Distributed Strain and Temperature Sensor

OZ Optics Limited

September 2024

shop.ozoptics.com
www.ozoptics.com

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OZ OPTICS LIMITED

OZ Optics

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Company Background

- **Founded in 1985**
- **Corporate Headquarter Located in Ottawa, Canada**
- **Manufacturing Facility in Ottawa / Canada, Izmir / Türkiye and Jiaxing / China**
- **Ten Product Groups:**
  - Laser-to-Fiber Delivery Systems
  - High Power Fiber Optic Components
  - Polarization Maintaining Products
  - Attenuators
  - Opto-Electronic Packaging
  - Fiber Optic Test Equipment
  - Fiber Optic Sensor Systems
  - Fiber Optics Components for Gyroscope
  - OCT
  - BioPhotonics
  - Quantum
- **Sales Offices in Canada, USA, Europe, Türkiye and China**

Ottawa, Canada

Izmir, Türkiye

Jiaxing, China

Corporate Statements and Quality Policy

Our Vision

- Capture and expand market share
- Be the preferred supplier of choice
- Maximize shareholder value

Our Mission

To become the leading provider of innovative optical products to telecom and non-telecom sectors

Our Core Values

- Leadership
- Teamwork
- Boldness
- Commitments
- Innovation
- Rewards

Our Quality Policy

Provide our Customers with a competitive advantage, leveraging performance, price and delivery, through a continuous process of Quality advancement in all areas of our Company.

Communicate effectively to our Customers, Suppliers and Shareholders our commitment to Quality, continuous improvement and to abide by any applicable requirements.

Promote opportunities of professional development for all members of our company through education, training and personal challenge.

Company Profile

Over 467 employees worldwide

OZ Canada

243+
Employees

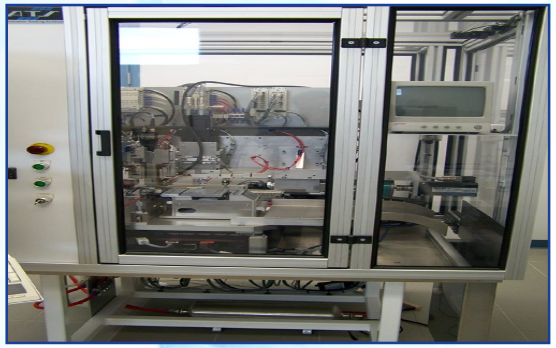
OZ China

87+
Employees

OZ Türkiye

137+
Employees

Company Profile



Advanced Proprietary Processing Technology

Canada
Certificate: FM 63463

China
Certificate: FM 577647

Turkey
Certificate: FM 601414

ISO9001:2015 Certified

Broad Patent Portfolio

Company Profile

OZ Optics is Lead by an Experienced Team:

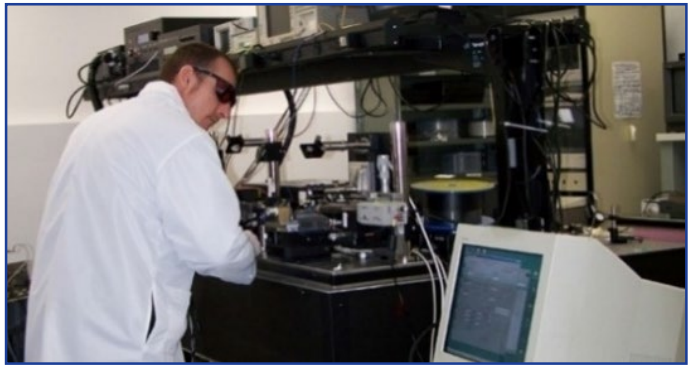
- **Ömür Sezerman, Chairman, President & CEO**
  - Founder and CEO since inception (40 years)
- **Zahide Sezerman, VP of Human Resources**
  - With OZ Optics since inception (40 years)
- **Garland Best, VP of Components Division**
  - 33 years at OZ Optics
- **Gordon Youle, VP of Test Equipment Division**
  - 26 years at OZ Optics
- **Saeed Pilevar, Senior VP of Business Development**
  - 3 months at OZ Optics
- **Onur Koca, General Manager of OZ Türkiye**
  - 3 year at OZ Optics
- **Bing Li, General Manager of OZ Optics China**
  - 21 years at OZ Optics

Company Profile

Experienced and Well-Trained Staff in Following Fields: Optical, Mechanical, Electronics & Software

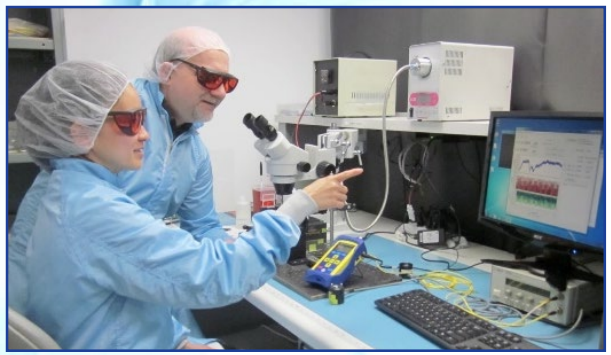
CNC Machine Shop

Femto-Second Laser Lab

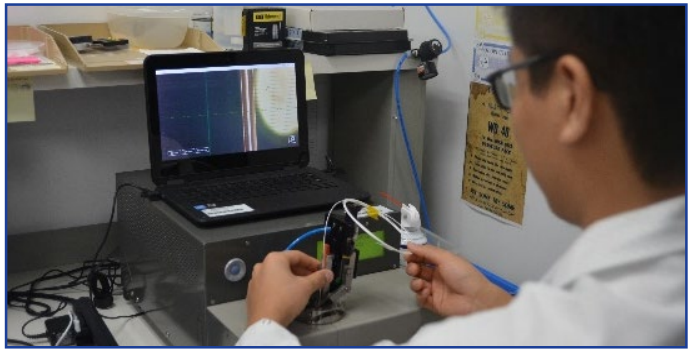


AR Coating

Clean Room



Laser Conditioning / Cleaving

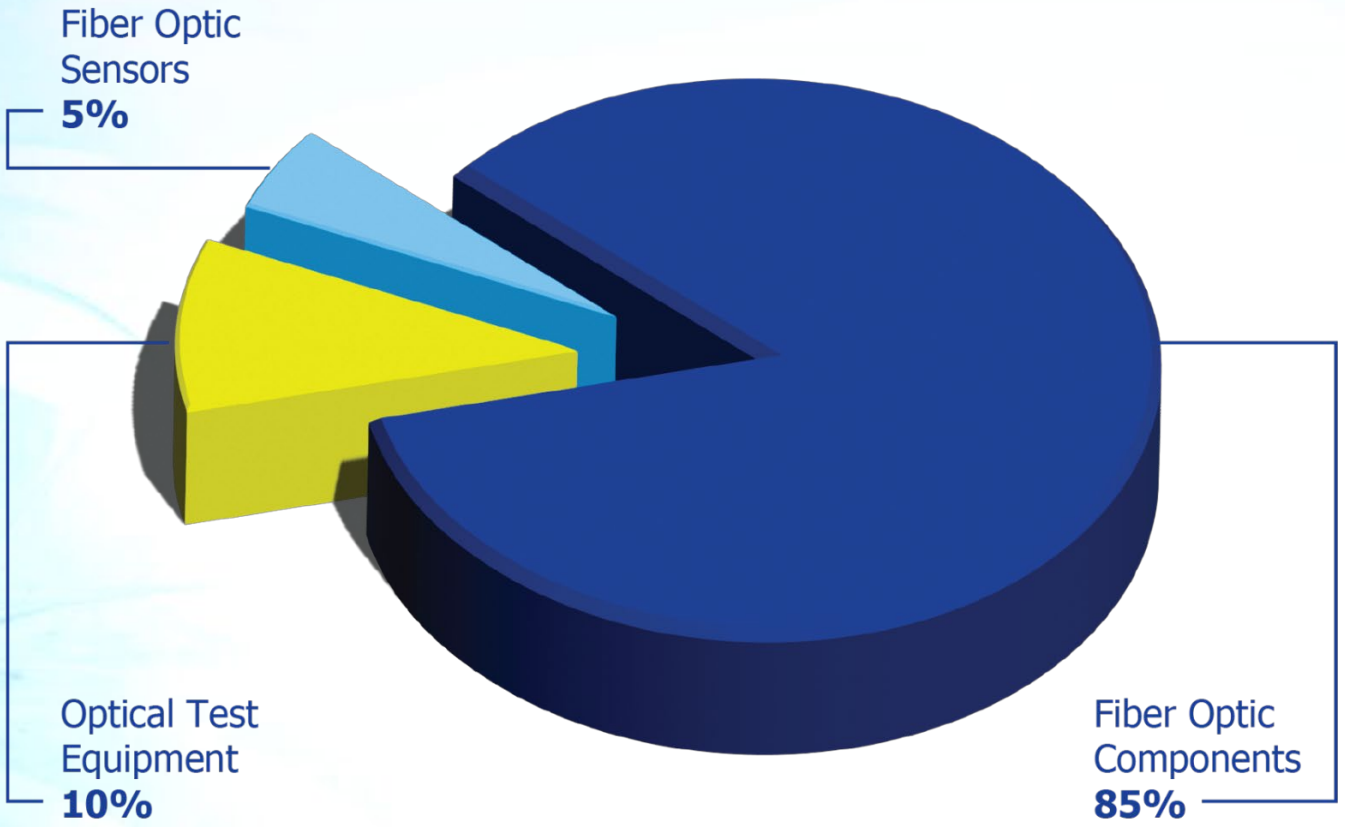


Core Competencies

- Pioneer in Polarization Maintaining (PM) Components & Custom Test Equipment, Including Polarization Test Equipment and FTTH Equipment
- Leader in Wavelength Flattened,
  High Power & Low PDL Components
- Leader in High Power Fiber Optic Delivery Systems
- Widest Range in Attenuator Product Offering
- Fiber Optic Distributed Strain and Temperature Sensors
- Complete product line for OCT, Gyroscope
  & BioPhotonics applications & 2 Micron
- Now available: Spectrometers and Quantum Light Sources

Leading Technology

Three Product Groups **Over 1,000 Products** **Leading Edge R&D**

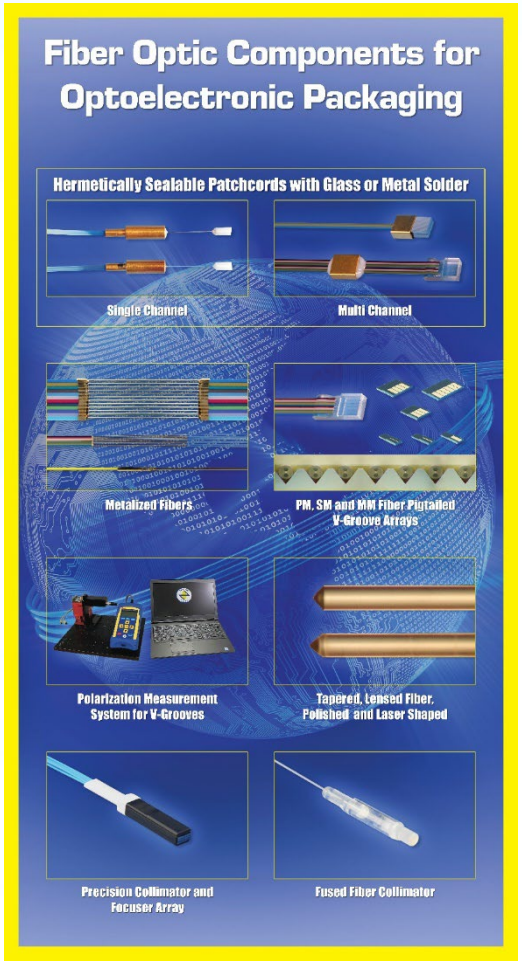


Leading Technology

Featured Products

Leading Technology

Featured Products



Leading Technology

Featured Products

New Fiber Optic Products

Fiber Optic Products for Gyroscopes

Quantum Entangled Photons Sources

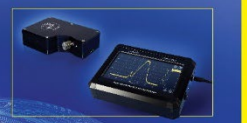
Fiber Optic Products for OCT Applications

Leading Technology

Featured Products

Fiber Optic Products for Biophotonics Applications


Universal Optical DNA Rapid Detection Systems for Pathogens


High-Resolution Optical Spectrometers

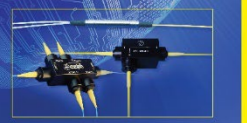

Fiber to Photodiode Couplers with Removable Filters


High and Low Power Patchcords


High Power Laser to Fiber Couplers


Pigtail, Receptacle Style Collimators and Focusers


Fiber Optic U-Bracket Assemblies

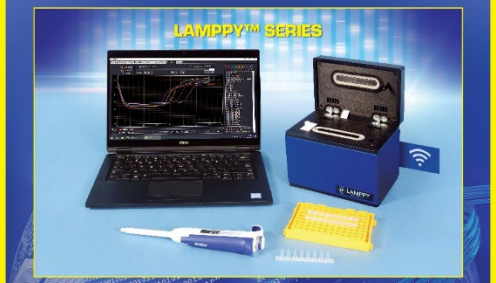

Wavelength Division Multiplexers and Beam Splitters


Turnkey, Ultra Stable Laser Modules


Pocket Optical Power Meter and Detectors

Universal Optical DNA Rapid Detection System

For Pathogens Including:
COVID-19, SARS, EBOLA, CHOLERA, SALMONELLA, ETC.



Features:
- Use to detect viral, fungal, and bacterial DNA/RNA
- Rapid DNA/RNA detection (as little as 20 minutes)
- Highly sensitive and specific detection of low viral levels
- Intuitive software displays real time data during testing
- Melt analysis available with the included software
- Lid heater prevents evaporation and condensation
- Compact modular design allows for easy cleaning and maintenance
- Pair with an external battery for a portable and field-deployable system
- Test up to 8 samples simultaneously
  (higher throughput systems with up to 96 samples available upon request)
- Wireless communication with dual-band Wi-Fi and Bluetooth connectivity
- A fraction of the cost of qPCR based systems
- OZ Optics also offers private labelling for volume OEM applications

In a lab study done at Acibadem University using saliva samples taken from patients at the Acibadem Hospitals, LAMPPY was compared to a well-known conventional qPCR machine in performance and speed. The comparison study was carried out with a sample size of 262 using the COVIX LAMP-based kit on both instruments and then verified with the KrosQuanT SARS-COV-2 (2019 nCOV) Real Time PCR Diagnostic Kit on a leading brand conventional qPCR machine.

