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Booth 615

Fiber Optic BUZZ!

Fiber Optic Sensors are enabling mission critical applications in Medical, Industrial and Aerospace

Presented by **Dennis Horwitz**, President

Sensors Converge LIVE Theater
Wednesday, June 26 2024

Today's Trends in Medical, Industrial, and Aerospace drive needs for Sensors of All Types

Trend	What/Why/Where	Issue
Electrification	Reduce use of fossil fuels, lower carbon footprint, combat climate change	Creates EMI/RFI Problems
Closed Loop Processing	Automation, robotics, process & equipment health feedback for increased efficiency and lower costs	Need for variety of sensors for better process monitoring and predictive maintenance
Medical Devices	Surgical & biopsy robots, treatment delivery, MRI, patient rehabilitation	Need variety of sensors, low cost, and small size, enhance health and longevity
Harsh Environments	Transformers, generators, oil & gas, pipelines, wind turbines, underwater, nuclear	Need very robust sensors – resistant to harsh environment factors
Hazardous Locations	Food industry, chemical, mines, food & process industries	Need for intrinsically safe or inherently safe sensors
Vehicle Health	Automotive, aerospace, rail transport	For increased safety and reliability
Structural Health	Buildings, dams, highways, railroad tracks, pipelines, transmission lines	For increased safety and reliability, eliminate waste caused by leakage

Why Fiber Optics?

Immune to Electrical and RF Fields

Immune to Lightning and High Voltage

Radiation Resistant

Extremely Small Size

Transparent to Magnetic Fields

Wide Temperature Range

Inherently Safe

Interference-Free Over Long Distances

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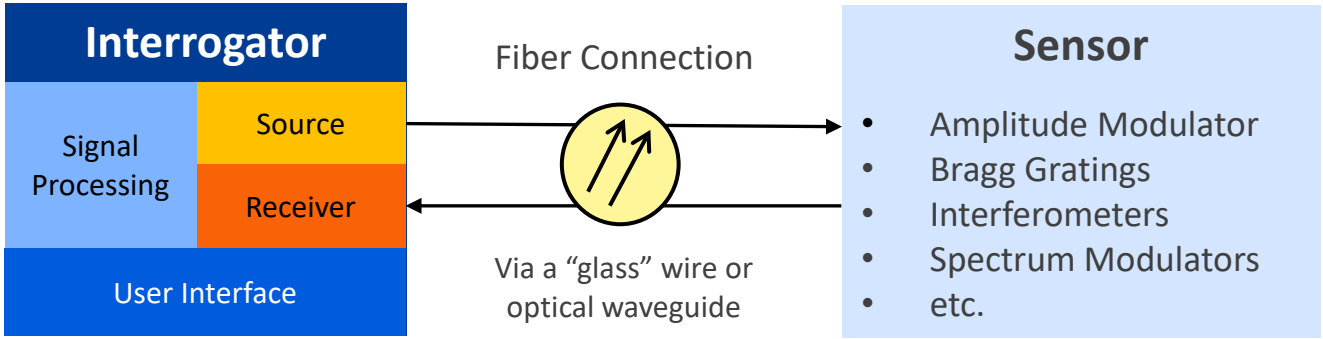
What is a Fiber Optic Sensor?

"Remote sensing and measuring of a physical quantity using photonics for both sensing and transmission."

Since most Fiber Optic Sensors are not of transducer[(1)] type they require an interrogator



➡ Non-electric – No Interference

(1) transducer – a device that converts one form of energy into another.

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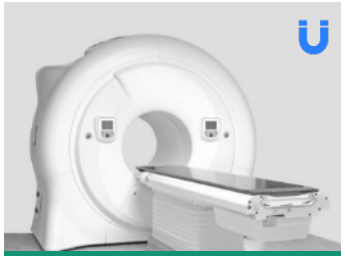
Numerous Applications



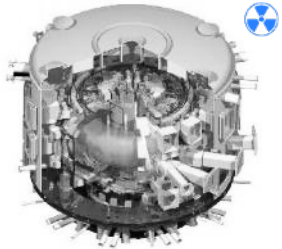
Medical (MRI)

