for

Safety and Security

PHOTONIC SENSING CONSORTIUM

Photonic Sensing Consortium
for Safety and Security

PhoSC

http:www.phosc.jp

We will contribute to creating a safe and secure society

In Japan and in many countries and regions around the world, the deterioration of social infrastructures has become a large issue.
There has also emerged a pressing need to gather new knowledge to respond to natural disasters that are becoming increasingly severe in recent years.
To address these social issues, a comprehensive and three-dimensional safety system needs to be promptly created to ensure proper monitoring, maintenance and operation of social infrastructures.
Fiber optic sensors are a promising technology that enable wide-area measurements that are indispensable to such a safety system. The performance of these sensors, such as their sensitivity, spatial resolution, and measurement speed, is improving day by day.
We at Photonic Sensing Consortium for Safety and Security will contribute to creating a safe and secure society for the next generation by coordinating our efforts with a broad range of partners to accelerate and promote the application of the fiber optic sensing technology to society.

Examples of fiber optic sensor applications

1. Management of dams (temperature, water level, displacement/deformation)
2. Management of railway tunnels (fire, cracks, displacement/deformation)
3. Management of road tunnels (fire, cracks, displacement/deformation)
4. Management of bridges (displacement/deformation, vibration, tension)
5. Management of wayside railway facilities (displacement/deformation, ground subsidence, falling rocks, weather)
6. Management of roads (temperature (freezing), surface deformation (slab joints, etc.), falling rocks)
7. Management of floodgates (water level, flow direction, opening/closing)
8. Management of inclines (falling rocks, landslides, slope deformation)
9. Management of energy facilities (displacement/deformation/leakage of LNG tanks and pipelines, weather, temperature/electric current of electric cables, strain on wind turbine blades)
10. Management of plants (temperature of furnaces/reactors/boilers/etc., fire, displacement/deformation, vibration)
11. Management of residential homes (fire)
12. Management of water supply facilities (water level, displacement/deformation, vibration (rainwater infiltration))
13. Management of rivers (water level, flow direction, displacement/deformation, flooding, erosion)
14. Management of underground transportation facilities (fire, displacement/deformation)
15. Management of underground shopping facilities (fire)
16. Management of large-scale public facilities (fire, displacement/deformation, crime prevention)
17. Earthquake/tsunami monitoring
18. Transportation (aircraft, rockets, vessels) (deformation, vibration, gyro)
19. Resource development (management of oil wells/gas wells/mines, security)

About Photonic Sensing Consortium for Safety and Security

Photonic Sensing Consortium for Safety and Security aims to contribute widely to public interests through the promotion of regional safety, the development of an information-based society, and the advancement of science and technology. It mainly engages in three areas of activities toward this end, namely the dissemination, education and promotion of the fiber optic sensing technology based on optical and other advanced technologies; research and development and the disclosure of R&D achievements; and the development of engineers.

with our fiber optic sensors

Photonic Sensing Consortium for Safety and Security

What are fiber optic sensors?

Fiber optic sensors provide an ultimate distributed sensing method for measuring the strain, temperature, and other such properties along the fiber optic cables continuously or at multi points along the cable. As the optical fiber itself is the sensing device, no electric energy needs to be supplied to the sensor body. Furthermore, with outstanding electromagnetic noise resistance and explosion resistance, the technology enables sensing that cannot be realized by other methods.

Small diameter, light weight, flexibility

Small diameter, lightweight, and flexible sensors are beneficial to installation and construction work in narrow spaces that are difficult to access, and in transportation equipment (aircraft and vessels) in which maneuverability and transport efficiency are essential.

High strength, durability, corrosion resistance, and measurement in extreme environments

In cases where constant, long-time use is required, sensors must be durable and last longer than the measuring equipment and the structural object to be measured. Fiber optic sensors have a sensor body made of glass, so they can be installed even in severe environments that are characterized by extremely high or low temperatures, high voltage, or radiation, and are thus being widely adopted for use in extreme environments.

Electromagnetic noise resistance, explosion resistance

With electric sensors, the measuring unit required a power supply, and the electronic components of these power supply and measuring units were at times damaged by thunder or a surge current. Additionally, when electronic or electric equipment is in close proximity, sensors that do not receive electromagnetic induction and other such countermeasures are needed.
Fiber optic sensors have "intrinsic safety." They are not affected by thunder, electromagnetic induction or power outages, and never emit sparks. Therefore, as an advantage, they can be used without taking any particular measures against diverse impediments that hinder the usage of sensors.

Remote measurement and distributed/quasi-distributed measurement

The transmission line or the measuring unit of a fiber optic sensor can be extended to several tens of kilometers.
Fiber optic sensors can be used to obtain continuous measurement along a linear object, as well as broad information by reciprocating the optical fiber.
Furthermore, by combining remote measurement and various converters, diverse information can be acquired at once from a wide range, including not only artificial objects such as large-scale structures and urban areas, but also natural environments such as the sea, mountains and rivers.