Fiber Optic Distributed Strain and Temperature Sensors

USA Patent Numbers: 7499151, 7599047, and 9568307

- BOTDA only, BOTDR only, or both BOTDA and BOTDR modules in one unit
- Fast, dynamic measurement of strain and/or temperature up to 200 km sensing range
- Simultaneous measurement of strain and temperature
- Uses standard telecommunications fibers to minimize costs

Fiber Optic Sensors for Pipeline Monitoring

USA Patent Numbers: 7499151, 7599047, and 9568307

- Pipeline leakage detection
- BOTDA only, BOTDR only, or both BOTDA and BOTDR modules in one unit
- Fast, dynamic measurement of strain and/or temperature up to 200 km sensing range
- Sensitive detection of corrosion / erosion, cracks and buckling
- Simultaneous measurement of strain and temperature
- Uses standard telecommunication fiber to minimize costs


Pipeline Monitoring


Corrosion and Erosion Monitoring


Fire Detection

Leading Technology

Featured Products

Fiber Optic Sensors for Fire Detection

USA Patent Numbers: 7499151, 7599047, and 9568307

- BOTDA only, BOTDR only, or both BOTDA and BOTDR modules in one unit
- Simultaneous measurement of strain and temperature
- Fast, dynamic measurement of strain and/or temperature up to 200 km sensing range
- Uses standard telecommunications fiber to minimize costs

Fiber Optic Sensors for Bridges, Dams and Buildings

USA Patent Numbers: 7499151, 7599047, and 9568307

- BOTDA only, BOTDR only, or both BOTDA and BOTDR modules in one unit
- Simultaneous measurement of strain and temperature
- Fast, dynamic measurement of strain and/or temperature up to 200 km sensing range
- Uses standard telecommunications fibers to minimize costs

Bridge Monitoring

Dam Monitoring

Building Fire Detection

Fiber Optic Sensors for Power Line and Smart Power Generator Monitoring

USA Patent Numbers: 7499151, 7599047, and 9568307

- BOTDA only, BOTDR only, or both BOTDA and BOTDR modules in one unit
- Simultaneous measurement of strain and temperature
- Fast, dynamic measurement of strain and/or temperature up to 200 km sensing range
- Uses standard telecommunication fiber to minimize costs

Underground Power Line Monitoring

Power Line Monitoring

Optical Ground Wire (OPGW)

Construction of OPGW

Gas Generator Monitoring

Fiber Optic Sensors for Security Monitoring

USA Patent Numbers: 7499151, 7599047, and 9568307

- BOTDA only, BOTDR only, or both BOTDA and BOTDR modules in one unit
- Simultaneous measurement of strain and temperature
- Fast, dynamic measurement of strain and/or temperature up to 200 km sensing range
- Uses standard telecommunication fiber to minimize costs

Border Security Monitoring

Highway Health Monitoring

Industry Standards

All Products Manufactured are in Strict Accordance with International Industry Standards:

- ISO 9001:2015 Certified (Canada, China and Türkiye)
- REACH Compliance
- RoHS Compliance
- CE Compliance
- Telecordia Compliance
- Controlled Goods Directorate Registered
- Critical Supplier for F35 and F18 Project
- TSCA (Toxic Substance Control Act) Compliance
- CHEMSHERPA Compliance
- IEC 61010 Compliance

Marketing Strategy

Application Market

Using our strong direct sales and distributors, we address the following markets:

- Energy – Oil and Gas
- Military and Homeland Security
- Educational
- Industrial
- Telecom / Datacom
- Medical & Pharmaceutical

Marketing Strategy

Application Market

By leveraging the technology and expertise gained since its inception, OZ Optics has attracted a broad range of customers in the telecom / datacom, medical, military, security, industrial, construction, aerospace, power utilities, petrochemical and educational sectors.

Marketing Strategy

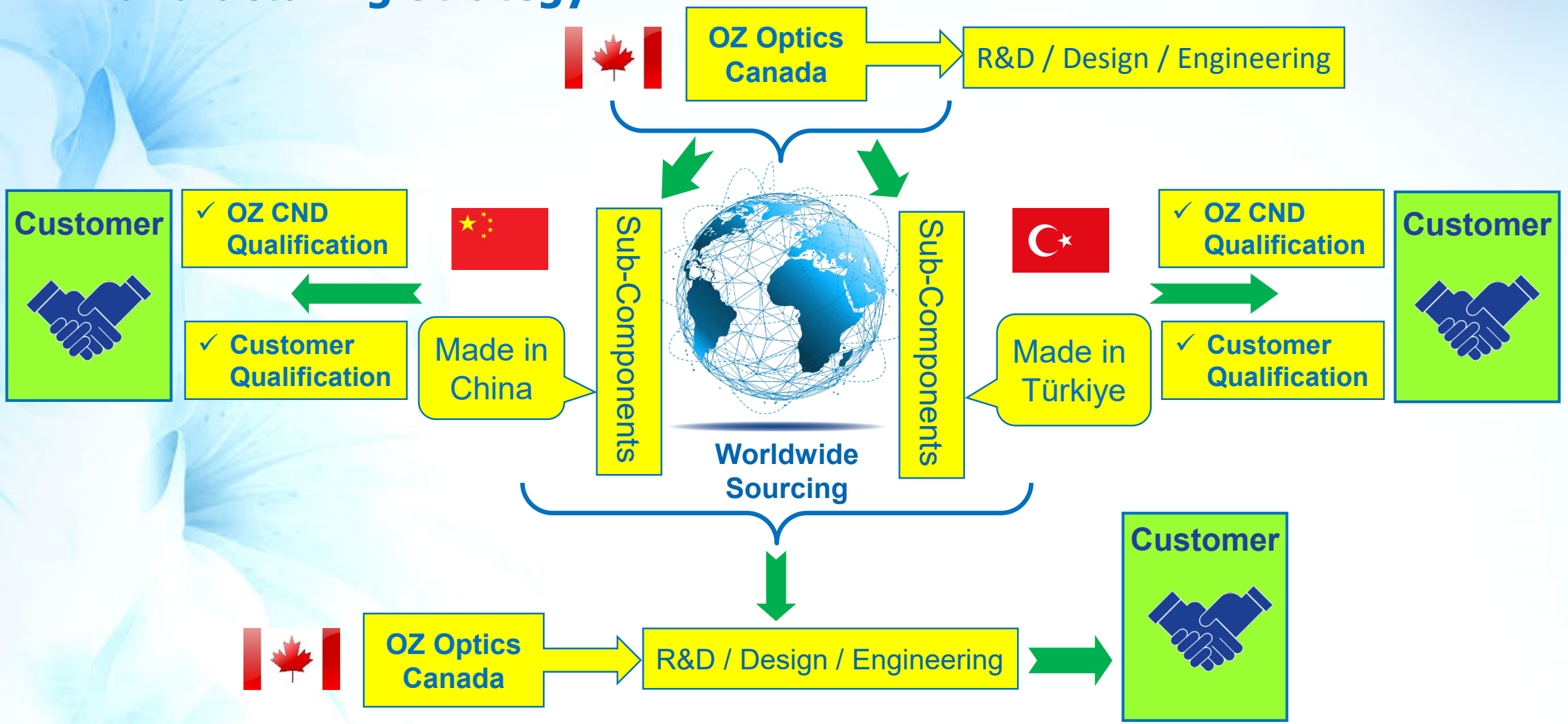
Global Sales Network

OZ Optics has resellers and distributors in over 30 Countries and Regions with over 10,000 customers worldwide:

- Austria
- Belgium
- Brazil
- Canada
- China
- Denmark
- France
- Germany
- Greece
- Hong Kong
- India
- Ireland
- Italy
- Japan
- Luxembourg
- Netherlands
- Norway
- Poland
- Portugal
- Singapore
- South Korea
- Sweden
- Switzerland
- Taiwan
- Thailand
- Türkiye
- United Kingdom
- United States

Operation Strategy

Manufacturing Strategy



Marketing & Operation Strategy

Competitive Advantage

- Superior Technology
  Innovative Engineering
- Competitive Pricing
- Global Presence
- Extensive Experience
  In Fiber Optics Manufacturing
- Exceptional Quality and Service

Branch Network

OZ OPTICS CANADA (Headquarters)

OZ OPTICS TÜRKIYE (Türkiye Factory)

OZ OPTICS CHINA (Jiaxing Factory)

Branch Network

Facility - Ottawa Headquarters

- 60,000 sq ft. - Manufacturing and R&D Facilities
- 15,000 sq ft. - Admin, Sales and Marketing
- 15,000 sq ft. - Training and Fitness Facilities

Branch Network

Facility - Ottawa Headquarters

Production Area

Training Centre Building

Meeting Room

Swimming Pool

Branch Network

Facility - Türkiye Factory (Izmir, Türkiye)

- Operational Since 2000
- 33,000 sq ft. Manufacturing Facility
- Located in Free Trade Zone
- Low Tax Rates
- Sub Component Parts Manufacturing
- High Quality Labor
- AR Coating Machine & Clean Room onsite

Branch Network

Facility - China Factory (Jiaxing, China)

- Operational Since June 2010
- Wholly Foreign Owned Enterprise
- Cost Effective Manufacturing
- High Quality Labor
- Supply Chain Integration

Branch Network

Facility - China Factory (Jiaxing, China)

- Located in Economic Development Zone
- 4000+ sq meters - Total Area
  - 500 sq meters – Administration, Sales and Marketing
  - 3500 sq meters – Manufacturing Area
    - √ 500 sq meter – Class 10,000 Clean Room
    - √ 300 sq meter – ESD Working Area

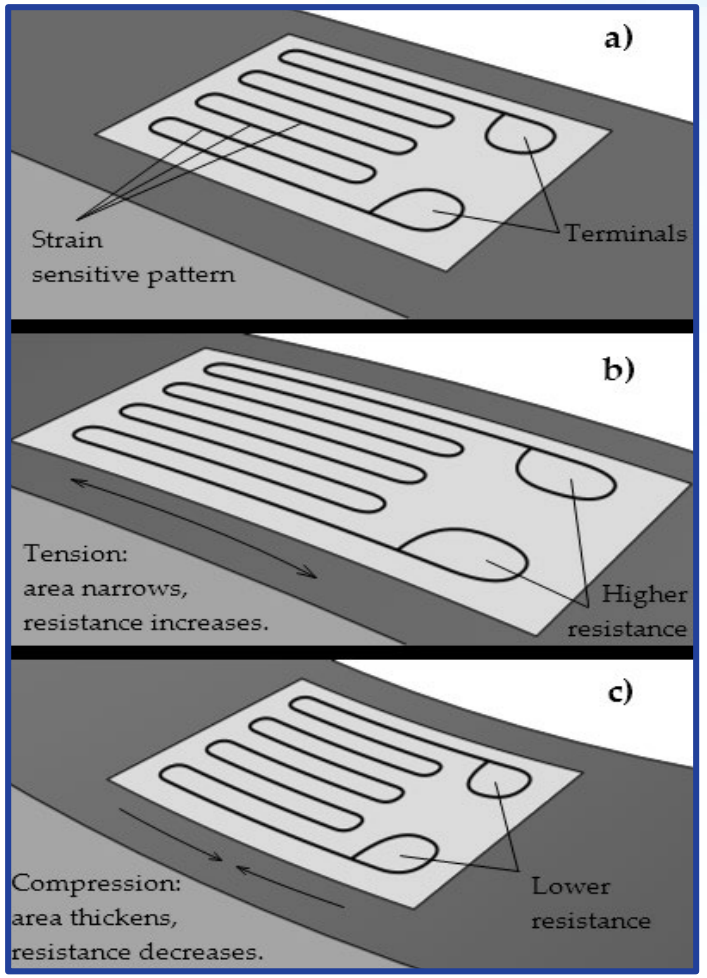
OZ Optics China

Zhejiang OZ Optics Technologies Co., Ltd

- Operational since June 2010
- Wholly Foreign Owned Enterprise
- NPI & Production Line Setup
- On-site Training by OZ CND
- Began Mass Production in September 2010
- Completed Main Facility Expansion in 2019

Conventional Temperature & Strain Sensors

- **Temperature Sensor: Thermocouple**
- **Strain Sensor: Electrical Strain Gauge**
  - Temperature Influence
  - Electromagnetic Interference (EMI)
  - Humidity Influence
  - Point Sensor