Aerospace

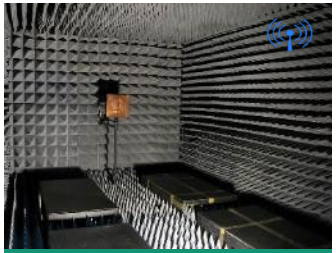
Power & Energy

Life Sciences

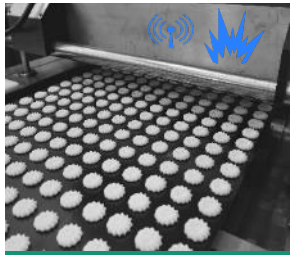
Semiconductor



Nuclear Energy



Test Chambers & Labs



Food & Beverage

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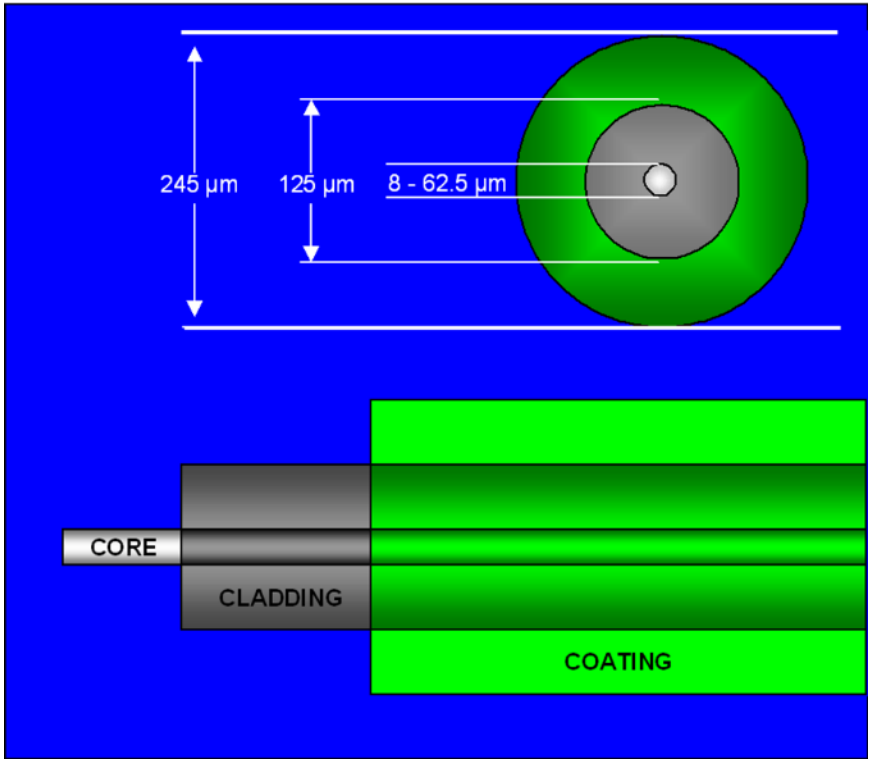
What is Fiber Optics?

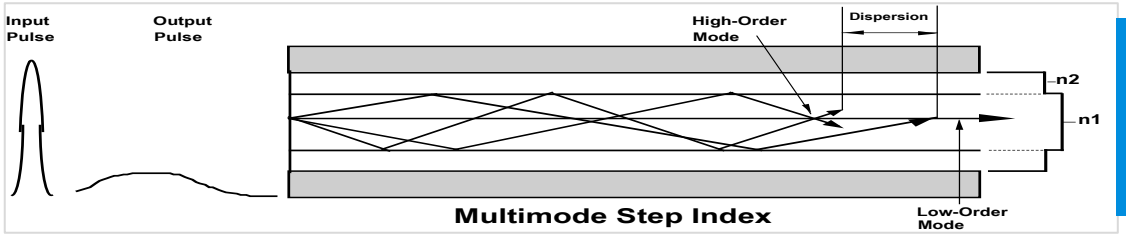


Core
- Carries the light signals
- Silica and a dopant, special pure silica core fiber
- POF uses polymer core
- 9µm for telecom SM, 5.6 µm for FiSens SM800 FBGs
- 50 or 62.5µm for multimode, 1mm for POF

Cladding
- Keeps light in the core
- Pure silicon or polymer

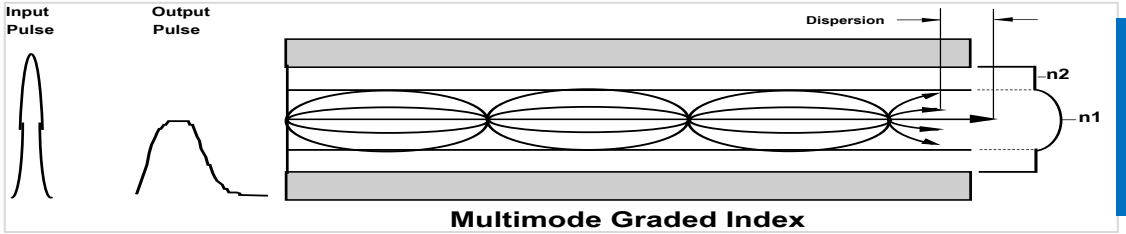
Coating
- Protects the bare fiber
- Acrylate (polymer) or Polyimide (for high temp)

