Fiber-based sensors

by: Khanh Kieu
Project #10: Fiber optics sensors

- Fiber taper temperature sensor
- FBG characterization
- Passive Fiber Optic Gyroscope (FOG)
Advantages of optical fiber sensors

- Compact size
- High sensitivity
- Multi-functional
- Remote accessible
- Multiplexing
- Resistant to harsh environment
- Immunity to electro-magnetic interference
- …
Optical Fiber Sensor Types

**Point sensor:**
detect measurand variation only in the vicinity of the sensor

**Multiplexed sensor:**
Multiple localized sensors are placed at intervals along the fiber length.

**Distributed sensor:**
Sensing is distributed along the length of the fiber
What can be measured?

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>CHEMICAL SPECIES</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRESSURE</td>
<td>FORCE</td>
</tr>
<tr>
<td>FLOW</td>
<td>RADIATION</td>
</tr>
<tr>
<td>LIQUID LEVEL</td>
<td>pH</td>
</tr>
<tr>
<td>DISPLACEMENT</td>
<td>HUMIDITY</td>
</tr>
<tr>
<td>VIBRATION</td>
<td>STRAIN</td>
</tr>
<tr>
<td>ROTATION</td>
<td>VELOCITY</td>
</tr>
<tr>
<td>MAGNETIC FIELDS</td>
<td>ELECTRIC FIELDS</td>
</tr>
<tr>
<td>ACCELERATION</td>
<td>ACOUSTIC FIELDS</td>
</tr>
</tbody>
</table>
What can be used?

LIGHT BEAM’S PROPERTIES THAT ARE MODIFIED BY THE EFFECT THAT IS BEING MEASURED:

- INTENSITY,
- PHASE,
- POLARIZATION,
- WAVELENGTH
- SPECTRAL DISTRIBUTION
Sensing the earth crustal deformation with nano-strain resolution fiber-optic sensors

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Abstract: Crustal deformation measurement with a high resolution on the order of nano-strains in static to low frequency region is required for geophysical research. Optical fiber sensors are very attractive in this research field due to their unique advantages including high resolution, small size and easy deployment. In this paper, a fiber optic strain sensor with nano-strain-resolution and large measurement range for sensing the earth crustal deformation is reported. With this sensor the tide induced crustal deformation and the seismic wave were successfully recorded in field experiments.

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OCIS codes: (060.2370) Fiber optics sensors; (060.3735) Fiber Bragg gratings; (120.0280) Remote sensing and sensors.
This is an active field of research.
Fiber taper sensors

Transmission oscillation observed during taper pulling process.

Fiber taper pulling setup

K. Kieu et al., PTL 2006
Fiber taper displacement sensors

- Transmission (%)
  - Initial
  - Stretched 80 µm
  - Stretched 160 µm

- Wavelength (nm)
  - Range: 1500 to 1575

- Wavelength shift (nm)

- Stretch distance (µm)
  - Taper length: 20548 µm
    - FSR: 9.4 nm
  - Taper length: 18382 µm
    - FSR: 15.4 nm
Laser’s wavelength was fixed when the fiber taper was stretched.

Detection sensitivity < 100 nm
Refractive index sensor

1.42x10^{-5} sensitivity achieved
Temperature sensor

- Temperature resolution: 1 °C (just by refractive index change)
- Temperature resolution: 0.1 °C (by using thermal expansion of holding substrate)
Fiber Bragg Grating

Bragg condition:

$$\lambda_B = 2n_e \Lambda$$
Fiber Bragg Grating

How to make fiber Bragg gratings?
Types of fiber Bragg Grating

1) Uniform Fiber Bragg Grating

2) Chirped Fiber Bragg Grating

3) Tilted Fiber Bragg Grating

4) Superstructure Fiber Bragg Grating
Rotation sensing - Sagnac effect
Rotation sensing-Sagnac effect

KVH e-core-2000 fiber optics gyroscope
My idea of the smallest gyroscope

Basic elements:

• Microring laser
• Fiber taper
• Near field tip
Questions for thoughts

Can we create a fiber sensor to predict earthquakes?

What have you learned from this class?

What are the other topics that would you like to be included?

Anything we should do to make the class better?

Would part-2 (more advanced nonlinear fiber topics) be interesting?