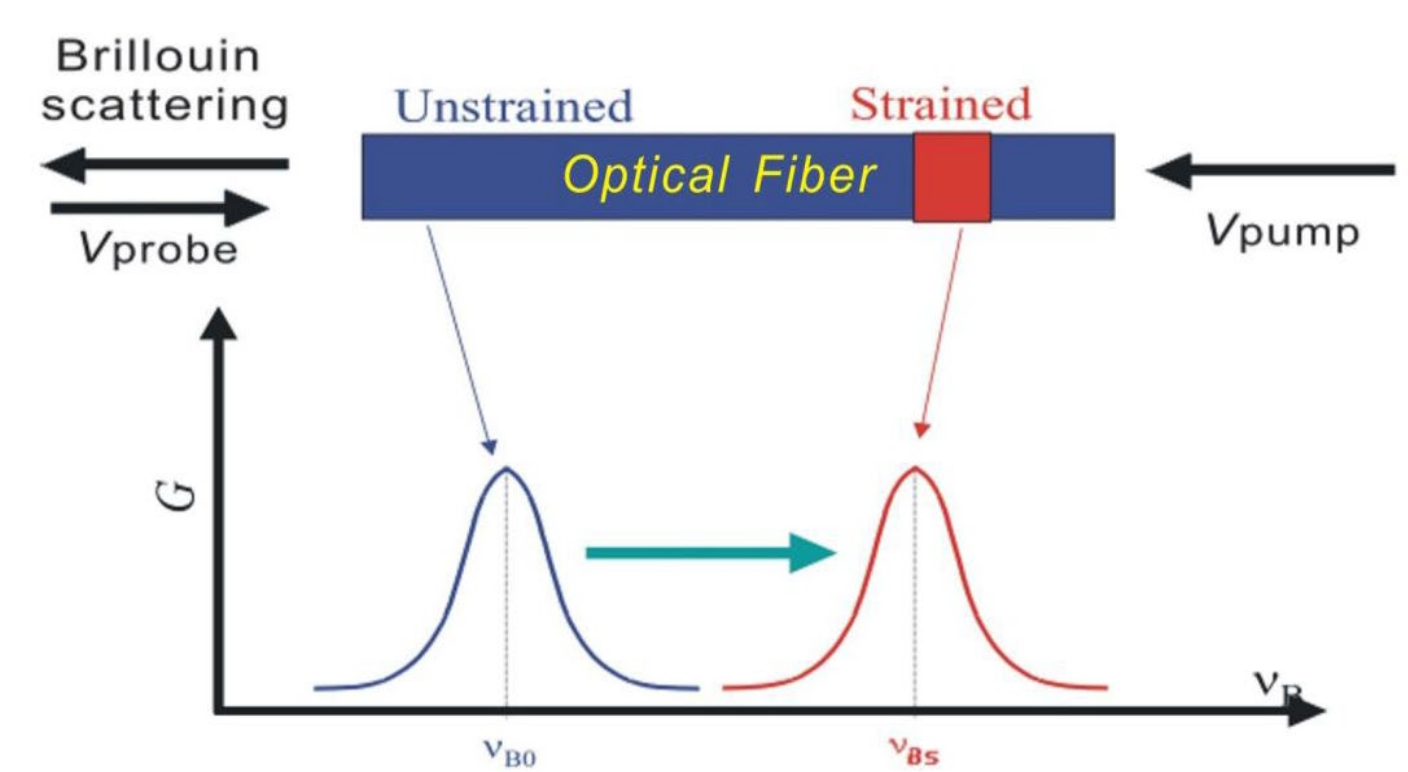
Fiber Optic Sensors

- **Advantages of Fiber Optic Sensors**
  - Electrically insulating materials (no electrical cables are required) — high voltage environments
  - Chemically passive, not subject e.g. to corrosion
  - Immune to electromagnetic interference (EMI)
  - Wide operating temperature range
- **Fiber Bragg Grating Sensor**
  - Strain resolution and accuracy: < 2 με
  - Cannot distinguish strain and temperature
  - Point sensor
- **Distributed Fiber Optic Sensors**
  - Raman scattering based — only temperature
  - Brillouin scattering based — both temperature and strain
  - Rayleigh scattering based — DAS, Luna (70 m long sensing fiber)

Fiber Optic Sensors

- **Fiber Bragg Grating Sensor**
  - Sensor medium: Fiber Bragg grating
  - Laser source and data acquisition system: Spectrum analyzer
- **Distributed Fiber Optic Sensors (Brillouin Sensors)**
  - Sensor medium: Conventional communication fiber (such as SMF, LEAF, etc..)
  - Laser source and data acquisition system: Brillouin sensor system
    - **OZ Optics** [Foresight™ DSTS (Distributed Strain and Temperature Sensors)]
    - **Omnisens** (STA)
    - **Yokogawa** (AQ8603) (Discontinued)
    - **Sensornet** (DTSS)
    - **Neubrex** (Neubrescope)
    - **fibrisTerre** (fTB 2505)
    - **febus**

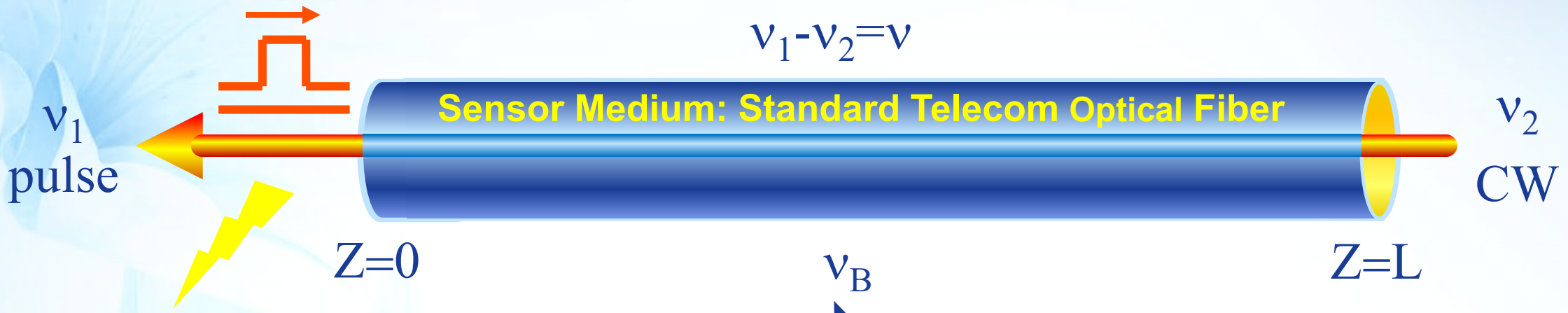
Working Principle — BOTDA



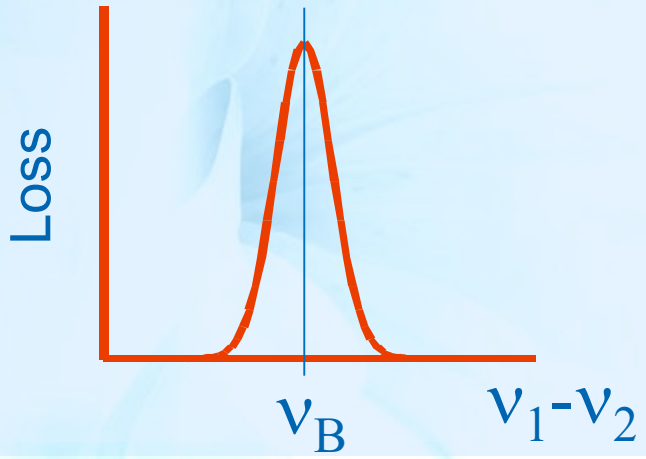
$$\nu_B = \nu_{B0} + C_T(T - T_0) + C_\varepsilon(\varepsilon - \varepsilon_0)$$

T and ε are variables. In order to differentiate these two variables, Brillouin peak in the spectrum is required.

Working Principle — BOTDA



Brillouin Spectrum

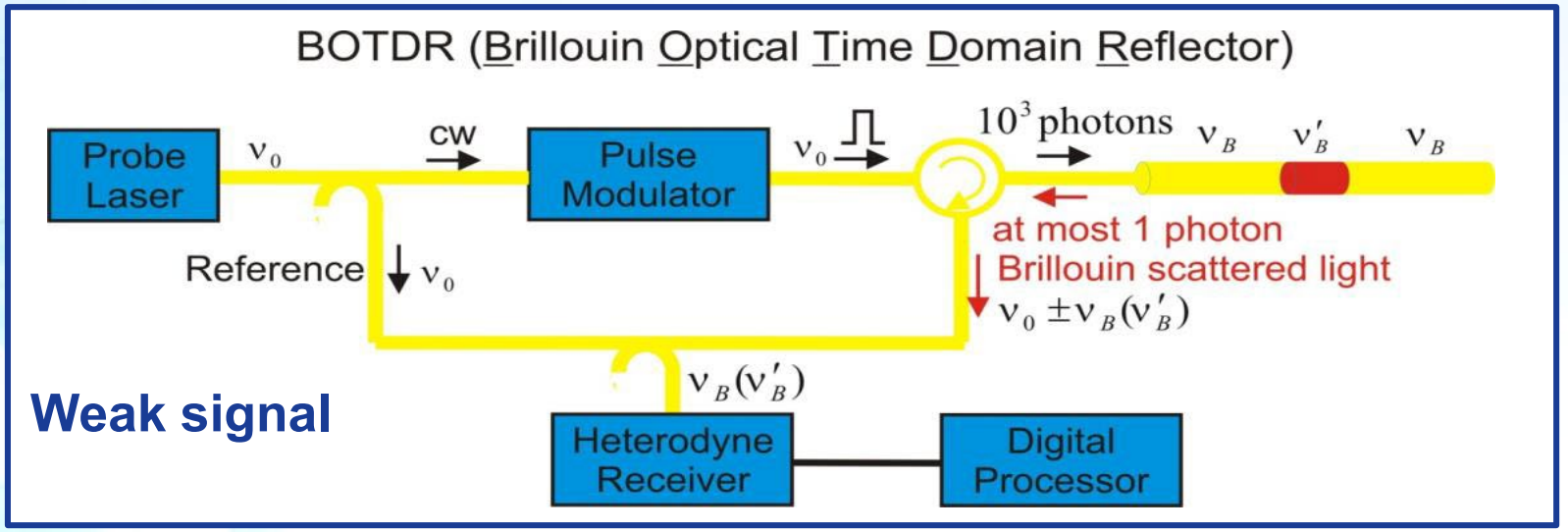


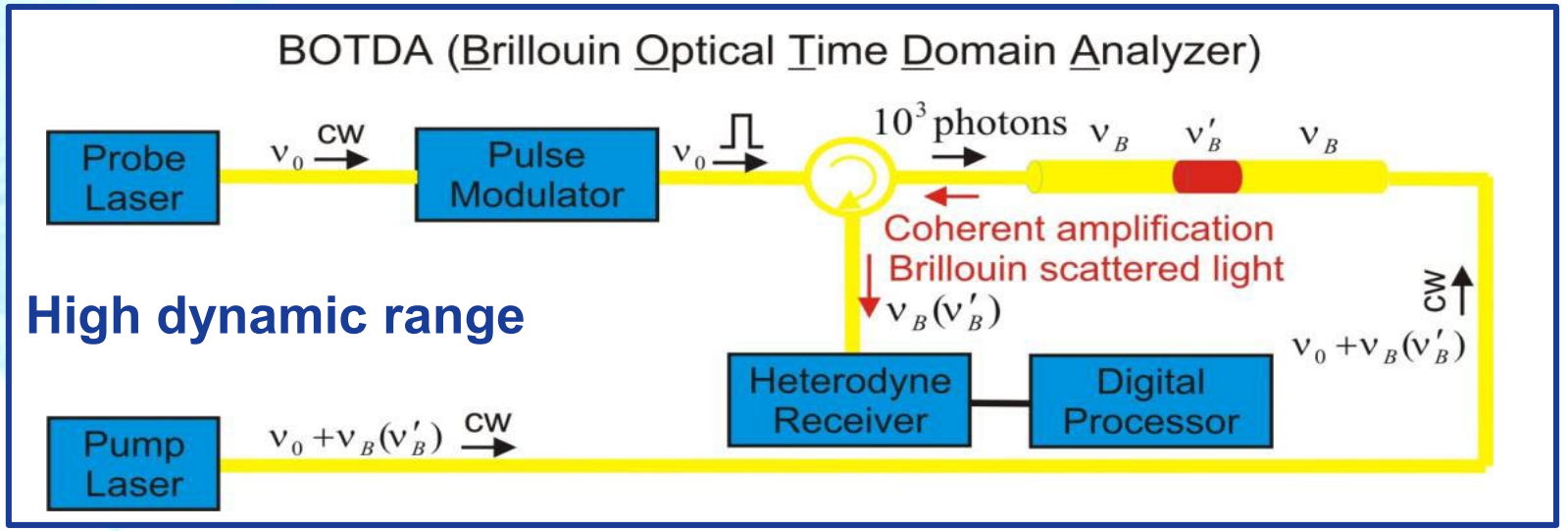
When the beat frequency matches intrinsic Brillouin frequency of the fiber ν_B, we will get maximum of Brillouin spectrum.

ν_B changes linearly with the strain and temperature exerted.

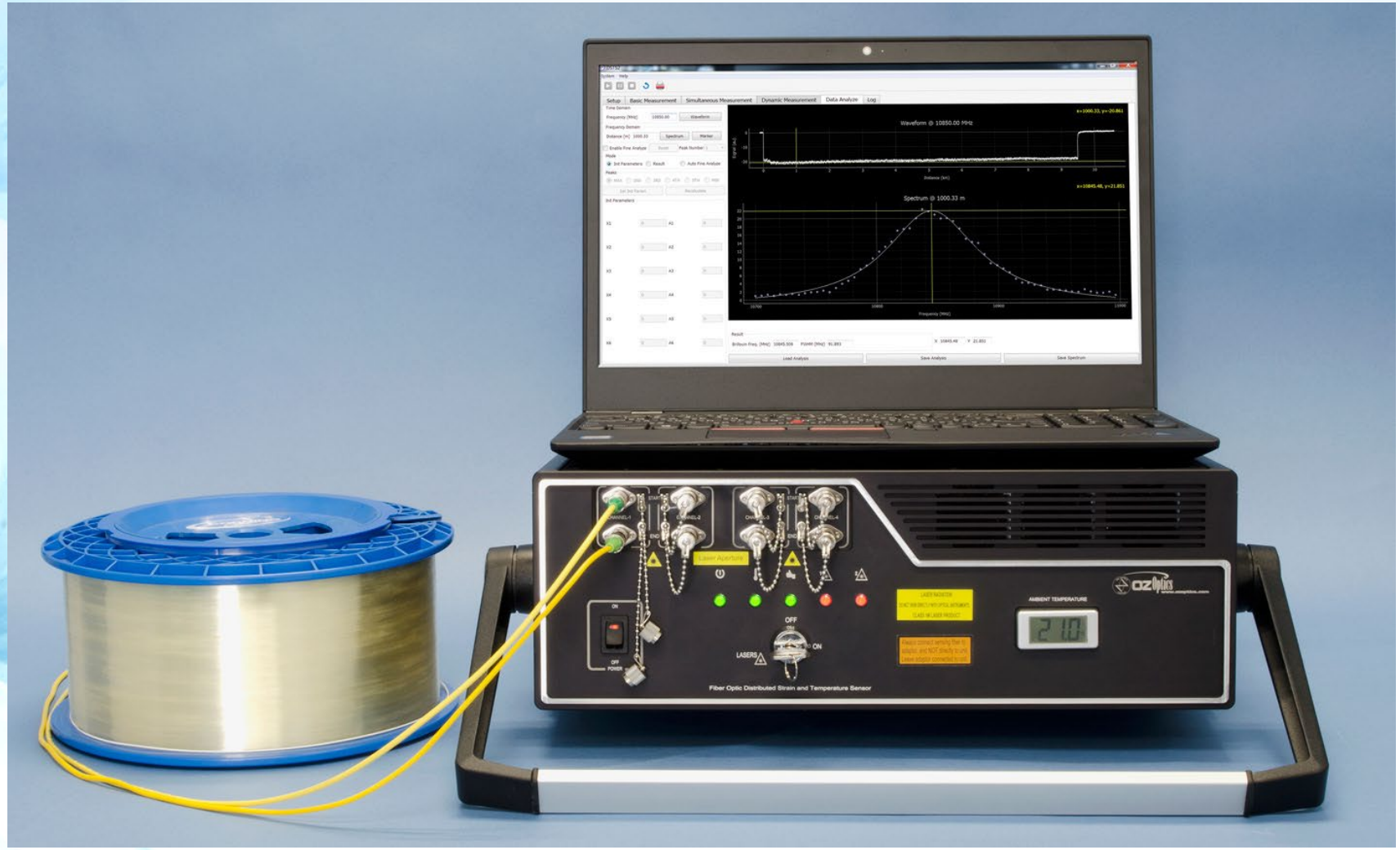
$$\nu_B = \nu_{B0} + C_T(T - T_0) + C_\varepsilon(\varepsilon - \varepsilon_0)$$