Single Mode versus Multimode, Many Types and Sizes of Optical Fiber



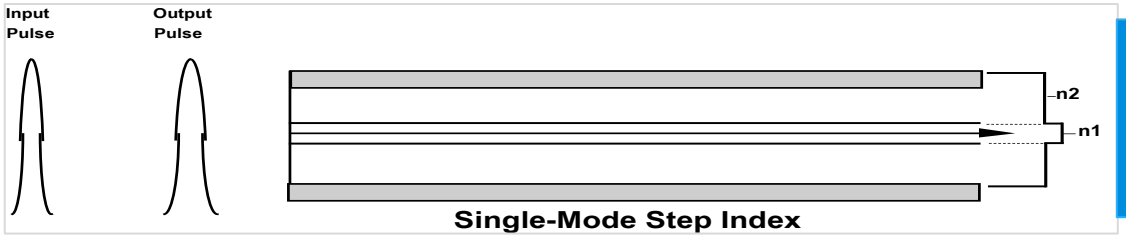
Multimode Step Index Fiber

- Short distance links, <100 m
- 10-100 Mb/s, Single λ
- POF, Large Core SI Fiber, FO Imaging Bundles



Multimode Graded Index Fiber

- Short-Medium distance links, 10m - 2000m
- 100 Mbs - 10Gb/s, Single λ
- 50/125 (OM2) or 62.5/125 (OM1/OM3)



Single Mode Fiber

- Long distance links, 1000m -100km, 1300-1550nm
- 10//100/1000 Gb/s, Single λ or WDM)
- 9/125 (OS1/OS2), Specialty SMF for other λ

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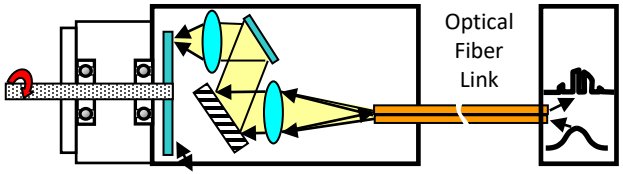
Fiber Optic Absolute Encoders

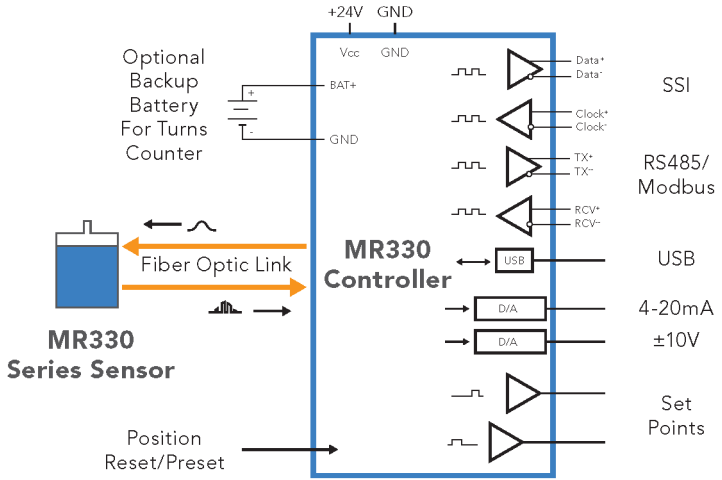
Absolute Encoder, aka Position Sensor

US Patent 8,461,514 B1



MR330
MMF-62.5/125
Series

MR430
M-POF
Series



Case Study #1: NASA Launcher Upgrades

FO Attributes

NASA/ORBITAL SCIENCES
StarBird Launcher
Azimuth and Elevation
Position Feedback

Micronor MR332 Absolute Encoder

SSI Displays

Micronor MR330-1 Controllers

9

Case Study #2: MRI Dynamic Brain Phantom

FO Attributes

MR431 POF-based Absolute Encoder

The ALA SCIENTIFIC MRI Dynamic Brain Phantom is designed to address training and quality assurance protocols for MRI machines by providing rapid control feedback from within the MRI bore, while remaining invisible to MRI scans.

