Distributed Pressure System (DPS) Based on High Precision Brillouin Sensing Technology

• High resolution is absolutely necessary for high precision
• Temperature and Strain
• Totally SM fiber scheme leads to economic, stable, long distance solution
• Fiber cable is the system – it is the sensor, is the communication line, is all you need

Give you a feel

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Pressure of underground water will seal the fuel in liquid phase for long time. As long as the water is exist, The storage is safe.
Reaction of DPS in water pressure monitoring

Observation Well  Observation Well

Pressure Distribution  Pressure Distribution

Water leak  Low pressure

Water comb

Fuel Tank

Well Head

Electric Sensor  Neubrescope

Water lever  House

Packer  Electric Sensor  Electric cables

DPS FO cable

Principle

Field Test Plan
DPS design and lab calibration

DPS cable

Elastic layer

Strength member

Skin

P T F

fibers

Size

Action image

Pressure (MPa)

Strain

Position

Pressure (MPa)
Whole SM Fiber Optical Scheme
10cm may be the essential request for DTSS

DTSS with 1m spatial resolution is difficulty to reach a precision of 100με (i.e. 5°C)

Ripple of period about 90cm, 150με
GUI DEMO
Field Test

DPS Cable Bobbin

Extend to building

Installation

NBX-6010
**Field Test Results**

**DPDT**
Distributed Pressure and Distributed Temperature System

**Spec:**
- Max. Pressure Range: 2MPa (200m)
- Max. temperature: 45 (℃)
- Pressure precision: ±0.01MPa (1m)

**Application:**
- Underground Storage of fuel
- EPS
- Dam
**Principle**

- **Stimulated Brillouin Scattering (SBS)**

  - Optical Pulse
  - Light Source
  - Receiver (Frequency Analysis)
  - Optical fiber
  - Pump
  - CW
  - Probe

  \[ \Rightarrow \text{Phonon in fiber is stimulated by pump light, the SBS is generated as a backwards scatter light} \]

- **Contents of back scattering**
  - Frequency of SBS \( \nu \pm 11 \text{GHz} \)
  - Incident Frequency: \( \nu \)
  - Power of SBS
  - Raman
  - Rayleigh
  - Raman

- **Graph**
  - Incident Frequency: \( \nu \)
  - Frequency of SBS: \( \nu \pm 11 \text{GHz} \)
  - Power of SBS
  - Raman
  - Rayleigh
  - Raman
Peak of local frequency represent the magnitude of strain (temperature)

\[ \varepsilon \]

Strain Distribution

Spatial Resolution (SP) is decided by the length of pump pulse
NeubreScope Based on PPP technology

Pulse PrePump light (A_p(t))

+25dBm
0dBm
0

D=1ns
D_{pre}=13ns

Pump light (Pulse only)

+25dBm
0dBm
0

D=1ns

Pump light (Pulse-PrePump only)

+25dBm
0dBm
0

D_{pre}=13ns

NeubreScope

Other vendors

Probe light (CW)

0dBm
0

Optical fiber
1200 µm
20 cm
z = 0

z = 10m

Position A
Position B
Position C

Sampling oscilloscope
Detection circuit

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Spectrum by Simple Pulse Pump

Spectrums at all positions (pulse light only)

Brillouin Frequency shift (GHz)

SBS (dB)

Position A  
Position B  
Position C

Sampling interval: 10 MHz
Spectrum by Pulse PrePump

Sampling interval: 10 MHz

Spectrums at all positions (step pulse light)

- Position A
- Position B
- Position C

Brillouin Frequency shift (GHz)

SBS (dB)
Strain distribution obtained by PPP

Sampling interval: 5 cm

Calculated strain values (from BGS spectrum)
To Achieve request of DPS, High quality signal processing is developed

High quality signals examples

Previous quality signals by NBX-6000
Progress Measured by Repeatability

![Histograms showing frequency distribution of NBX-6000 and NBX-6010 with standard deviations.

- NBX-6000: Standard deviation $\sigma = 10.4 \mu \varepsilon$
- NBX-6010: Standard deviation $\sigma = 2.9 \mu \varepsilon$]
NEUBRESCOPE NBX-6000

Spatial Resolution: less than 10cm
Strain Precision: ±25 με (±0.0025%)
Repeatability: ±15 με (±0.0015%)
Cut edge Technology of PPP-BOTDA NBX-6020:  
2cm Spatial Resolution

Brillouin Spectrums of 1cm space

Neubrescope NBX-6020
### Technical details and comparison

<table>
<thead>
<tr>
<th>Feature</th>
<th>PPP-BOTDA</th>
<th>conventional</th>
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</thead>
<tbody>
<tr>
<td>Spatial resolution</td>
<td>10cm</td>
<td>1m</td>
</tr>
<tr>
<td>Max. available measurement distance</td>
<td>10cm resolution</td>
<td>1km</td>
</tr>
<tr>
<td></td>
<td>1m resolution</td>
<td>30km</td>
</tr>
<tr>
<td>Strain accuracy</td>
<td>25 με</td>
<td>Approx. 100 με</td>
</tr>
<tr>
<td>Temperature accuracy</td>
<td>0.6°C</td>
<td>1°C</td>
</tr>
<tr>
<td>Measurement time</td>
<td>3min</td>
<td>2min</td>
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<tr>
<td>Repeatability</td>
<td>10 με</td>
<td>50 με ?</td>
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</table>

### Measurement distance vs. resolution

<table>
<thead>
<tr>
<th>Resolution (cm)</th>
<th>10</th>
<th>20</th>
<th>30</th>
<th>50</th>
<th>100</th>
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</thead>
<tbody>
<tr>
<td>Pulse time (ns)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>measurement distance (km)</td>
<td>1</td>
<td>5</td>
<td>10</td>
<td>20</td>
<td>30</td>
</tr>
</tbody>
</table>
NeubreScope NBX-6000 Series

=> High resolution and High accuracy and High Speed
=> Strain/Temperature/Pressure combine

High resolution and High accuracy and High Speed

Strain/Temperature/Pressure combine

Hi Resolution

Hi Precision

Commercial available use

PPP–BOTDA

Hi Resolution

Hi Precision

Next generation

NBX–6100
PPP–v2

R&D

Hi Resolution

Hi Precision

Commercial available use

PPP–BOTDA

Hi Resolution

Hi Precision

Commercial available use

PPP–BOTDA

Hi Resolution

Hi Precision
Temperature changes during operation
Mechanical strain changes during operation without thermal effect
Neubrex Solution
A full SM FO system for smart structure

Submarine cable
Horiguchi et al, NTT (1989)
• SP ~ 100m
• Desktop System

First Generation

Application to Civil engineering
• SP ~ 1m
• Portable
• Strain Precision 100με

Second Generation

Application to metal structures
2ns for 5km
NEUBRESCOPE
NEUBRESTATION
NEUBREGATE
• SP < 10cm
• Strain Precision < 10με
• Structural Health Monitoring system

Third Generation

Give you a feel
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