Comparison of BOTDR and BOTDA





3U + Laptop, 4 Channel Model



Foresight™ DSTS

Awards & Accolades

Silver Level Winner

FROST & SULLIVAN

2009 BEST PRACTICES AWARD

NORTH AMERICAN FIBER-OPTICS BASED STRUCTURAL HEALTH MONITORING SYSTEMS TECHNOLOGY INNOVATION AWARD

US Patents #: 7499151, 7599047 and 9568307

Merits of DSTS BOTDA

- **Coherent Amplification of Brillouin Scattering Signal**
  ⇒ Longest measured range (200 km fiber length)
- **Narrowest Brillouin Spectrum (~ 45 MHz)**
  ⇒ Highest resolution of strain and temperature
- **Special Low Loss Fiber Components and Electronic Processing**
  ⇒ High stability of system
- **With Proprietary Techniques, Brillouin Frequency Is Extracted Accurately**
  ⇒ Highest accuracy in measuring strain and temperature separately or simultaneously
- **New Technology**
  ⇒ Quick measurement of strain and temperature (as low as 1 second: 1 Hz)

Merits of DSTS BOTDR

- **Low Noise Detection for Weak Spontaneous Brillouin Scattering Signal**
  ⇒ Long measured range (70 km in one direction)
- **Special Low Loss Fiber Components and Electronic Processing**
  ⇒ High stability of system
- **Sophisticated Design**
  ⇒ Small size and light weight

Double End (A) Competitive Analysis

Company	OZ Optics	OmniSens	Neubrex	fibrisTerre
Technology	**BOTDA**	BOTDA	BOTDA	BOFDA
Maximum Sensing Range	**(fiber length up to 200 km)**	60 km (120 km max. total fiber loop distance)	27 km	25km
Channels	**Internal 4** **External 24** **More channels optional**	Internal 4 up to 20 channels via external SO-N Switch module	N/A	N/A
Highest Spatial Resolution / Spatial step (sample interval)	**10 cm[1] / 5 cm**	50 cm / 25 cm	2 cm / 1 cm	50 cm / 5 cm
Dynamic Range at highest spatial resolution	**7 dB**	N/A	0.5 dB	N/A
Strain / Temperature Accuracy (Repeatability)(σ)	**2 με / 0.1 ºC** **(1 m spatial resolution / 2 km fiber / 1 minute 40 seconds)**	2 με / 0.1 ºC (1 m spatial resolution / 2 km fiber / 10 minutes)	7.5με / 0.35 ºC	2 με / 0.1 ºC
Strain / Temperature Resolution	**0.1 με / 0.005 ºC**	2 με / 0.1 ºC	N/A	N/A

Specifications of other vendor's products are based on their public datasheets.

1) Based on scientific definition, the spatial resolution is defined by pulse width. 10ns pulse width is equivalent to 1 m spatial resolution while 1ns pulse width is equivalent to 0.1 m spatial resolution.

Single End (R) Competitive Analysis

Company	OZ Optics	OmniSens	Neubrex	Febus
Technology	**BOTDR**	BOTDR	BOTDR	BOTDR
Channels	**Internal 4 External 24 More channels optional**	Internal 4 up to 20 channels via external SO-N Switch module	N/A	N/A
Maximum Sensing Range	**70 km (max 100 km)**	45 km	27 km	30 km (max 100 km)
Highest Spatial Resolution / Spatial step (sample interval)	**1 m[1] / 5 cm**	1.5 m / 25 cm	0.5 m / 5 cm	1m
Dynamic Range at highest spatial resolution	**10 dB**	10 dB	2 dB	N/A
Strain / Temperature Accuracy (Repeatability) (σ)	**10 με / 0.5 ºC**	20 με / 1 ºC	30 με / 1.5 ºC	10 με / 0.5 ºC
Strain / Temperature Resolution	**0.1με / 0.005 ºC**	2 με / 0.1 ºC	N/A	N/A

Specifications of other vendor's products are based on their public datasheets.

1) Based on scientific definition, the spatial resolution is defined by pulse width. 10ns pulse width is equivalent to 1m spatial resolution while 1 ns pulse width is equivalent to 0.1 m spatial resolution.

Combo Unit Competitive Analysis

Company	OZ Optics		OmniSens		Neubrex	
Technology	**BOTDA**	**BOTDR**	BOTDA	BOTDR	BOTDA	BOTDR
Maximum Sensing Range	**(fiber length up to 160 km)**	**70 km** (max 100 km)	60 km (120 km max. total fiber loop distance)	45 km	27 km	27 km
Channels	**Internal 4 External 24 More channels optional**		Internal 4 up to 20 channels via external SO-N Switch module		N/A	
Highest Spatial Resolution / Spatial step (sample interval)	**10 cm[1] / 5 cm**	**1 m[1] / 5 cm**	50 cm / 25 cm	1.5 m / 25 cm	2 cm / 1 cm	0.5 m / 5 cm
Dynamic Range at highest spatial resolution	**7 dB**	**10 dB**	N/A	N/A	0.5 dB	2 dB
Strain / Temperature Accuracy (Repeatability)(σ)	**2 με / 0.1 ºC** (1 m spatial resolution / 2 km fiber / 1 min 40 secs)	**10 με / 0.5 ºC**	2 με / 0.1 ºC (1 m spatial resolution / 2 km fiber / 10 mins)	20με/1ºC	7.5 με / 0.35 ºC	30 με / 1.5 ºC
Strain / Temperature Resolution	**0.1 με / 0.005 ºC**	**0.1 με / 0.005 ºC**	2 με / 0.1 ºC	2 με / 0.1 ºC	N/A	N/A

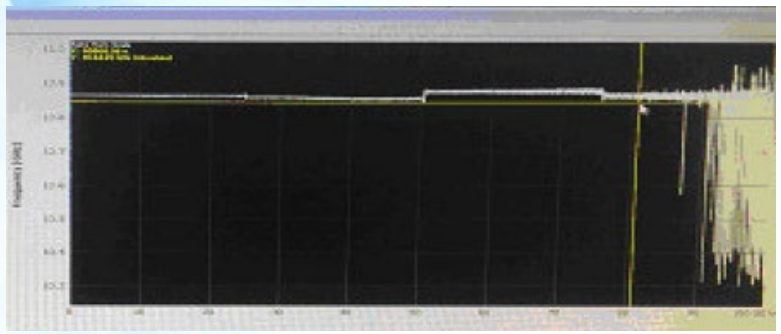
Specifications of other vendor's products are based on their public datasheets.

1) Based on scientific definition, the spatial resolution is defined by pulse width. 10ns pulse width is equivalent to 1m spatial resolution while 1ns pulse width is equivalent to 0.1m spatial resolution.

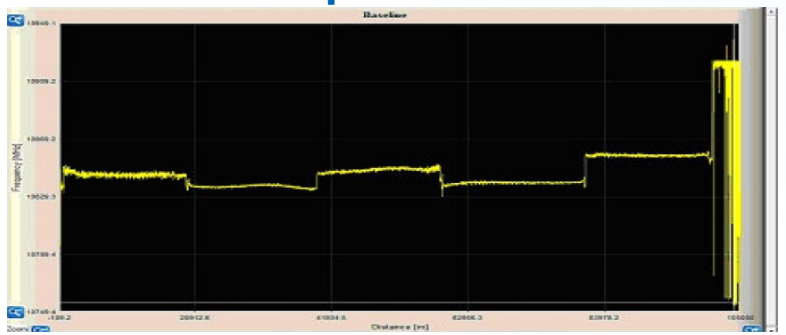
Detailed Comparison Facts

Sensing Range - The Longest Functional Measurement Fiber Length.
Results comparison between OZ unit and other vendor's unit.
Fiber under test is 101km long. Results are displayed below. Same test configurations are applied.

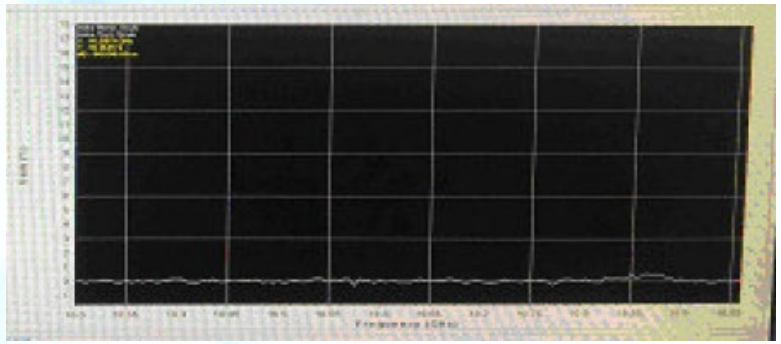
Other Vender



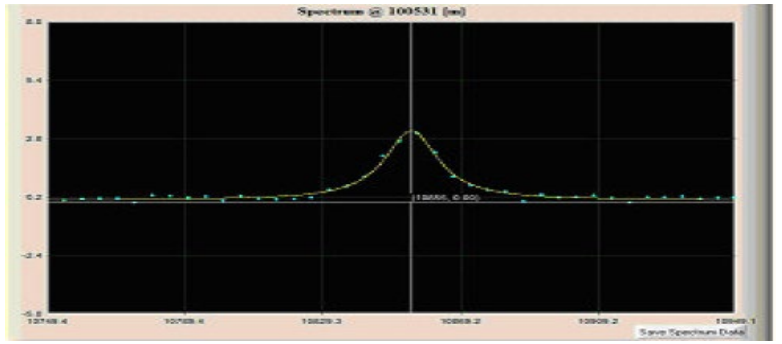
OZ Optics DSTS



Brillouin Center Frequency vs Fiber Length (Full Scale)



Brillouin Spectrum at 80km.
Reasonable Spectrum can be only found at 55km.



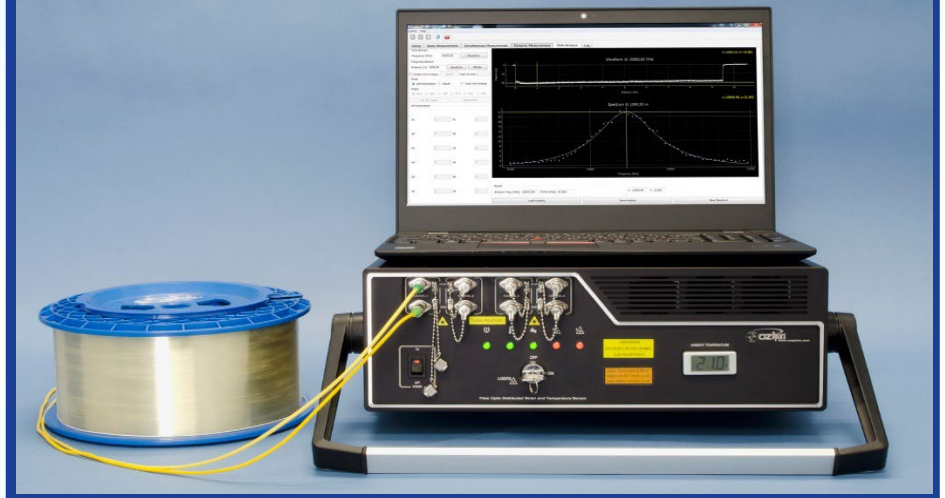
Brillouin Spectrum at 100.5km.

Comparison:
DSTS BOTDA and Raman based DTS

Company	OZ Foresight™ DSTS	Raman based DTS
Max Fiber Length	**200 km round-trip (physical distance 100 km)**	20km (MM)
Fiber Type	**Standard telecom singlemode**	Multimode
Response time @ 20km, 2C Resolution	**30 seconds to 3 minutes**	More than 10 minutes
Configuration	**Single ended or double ended**	Single ended or double ended
Measurement Base and Precision	**Frequency based** **No calibration required after setup** **Not sensitive to attenuation changes**	Intensity based Require calibrations Sensitive to attenuation changes
Dynamic Range	**25-30 dB** Allows better immunity to attenuation Wider measurement range and longer use of installed fiber	3-4 dB May fail when attenuation increases
Measurand	**Temperature and Strain**	Temperature
Measurement Resolutions	**Comparable @ several seconds**	Comparable @ over 1 minute