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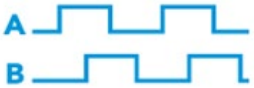
Fiber Optic Incremental Encoders

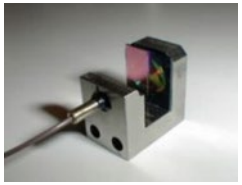


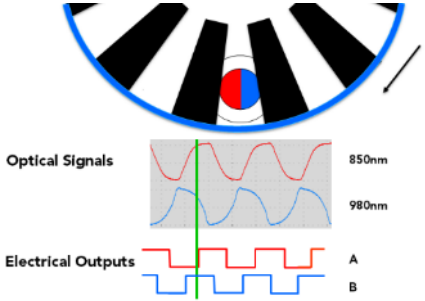
Incremental Encoder

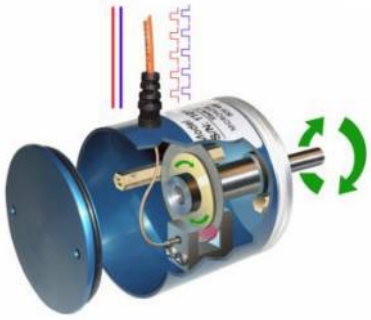
US Patent 7,196,320

MR340

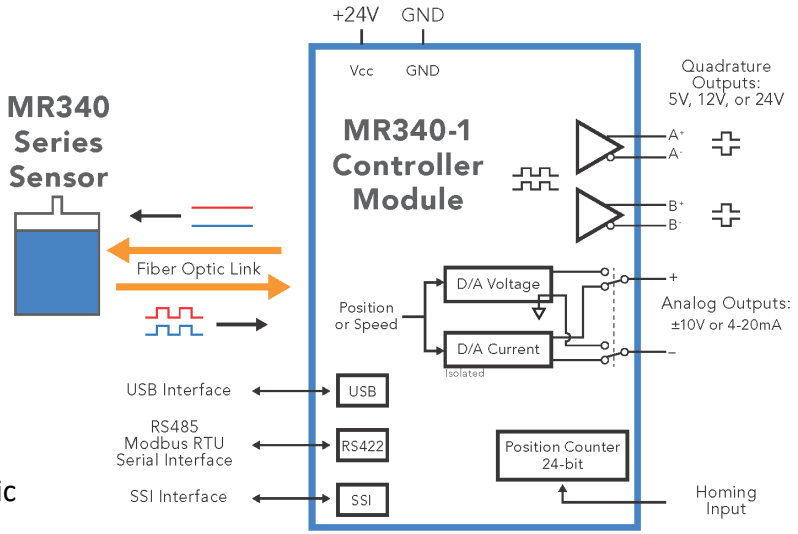
MMF-62.5/125 Series





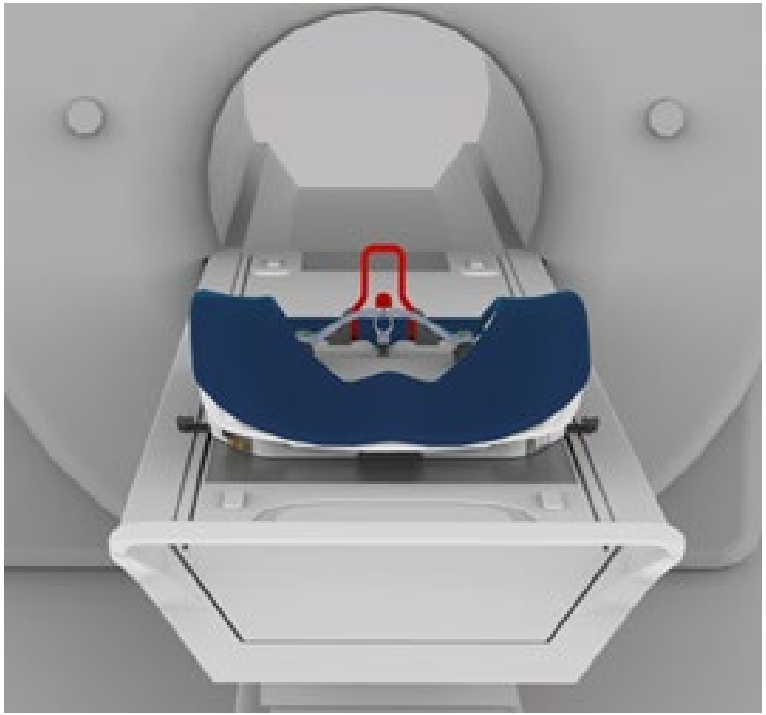


- Sensor is all-optical.
- No electronics. No power supply required.
- Sensor system consists of 3 components: passive sensor, fiber link and optoelectronic controller/converter.

