due to molecules in the air. Rayleigh scattering in optic fiber, meanwhile, is caused by collisions with glass molecules.

## FBI-Gauge accuracy

### Comparison with Extensometer and Strain gauge

In this example, we compare an extensometer and strain gauge in a tensile test on a test piece. The extensometer and strain gauge generate results at the same degree of precision. While the extensometer and strain gauge use a single sensor at a single location, optic fiber enables continuous measurement over the entire fiber length.




The data from the FBI-Gauge is highly consistent with the extensometer and strain gauge observations.