Competitive Analysis

Sensornet



OZ Optics

Omnisens

Neubrex

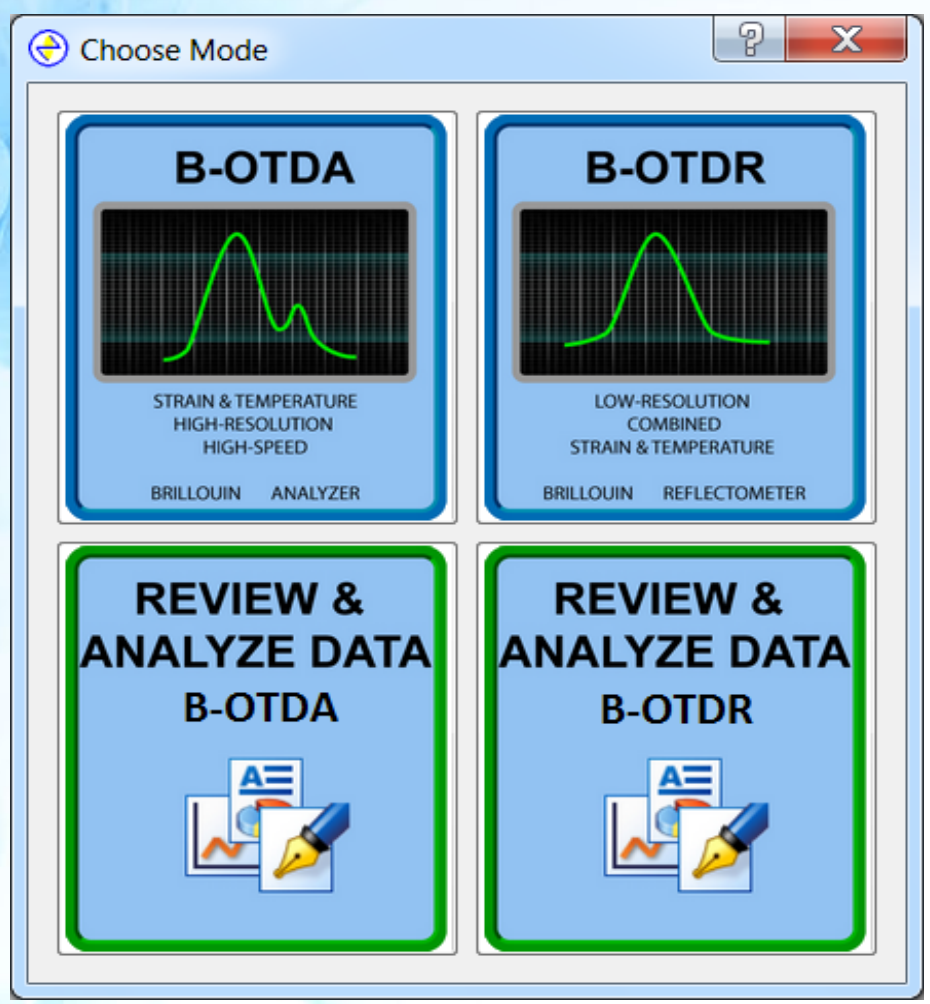
fibrisTerre

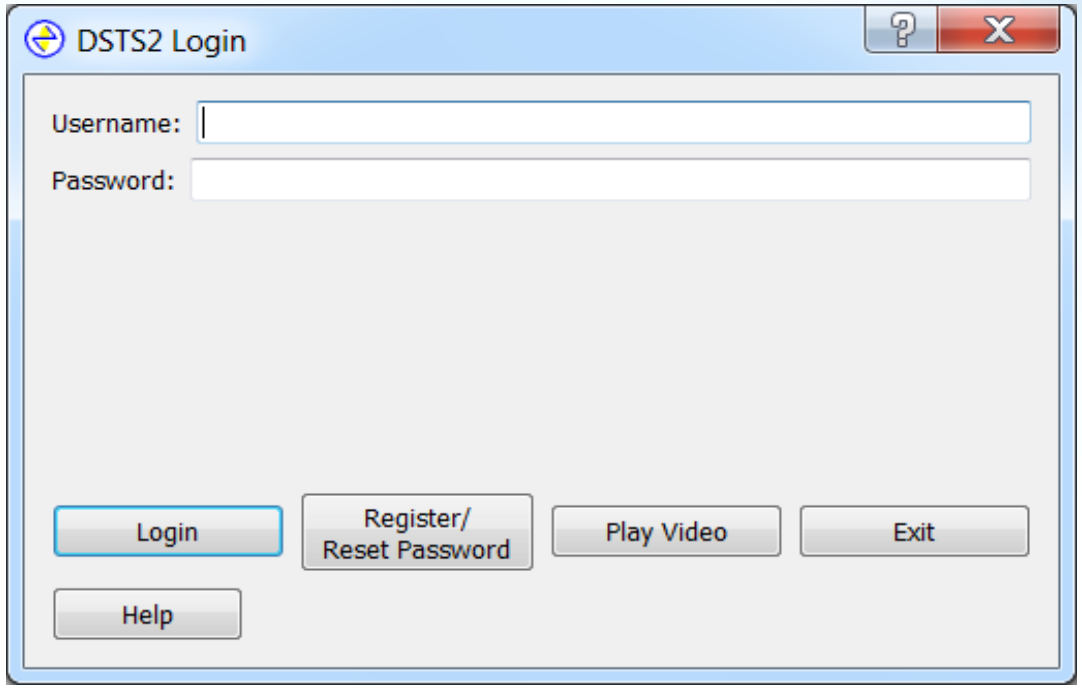
Febus Optics

New Features

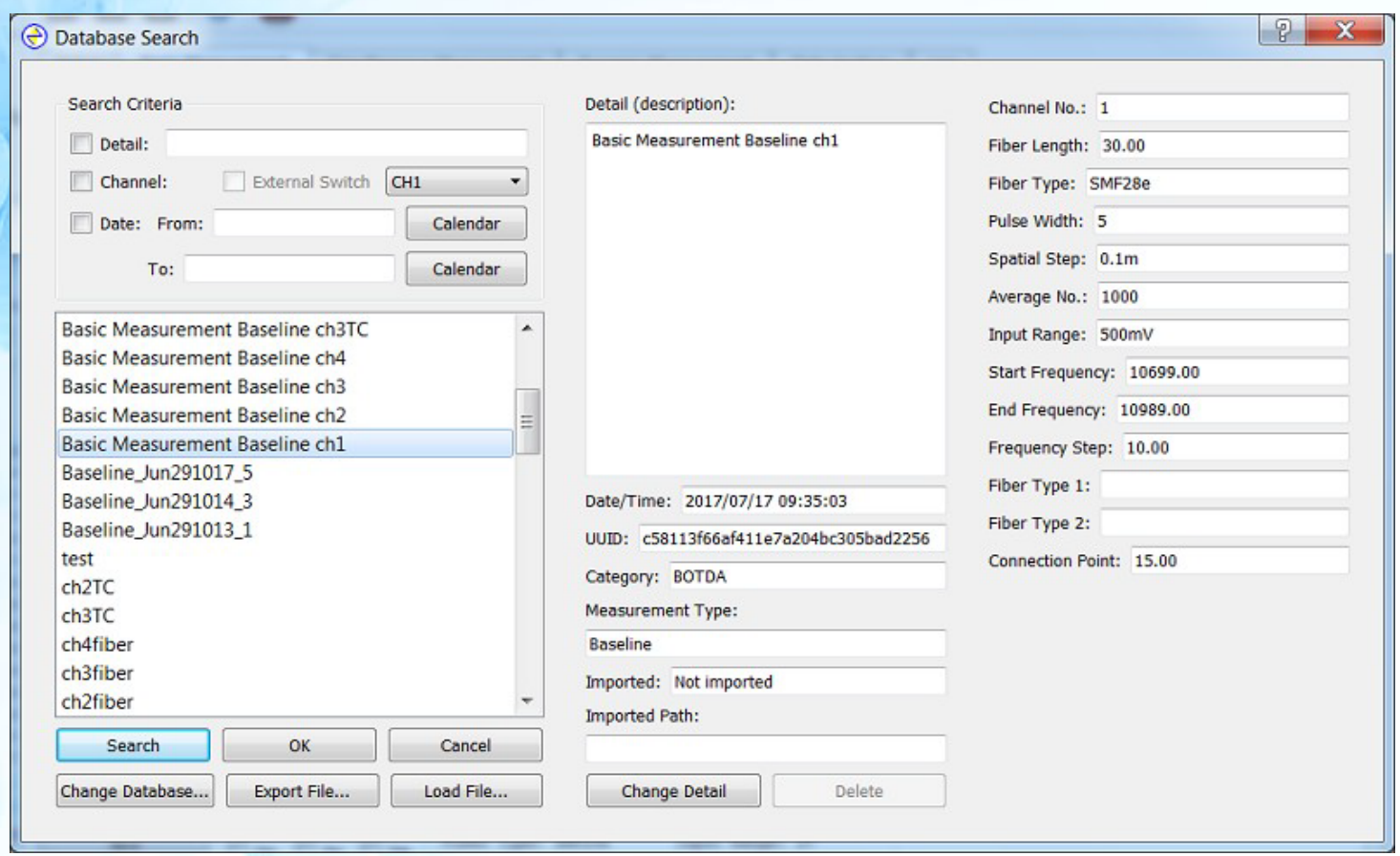
- Switched to only 3U design with laptop computer (1U PC is option only per demand and will increase the overall cost due to limited availability).
- Full DLL Support
- Auto-Recovery from Power Outage
- Auto Channel Switch allows continuous scans between channels. Various switches are available.
- Optional SCADA interface under development and will be available within 2 months.

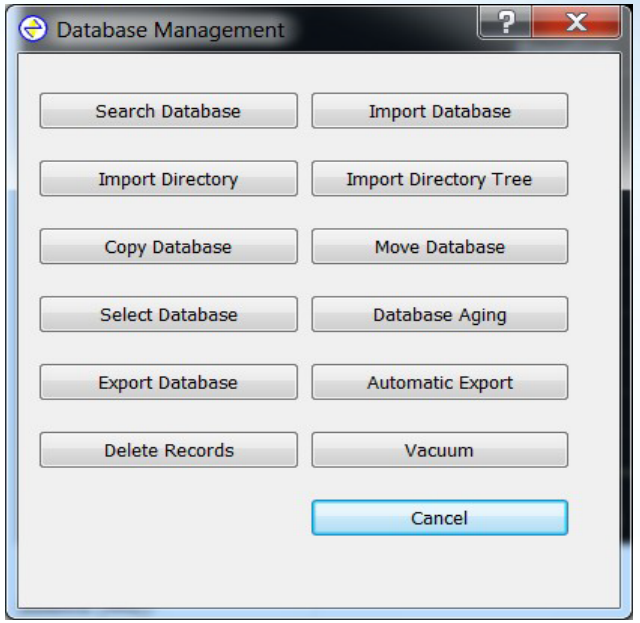
New GUI Login



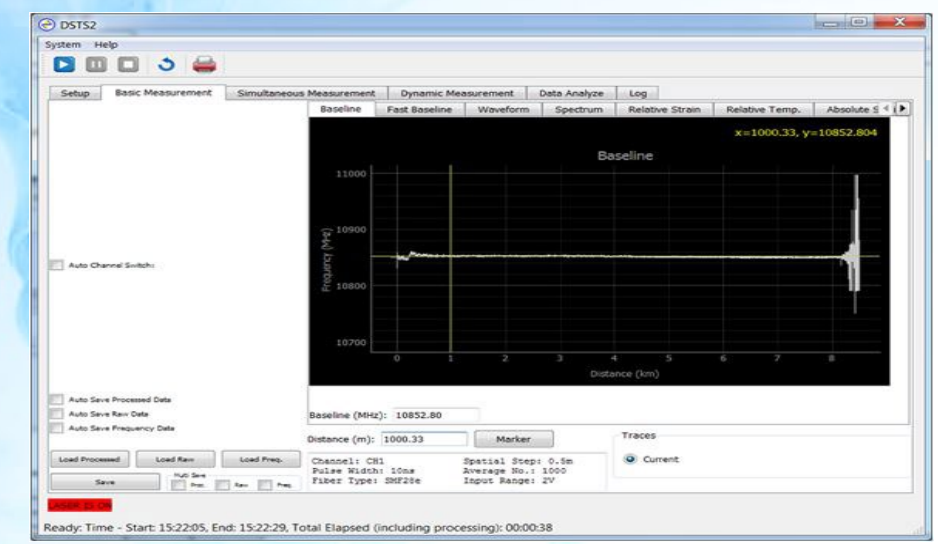


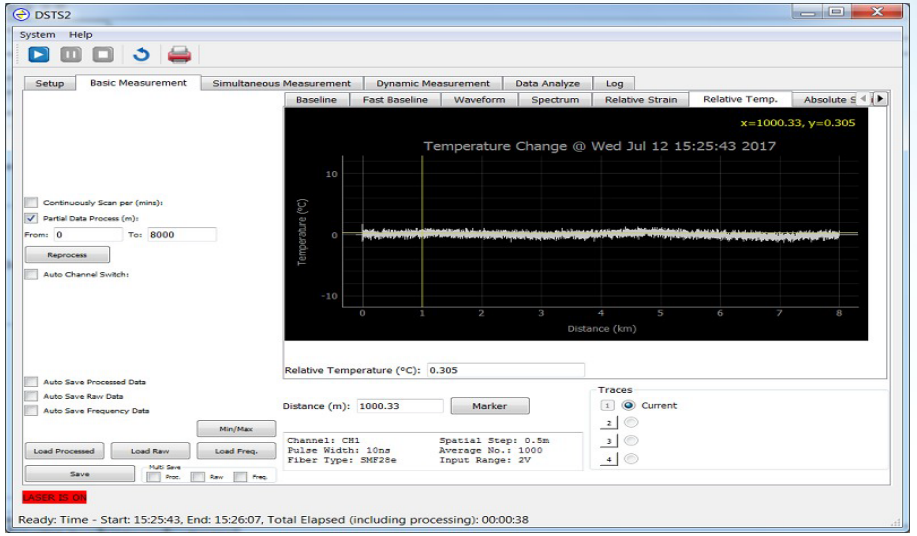
Database

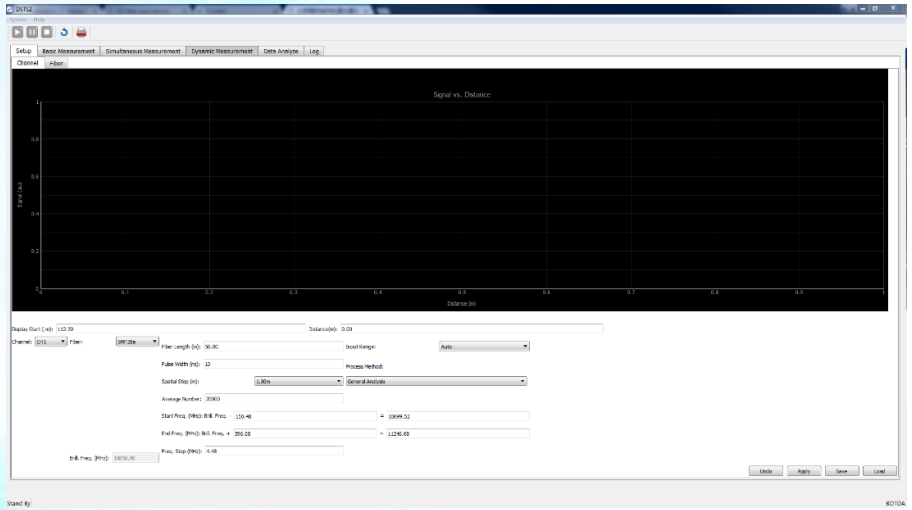

Database Search
Search Criteria
Detail:
Channel:
External Switch
CH1
Date: From:
Calendar
To:
Calendar
Basic Measurement Baseline ch3TC
Basic Measurement Baseline ch4
Basic Measurement Baseline ch3
Basic Measurement Baseline ch2
Basic Measurement Baseline ch1
Baseline_Jun291017_5
Baseline_Jun291014_3
Baseline_Jun291013_1
test
ch2TC
ch3TC
ch4fiber
ch3fiber
ch2fiber
Search
OK
Cancel
Change Database...
Export File...
Load File...
Detail (description):
Basic Measurement Baseline ch1
Date/Time: 2017/07/17 09:35:03
UUID: c58113f66af411e7a204bc305bad2256
Category: BOTDA
Measurement Type:
Baseline
Imported: Not imported
Imported Path:
Change Detail
Delete
Channel No.: 1
Fiber Length: 30.00
Fiber Type: SMF28e
Pulse Width: 5
Spatial Step: 0.1m
Average No.: 1000
Input Range: 500mV
Start Frequency: 10699.00
End Frequency: 10989.00
Frequency Step: 10.00
Fiber Type 1:
Fiber Type 2:
Connection Point: 15.00