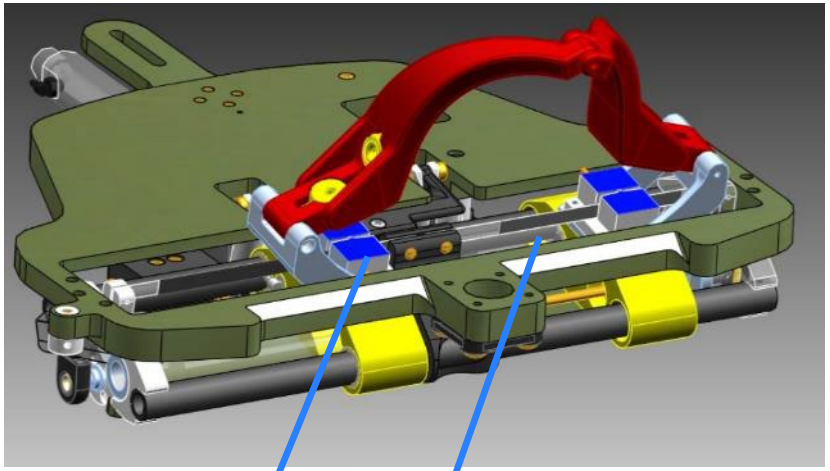


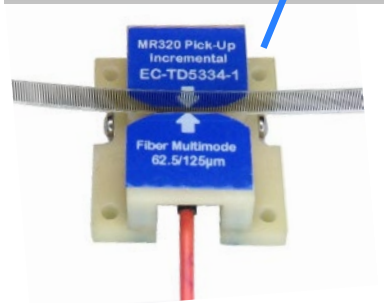
Case Study #3: MRI Guided Biopsy Robot

FO Attributes



Photos and renderings courtesy of
Polymer Robotics / Umano Medical





Precision MR343
Incremental
Film Strip
(2 Axes Shown)

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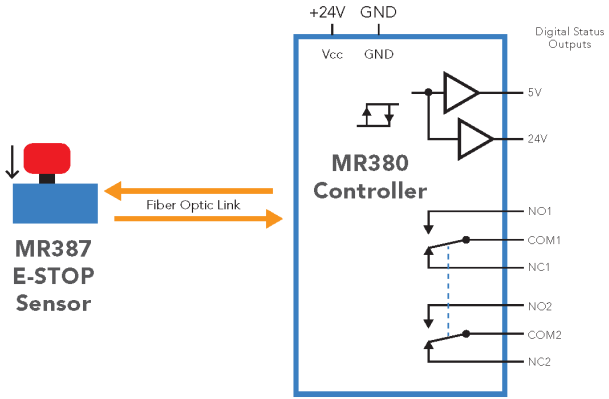
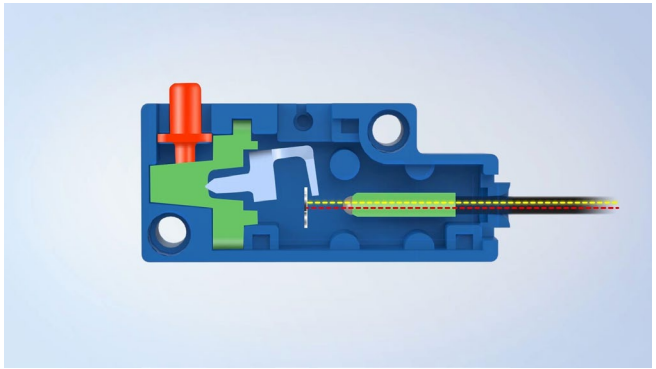
Fiber Optic Emergency Stop and Microswitch

Operate on basic principle of photo interruption
(light on / light off)





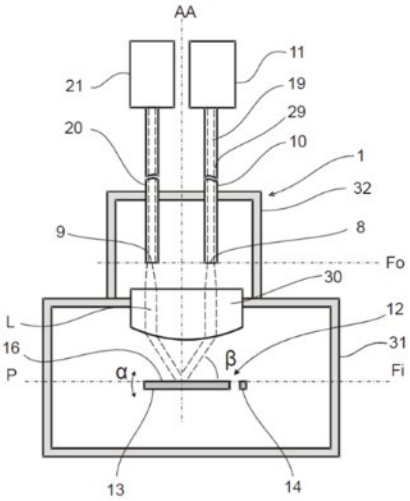
Case Study #4: LAX Consolidated Rent-A-Car