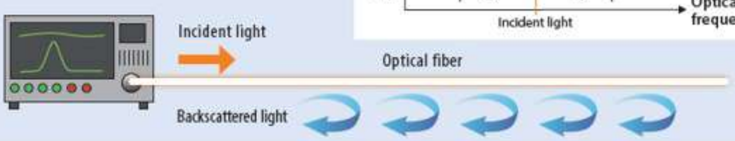
Reduced introduction cost and running cost

Introduction cost is minimized, as fiber optic sensors require no communication equipment, power supply facilities, wiring lead-ins, or ancillary facilities such as lightning arresters. Furthermore, they seldom malfunction compared to sensors that use electronic components, so a long-life sensor system with a low failure rate can be created.

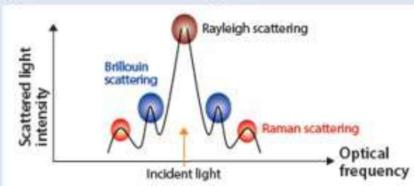
Types and principle of fiber optic sensors

Distributed sensors

- Distributed measurement is performed over the entire length of the optical fiber.
- Backscattered light is used.



Types of backscattered light



Distributed temperature sensor (DTS)

- Uses Rayleigh scattering, Raman scattering and Brillouin scattering
- ROTDR, BOTDR/A, BOCDR/A, OFDR, COTDR

Distributed strain sensor (DSS)

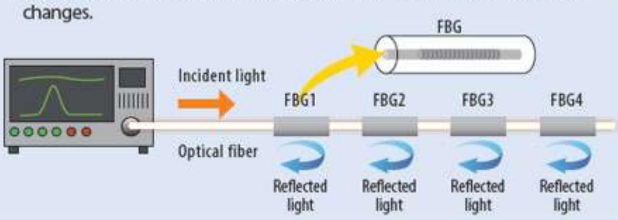
- Uses Rayleigh scattering, Brillouin scattering
- BOTDR/A, BOCDR/A, OFDR, COTDR

Distributed acoustic/vibration sensor (DAS/DVS)

- Uses Rayleigh scattering
- COTDR

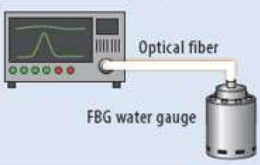
Quasi-distributed (multi-point) sensors

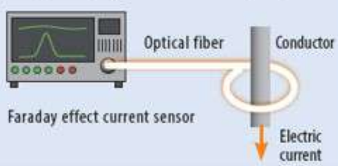
- As represented by FBG (Fiber Bragg Grating), FBG with differing properties (reflection wavelengths) are arranged in series to enable multi-point measurements.
- OTDR (loss distribution) also enables multi-point measurement using loss changes.



Single-point sensors

- Measures one point only.
- Interference sensors, wavelength-modulated sensors, intensity-modulated sensors, polarization-modulated sensors, etc.
- Measures numerous parameters (strain, temperature, stress (pressure), vibration, acoustics, acceleration, angular velocity (gyro), displacement, magnetic field (electric current), water level, precipitation, proximity sensor, open-close detection, etc.).





OTDR: Optical Time Domain Reflectometer
ROTDR: Raman Optical Time Domain Reflectometer
BOTDA/R: Brillouin Optical Time Domain Analysis / Reflectometer
BOCDA/R: Brillouin Optical Correlation Domain Analysis / Reflectometer
OFDR: Optical Frequency Domain Reflectometer
COTDR: Coherent Optical Time Domain Reflectometer