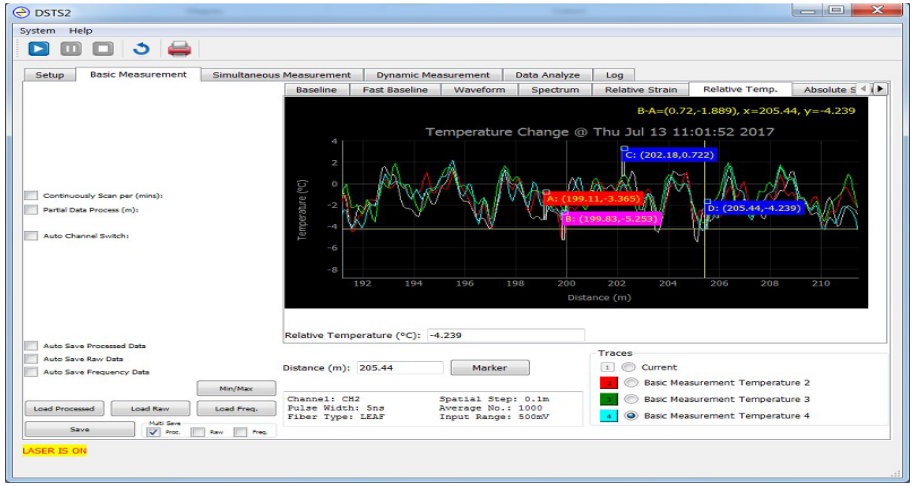

Database Management
Search Database
Import Database
Import Directory
Import Directory Tree
Copy Database
Move Database
Select Database
Database Aging
Export Database
Automatic Export
Delete Records
Vacuum
Cancel

Measurement Screens







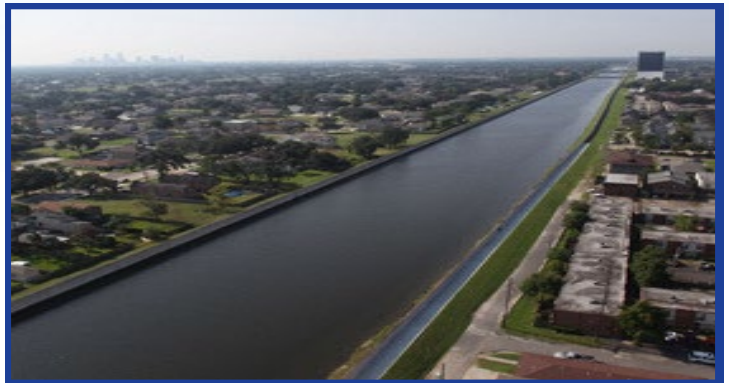


OZ Optics Foresight™ DSTS Benefits

- Reducing Risk and Influence of Failure
  - Fast Response
  - Status Trend in Long Term
  - Full Range of Coverage
- Reducing Operating Expenses
  - No Future Re-Calibration of Unit
  - Expected Cable Life over 20 Years

Applications

Oil and Gas Pipeline Monitoring



Dyke and Levee Monitoring

Power Line Monitoring

Oil and Gas Well Monitoring

Bridge and Building Monitoring

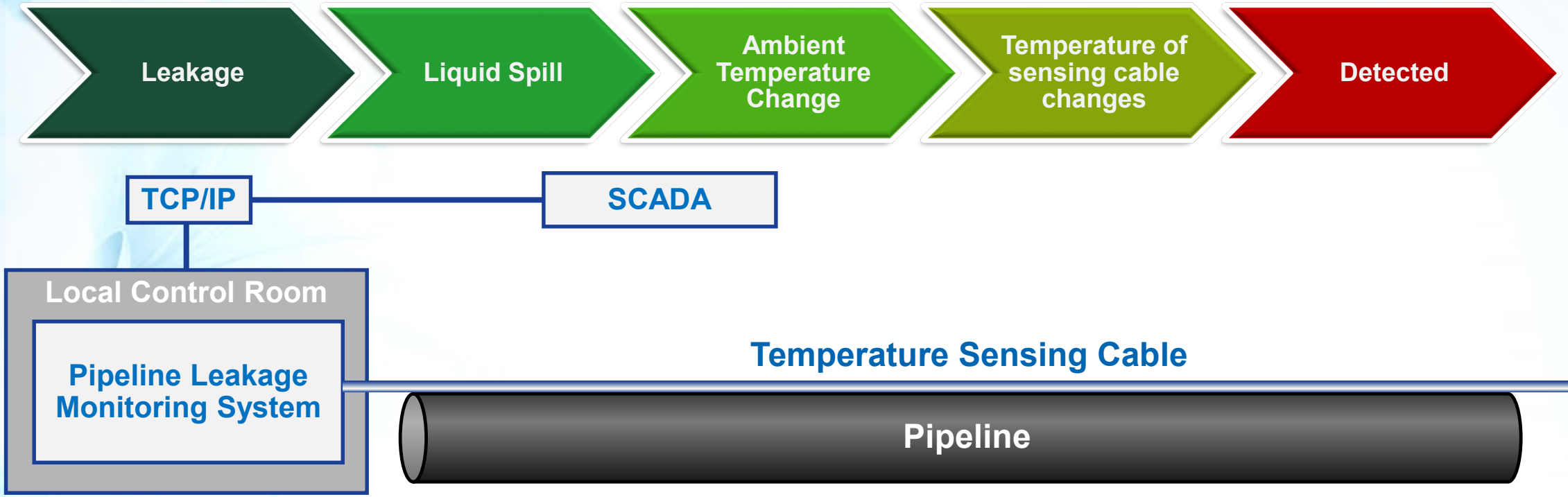
Border Security Monitoring

Oil and Gas

- Pipeline Leakage Monitoring
- Well Integrity Management
- Refinery Temperature Monitoring

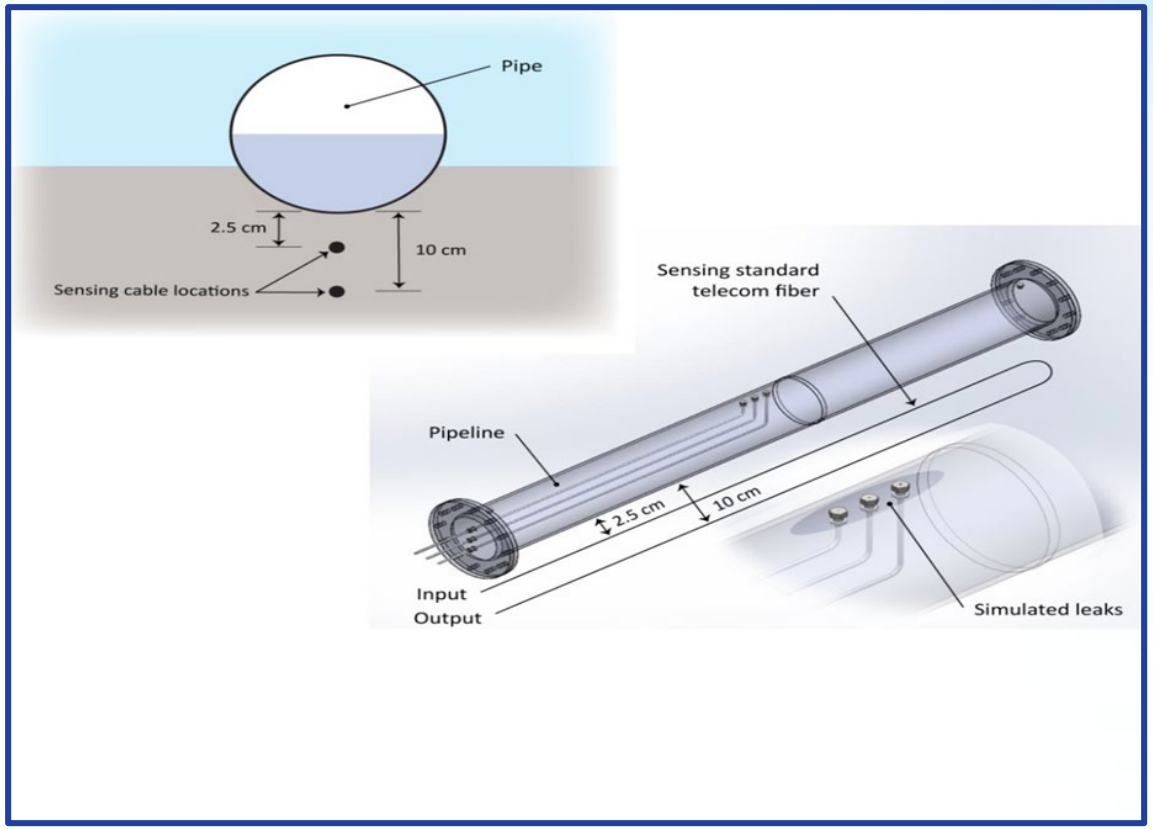
Pipeline Leakage Monitoring System

- Policy Requirement
- Economic Requirement

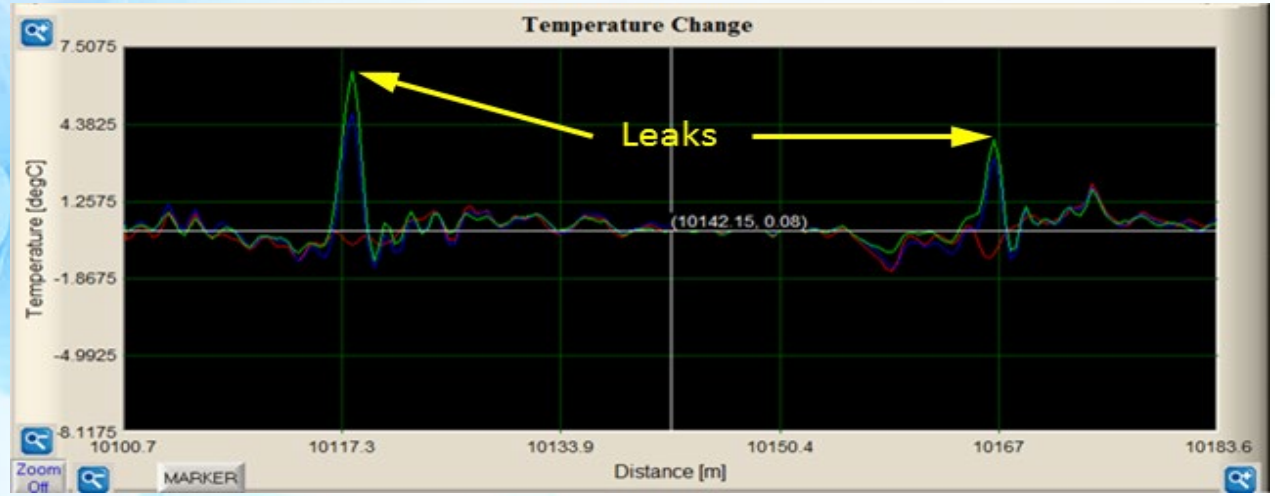


Third Party Evaluation

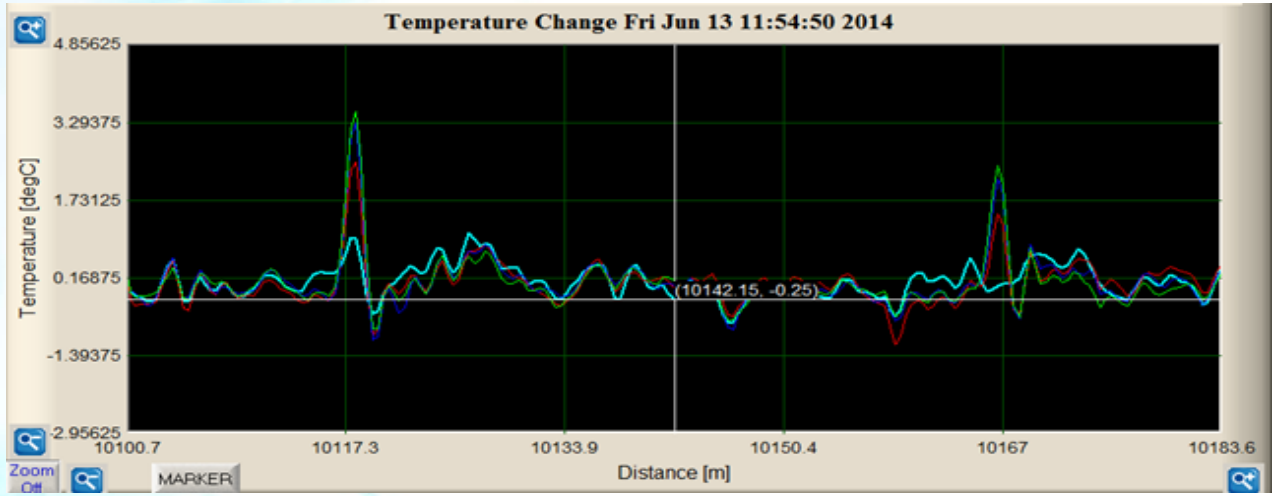
- Leakages from a 1/8” orifice with an injection pressure as low as 22 psi, and a temperature difference of 20°F between the soil and line temperatures, have been easily detected and accurately located.
- An impressive leakage detection response time of less than 2 minutes has been achieved.
- Evaluation was done under laboratory conditions over a period of one month, by Southwest Research Institute (SwRI) and funded by major oil companies through a joint industry program.