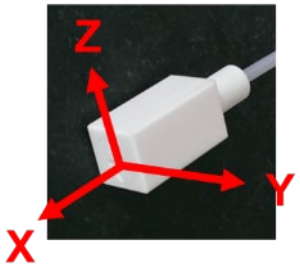
Application: FO E-Stop between Main and Utility Buildings

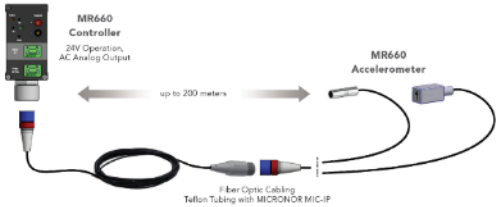
FO Attributes

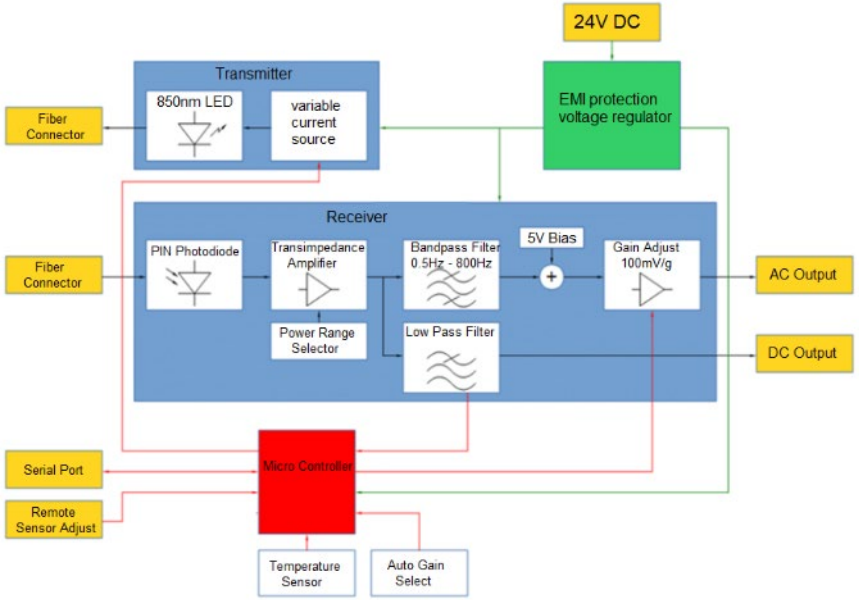
Multi-Axis Fiber Optic Acceleration/Vibration Sensor

A dedicated MEMS membrane/mirror is aligned with a specific axis and light is modulated only by that axis.









Case Study #5: Electric Train Pantograph

FO Attributes

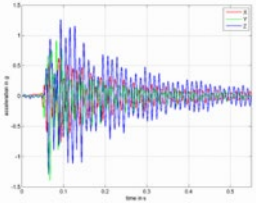
CHALLENGE

Dynamically monitor pantograph operation in real time during train operation. A serious failure of pantograph can not only damage contact wires but can also inflict widespread damage on the catenary system network.

SOLUTION

Providing high voltage immunity and isolation, a multi-axis fiber optic accelerometer mounts directly on the pantograph to monitor system health in real time.

Customer: Swiss Railway



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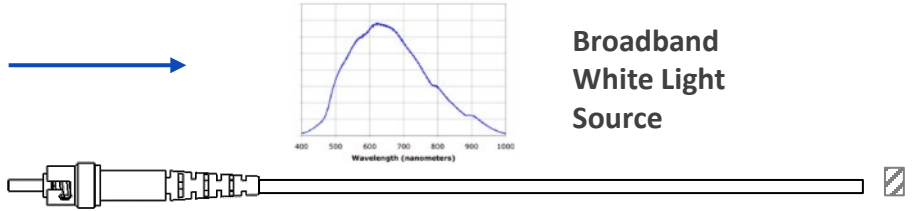
Gallium Arsenide (GaAs) FO Thermometry

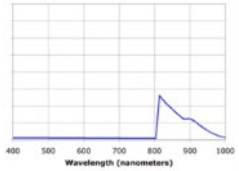
T

INTERROGATOR



Broadband White Light Source

FIBER-OPTIC IMMERSION-STYLE PROBE

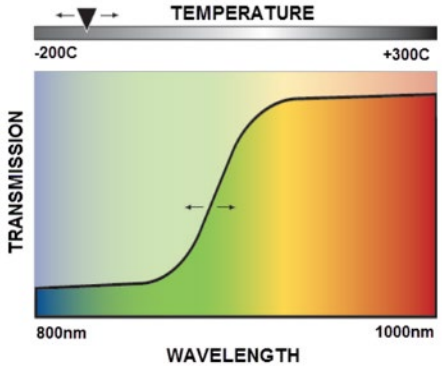


Reflected Spectrum

GaAs Crystal
300µm x 300µm
Mounted on end of
200µm MM fiber

Principles of Operation

1. GaAs is a non-metallic semiconductor crystal in which the effect of temperature is based on the inherent light absorption and transmission properties of the crystal.
2. Light source transmits light to the crystal. Some of the light is absorbed and the rest is reflected back to the spectrometer.