Types, features and applications of fiber optic sensors

Sensor type	Measuring method	Measurement parameter: Distributed	Measurement parameter: Quasi-distributed (multi-point)	Measurement parameter: Single-point	Measurement objects: Temperature	Strain	Vibration	Acoustics	Acceleration Angular velocity	Stress Pressure	Current Magnetic field	Disconnection Bending	On/Off Open/Close	Measuring method, main applications and uses
Distributed sensors	COTDR	●			●	●	●	●						**Measures acoustic/strain/temperature distribution along the optical fiber** → Pipeline leakage detection, oil/gas well condition monitoring, etc.
Distributed sensors	ROTDR	●			●							●		**Measures temperature distribution along the optical fiber** → Underground power transmission line monitoring, fire detection, plant condition monitoring, etc.
Distributed sensors	BOTDR/BOTDA BOCDR/BOCDA	●			●	●	●			●		●		**Measures strain/temperature distribution along the optical fiber** → Structural strain (bridges, tunnels, etc.), slope monitoring, vessel/aircraft strain, etc.
Distributed sensors	OFDR	●			●	●	●							**Measures strain/temperature distribution along the optical fiber at high speed and high spatial resolution** → Concrete crack detection, measurement of spatial temperature distribution in engine rooms, etc.
Wavelength-modulated sensors	FBG(Fiber Bragg Grating)		●	●	●	●	●		●	●		●	●	**Measures FBG strain and temperature** → Strain gauge, water gauge, thermometer, pressure gauge, accelerometer, vessel strain, strain on wind turbine blades, etc.
Wavelength-modulated sensors	BOF(Band-pass filter On Fiber-end)		●	●	●					●				**Measures BOF temperature, stress** → Thermometer, pressure gauge, vibrometer, etc.
Interference sensors	Michelson interferometer Fabry-Perot interferometer		●	●	●	●	●	●	●	●				**Measures vibration, acceleration, pressure, temperature, displacement, impact, etc. with high sensitivity** → Seismometer, pressure gauge, thermometer, sonar, etc.
Interference sensors	Optical fiber gyro (Sagnac effect)			●					●					**Measures angular velocity with high sensitivity** → Angular velocity sensor, attitude control, etc.
Polarimetric sensors	Polarimeter (Farady effect)			●							●			**Measures the current in electrical wires (magnetic field)** → Optical CT, current sensor, etc.
Polarimetric sensors	Polarimeter (photoelastic effect)		●	●			●					●		**Measures optical fiber vibration** → Detection of falling rocks and landslides, impact detection, etc.
Light intensity-modulated sensors	OTDR		●	●								●	●	**Measures disconnection/bending position from optical loss along the optical fiber** → Detection of landslides and falling rocks, floodgate open-close detection, etc.
Light intensity-modulated sensors	Hetero-core sensor			●								●		**Measures optical loss generated by a bend in the hetero-core portion** → Displacement gauge, inclinometer, water gauge, mat sensor, etc.
Light intensity-modulated sensors	Proximity sensor (Faraday effect)			●									●	**Detects magnetic proximity** → Floodgate open-close detection, flood detection, rain gauge, detection of falling rocks, etc.

Inquiries about fiber optic sensors

We have actively established a support framework composed of a large number of outstanding advisors and engineers, to meet your expectations. We are open to any type of consultation, from basic to advanced, specialized matters. Please feel free to contact us with any inquiries you may have regarding fiber optic sensors.

Creating a fiber optic sensing system

To incorporate fiber optic sensors into your system and make effective use of them, you need to know about the various sensing methods that exist and their performance, as well as methods for designing and constructing a fiber optic sensing system. Furthermore, upon envisioning the entire light propagation structure, you also need to have knowledge about the performance and specifications of each device and design them so the system operates as planned. The construction of the measuring unit becomes extremely important to ensure accurate and stable measurements over a long term. Generally speaking, the measuring unit of a fiber optic sensor that does not include electronic parts provides high reliability. However, it is necessary to employ a reliable method of securing the sensor to guarantee long-term accuracy and sensitivity such as when monitoring for deformations, for example. (Cited from "Introduction of fiber optic sensing")

History

Jun. 2004	Established Fiber Optic Disaster Prevention System Promoting Consortium as a private organization that aims to implement activities for disseminating and promoting temperature and fire detecting devices that utilize optical fiber properties.
Apr. 2008	Reorganized as a new private organization named Optical Disaster Prevention Sensing Promotion Consortium that also handles optical strain sensors, for dissemination of the fiber optic sensing technology.
May 2008	Inaugural meeting of the Optical Disaster Prevention Sensing Promotion Consortium (first chairman: Prof. Yoichi Fujii (Nihon University))
Aug. 2008	Commissioned by the Disaster Prevention Research Laboratory of the Research & Development Center of JR East Group to undertake the "basic survey for development of an optical disaster prevention sensor," and commenced a basic study for development of the sensor.
Apr. 2009	Received certification as an NPO.
Jun. 2011	Launched structural monitoring for a research project on the safety of Myoko Ohashi Bridge within the district governed by the Hokuriku Regional Development Bureau.
Jun. 2013	Changed the name of the organization to Photonic Sensing Consortium for Safety and Security.
Nov. 2014	The application was adopted as an R&D topics "Infrastructure Maintenance, Renovation and Management" by SIP (Crossministerial Strategic Innovation Promotion Program).
Aug. 2015	Prof. Kentaro Nakamura (Tokyo Institute of Technology) assumes the post of chairman.
May 2018	Co-hosted the Asia Pacific Optical Sensors Conference (APOS).
May 2019	Launched monitoring operations of Kesennuma Oshima Ohashi Bridge under a cooperation agreement with the Miyagi Prefecture Kesennuma Civil Engineering Office concerning Oshima bridge monitoring and survey operations.

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Hulic Ginza Wall Bldg. 7th Floor, 6-13-16 Ginza, Chuo-ku, Tokyo 104-0061
TEL: +81 (3) 6869-5738 FAX: +81 (3) 6278-7420 e-mail: info@phosc.jp
URL http:www.phosc.jp

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