Performance

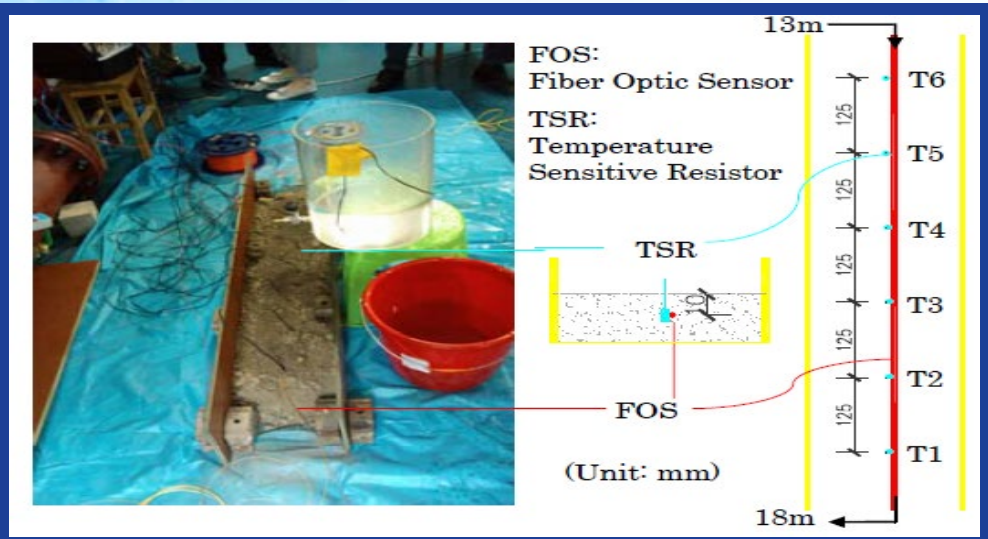


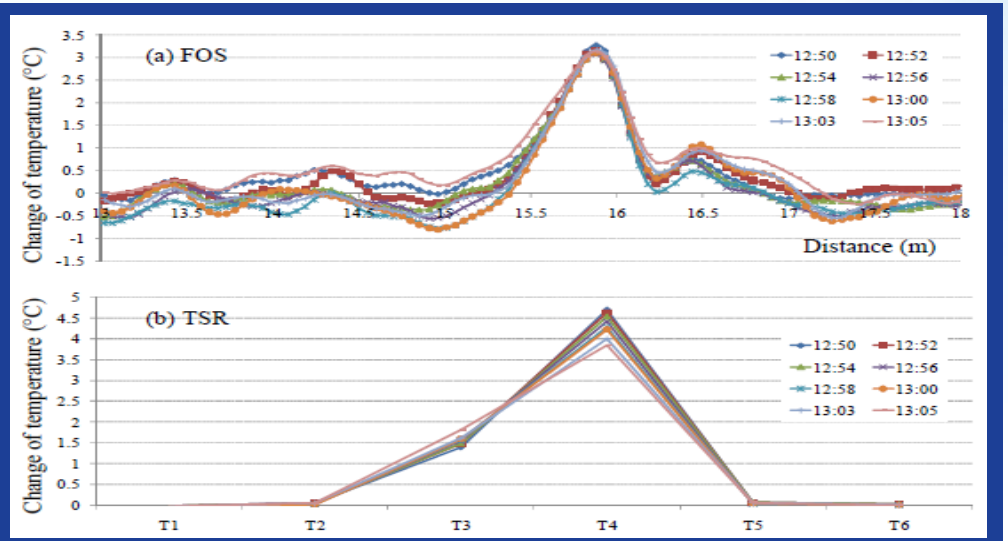
Large leakage detection from 1/8” orifice with 400 psi injection pressure, soil temperature before test: 85°F, line temperature: 115°F

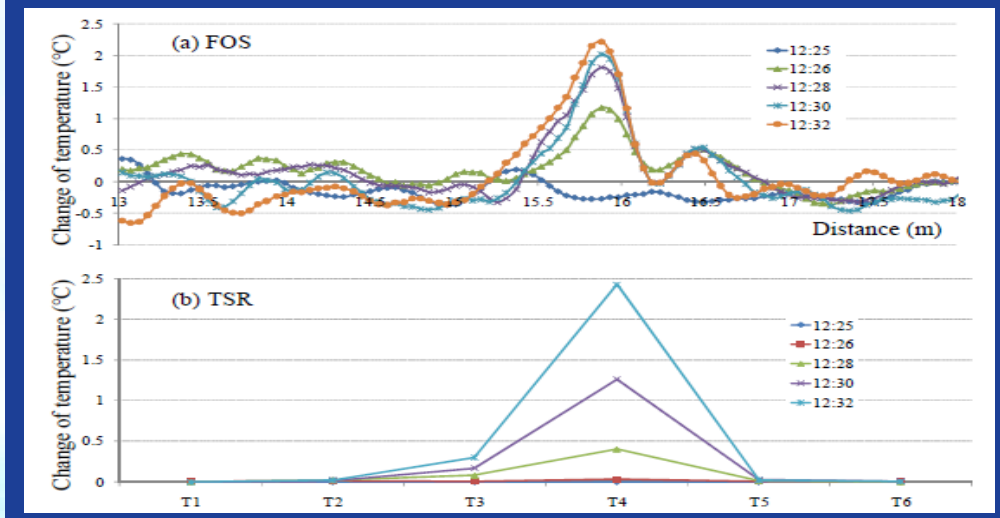


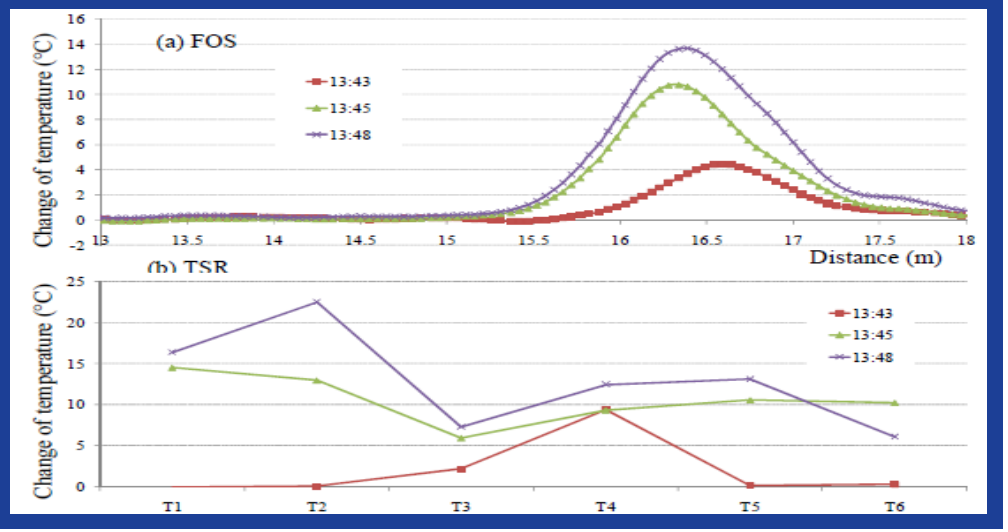
Small leakage detection from 1/8” orifice with 50 psi injection pressure, soil temperature before test: 73°F, line temperature: 90°F

Soil Temperature Monitoring



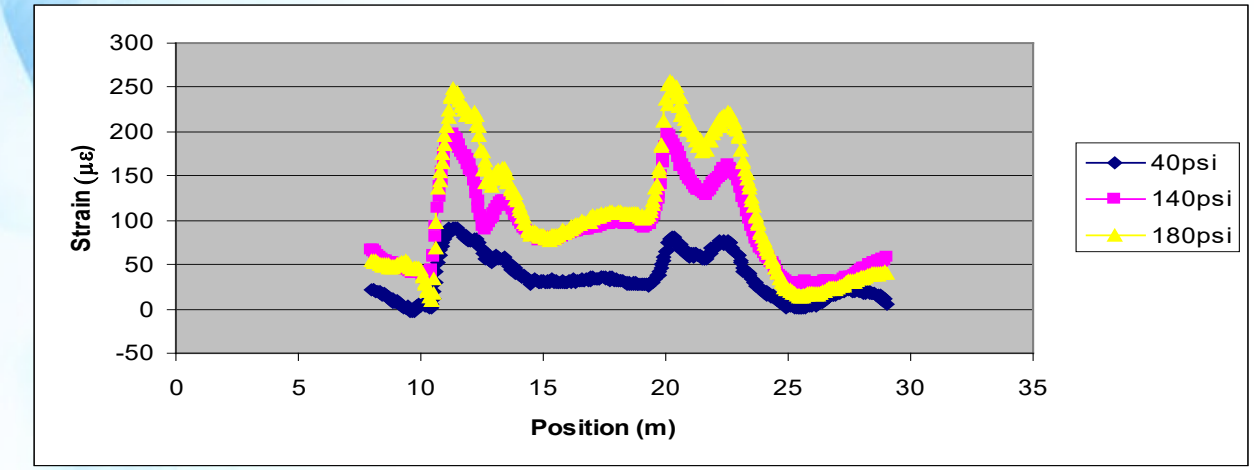


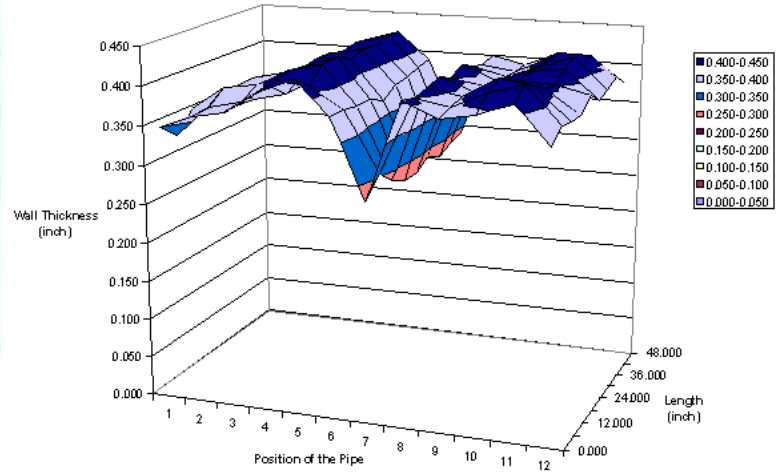




Pipeline Corrosion Monitoring

Pipeline corrosion monitoring in Canmet Materials Technology Laboratory, NRCan, Ottawa, NACE International — Corrosion 2008 Conference and Expo, New Orleans (Louisiana, USA 16-20 March, 2008).





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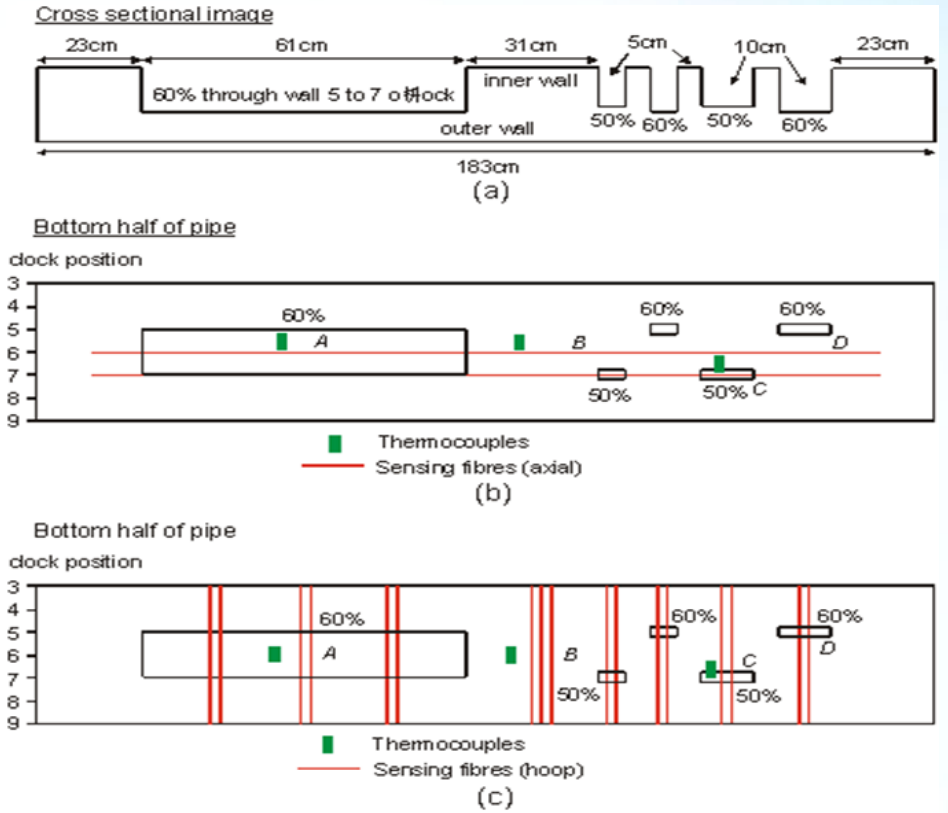
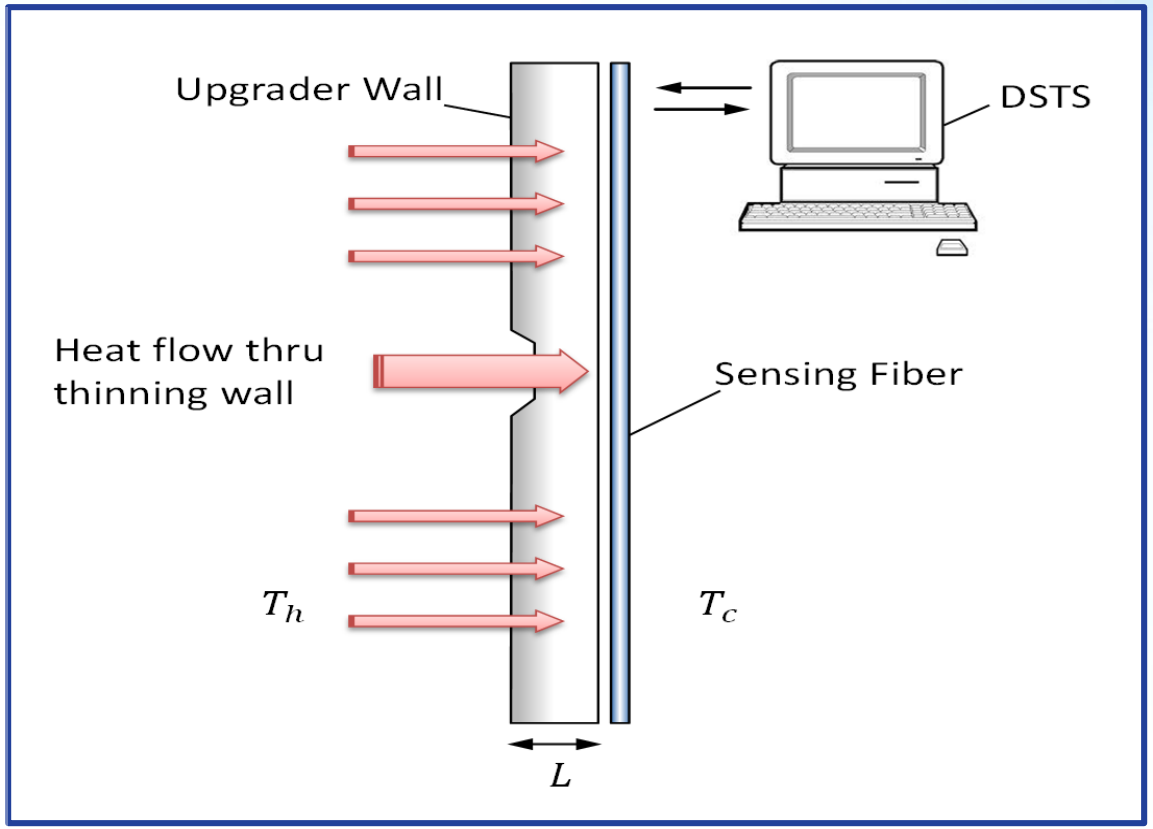