Optical beam probes the wavelength dependence of the intrinsic band-gap of GaAs which is dependent on absolute temperature.

$E_{gap} = 1.423eV$ ⇨ 300°K = 872nm

$dE_{gap}/dT = -0.452meV/°K$ ⇨ ≈ 0.315nm/°K

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Case Study #6: Induction Heating

FO Attributes

CHALLENGE

Magnetic nanoparticles are heated with induction to selectively ablate tumor cells, powers from 1kW to 10kW, frequencies from 150kHz to 400 kHz. This non-contact selective heating only elevates the temperature of the material or tissue with embedded magnetic nanoparticles. Requires RF immune temperature sensor to monitor actual temperature.

SOLUTION

Ambrell EASYHEAT® System is a compact induction heating system for the lab which offers Weidmann TS3 GaAs sensor (both non-metallic and RF-immune) for both temperature indication and closed loop control of the customer's process.

Case Study #7: Microwave Ovens

FO Attributes

Microwave Food Processing using TS3 GaAs Temperature Probe

CHALLENGE

Develop optimized process for meat thawing as well as production of partially cooked food product.

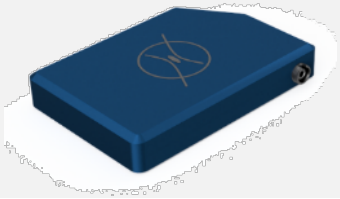
SOLUTION

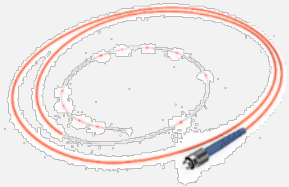
A&B Famous Gefilte Fish uses multichannel Bench Top FOTEMP signal conditioner together with TS3 series GaAs temperature probes.

A&B developed a proprietary microwave oven-based process for raw fish thawing as well as production of their partially cooked frozen gefilte fish product. For the latter, a microwave oven process was developed that precisely cooks and cools the product without rendering the proteins fully cooked.

Multipoint Temperature & Strain Sensing with Fiber Bragg Gratings (FBG)

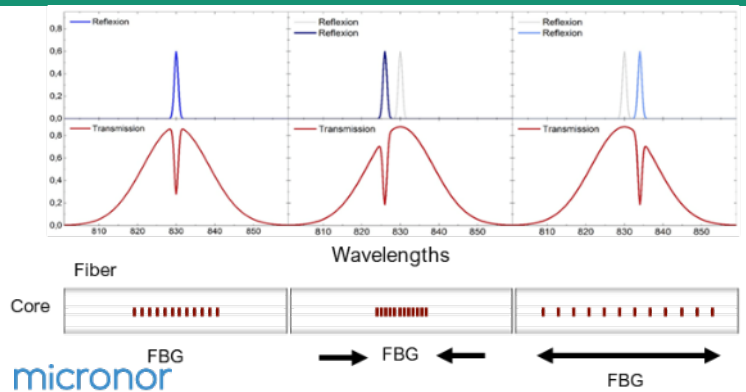
FiSens® FBG System: Interrogator + Fiber Sensor Chain





FiSens® is a trademark of FiSens GmbH

Principles of Operation



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The Bragg wavelength is sensitive to both strain and temperature. The relative shift in the Bragg wavelength $\Delta\lambda_B/\lambda_B$, is due to applied strain ε and change in temperature ΔT:

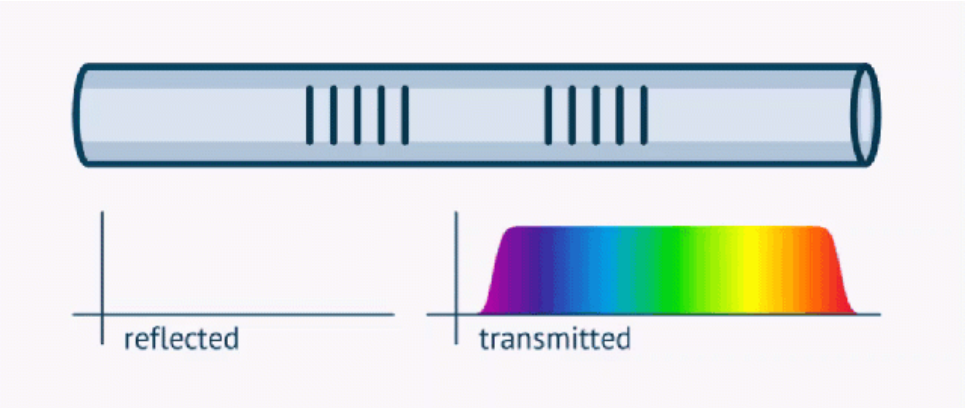
$$\left[\frac{\Delta\lambda_B}{\lambda_B}\right] = C_S\epsilon + C_T\Delta T$$

where:

C_S is the coefficient of strain

C_T is the coefficient of temperature

Single and Multipoint Sensing - FBGs



Reflected wavelength of a particular FBG is a function of both temperature and strain on that FBG.

FiSpec FBGs and interrogators operate in the 850nm window, the fundamental Bragg Wavelength of each FBG corresponds to 21°C and 0 με (μm/m).

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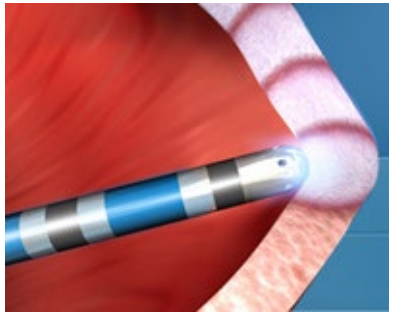
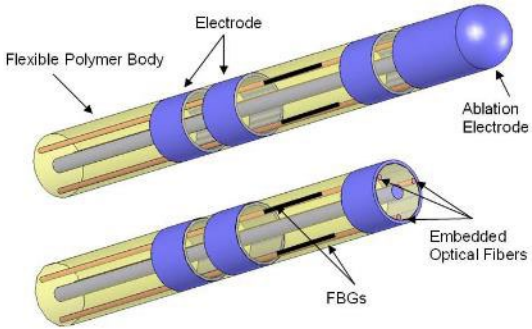
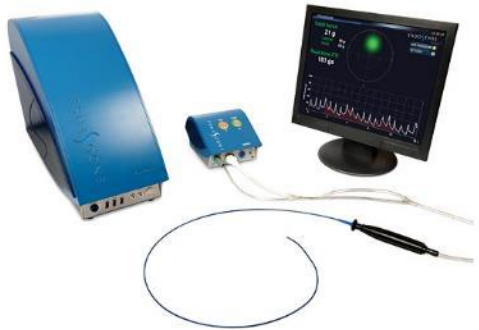
Case Study #8: Medical – RF Ablation

FO Attributes







CHALLENGE

RF ablation catheter is directed through the body and positioned to burn off tumors. Physicians require real-time, objective measure of contact force during treatment of cardiac arrhythmias or tumors.

SOLUTION

The TactiCath force-sensing ablation catheter provides physicians with a real-time, objective measure of contact force during the treatment of cardiac arrhythmias. It includes a smaller fiber optic sensor at the tip, a force-time integral display and automatically generated summary reports of the procedure. Contact force is derived from three sensor fibers which measure micro deformation of the catheter tip using Fiber Bragg Grating technology.

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Multipoint Process, Structural & Health Monitoring

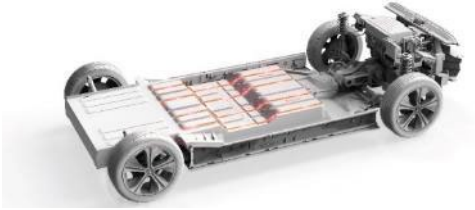
FO Attributes

Civil Structure Health
and Safety Monitoring

Infrastructure Health
and Safety Monitoring

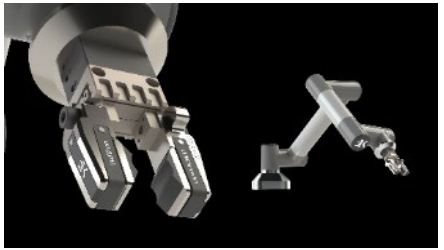
Wind Turbine Blade and
Generator Health Monitoring

Aircraft Structural
Health Monitoring



Battery
Health Monitoring

Next
Presentation



Robotic Force, Load and
Balance Monitoring

Questions?

Visit Booth 615 for FBG and Force Sensor Demonstrations

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