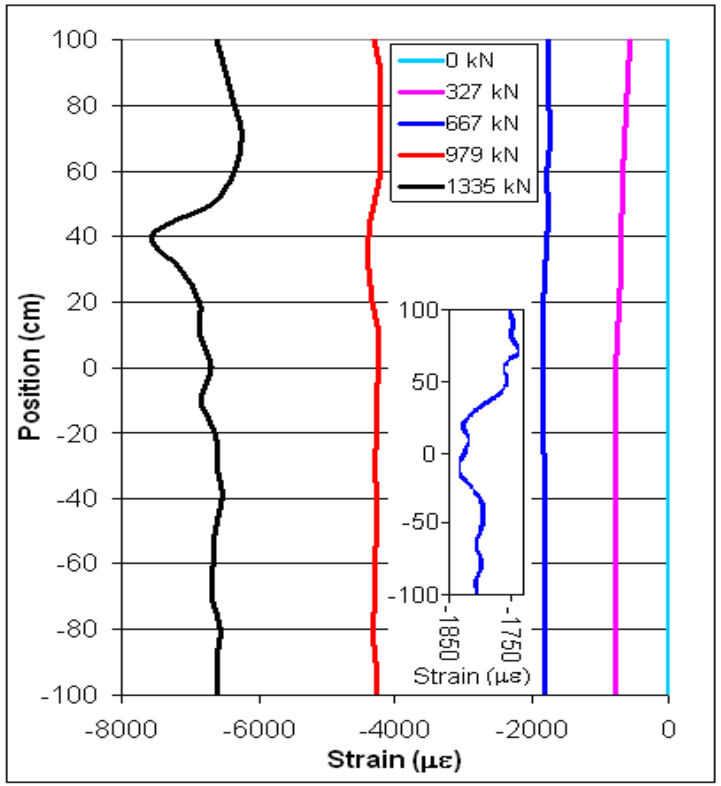
Refinery Temperature Monitoring

- Refineries use reactors and pressure vessels to transform heavy oil into synthetic crude oil.
- The upgrader reactors are operated at very high temperatures, exceeding 500 ℃.
- Due to the thermal stress exerted on the structure of the reactor, a wall-thinning problem might occur, resulting in conductive heat dissipation.
- Without the proper sensing technology, the refinery operator might prematurely shut down operations to perform untimely maintenance, or worse yet, the problem might go unnoticed, resulting in a catastrophic accident.



Pipeline Buckling Detection

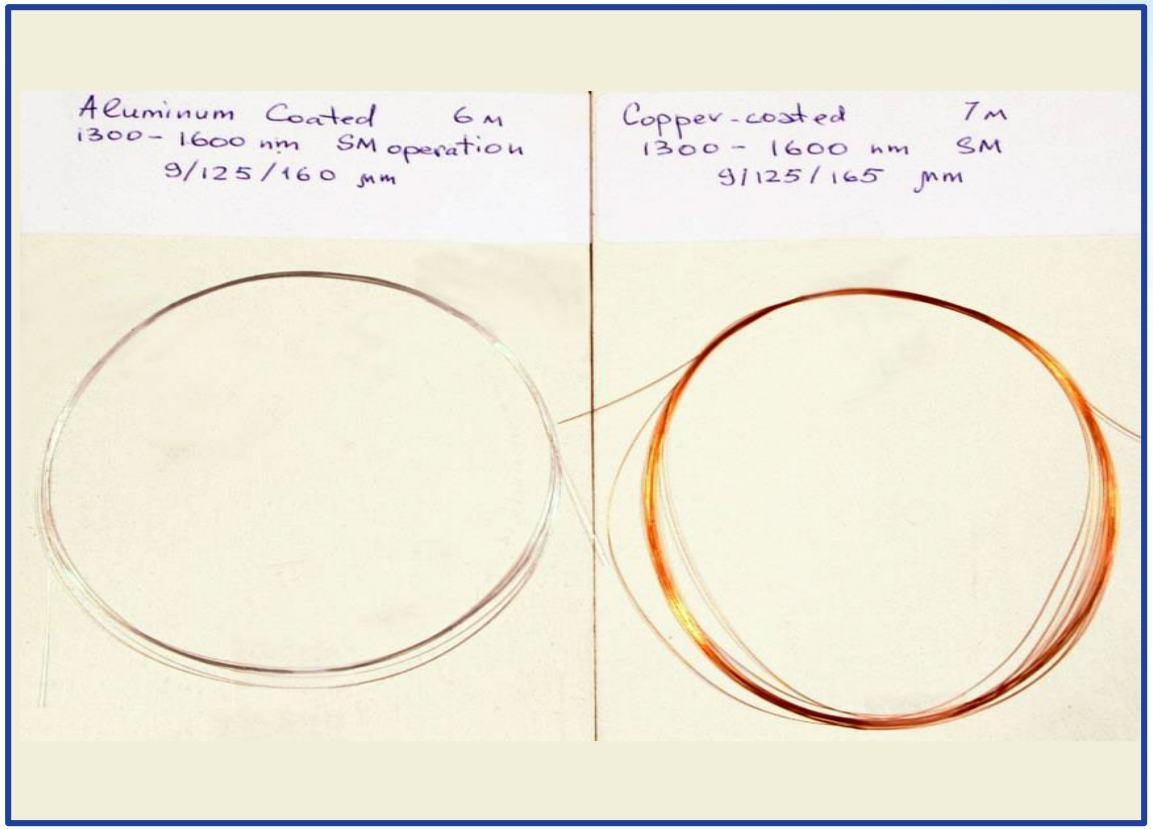
Pipeline buckling detection in TransCanada Pipeline Ltd, Calgary, and C-FER Technology, Edmonton



Metal/Polyimide Coated Hermetic Fibers

Coating Materials and Maximum Sustainable Temperatures

• UV-Cured Acrylate	100°C
• UV-Cured Dual Acrylate	150°C
• Polyimide	400°C
• Copper + Polyimide	400°C
• Aluminum	450°C
• Copper Alloy	600°C
• Gold	700°C +



Power Utility

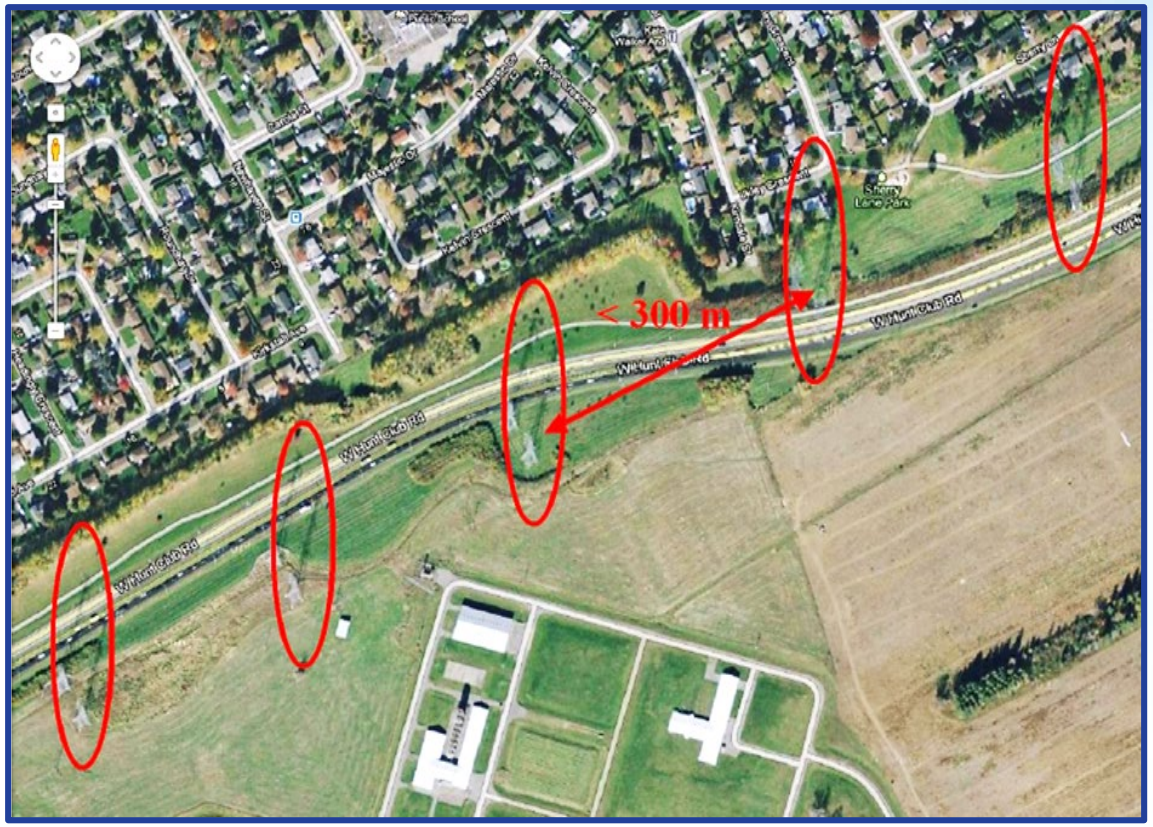
- OPGW Monitoring
- Power Cable
  (Submarine Cable) Monitoring
- Temperature Profile Monitoring
  of an Air-Cooled Gas Generator

OPGW Monitoring

- Monitoring the Working Status of Opgw
- Abnormal Event Found and Located
- Event Caused by Broken Strand, Lightning, Frost Covering, Change of Strain, Etc..

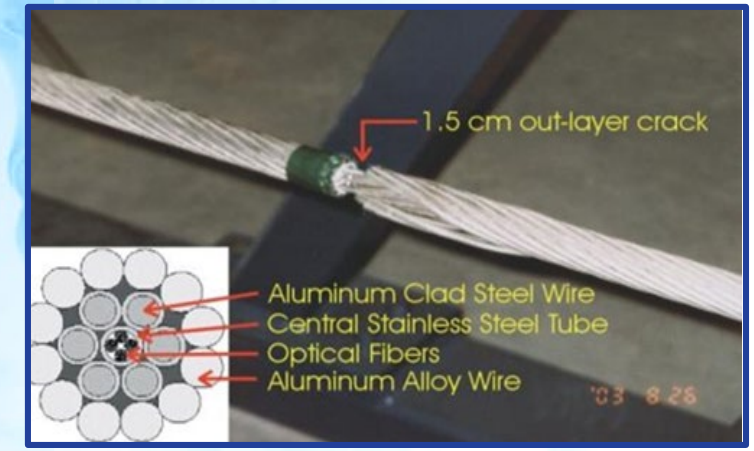
OPGW Status Monitoring

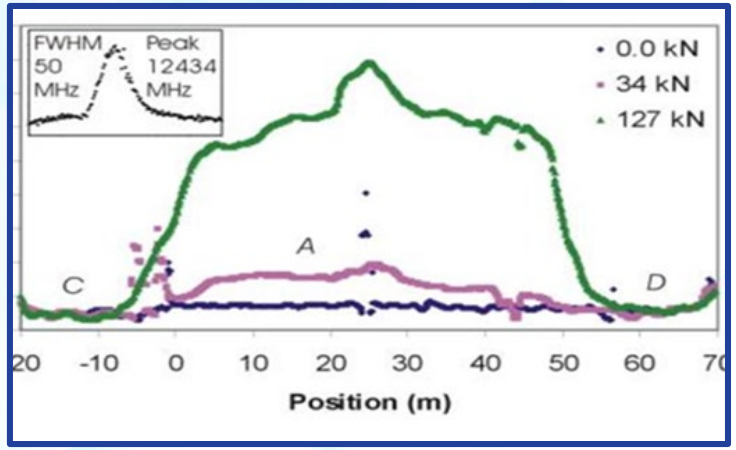
- The OPGW is located from Smith Falls to Merivale-Ottawa, Ontario, Canada.
- The total fiber length was close to 140 km.
- The BOTDA located in Merivale-Ottawa made measurements as often as once every 60 minutes starting in June 2012 and continuing till July 2013.

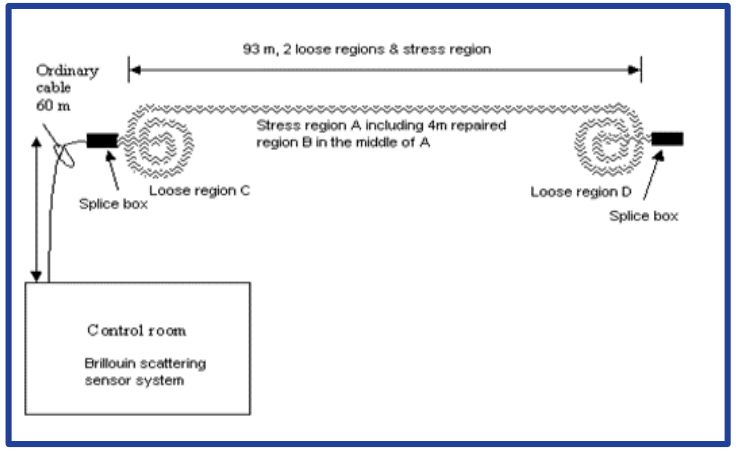


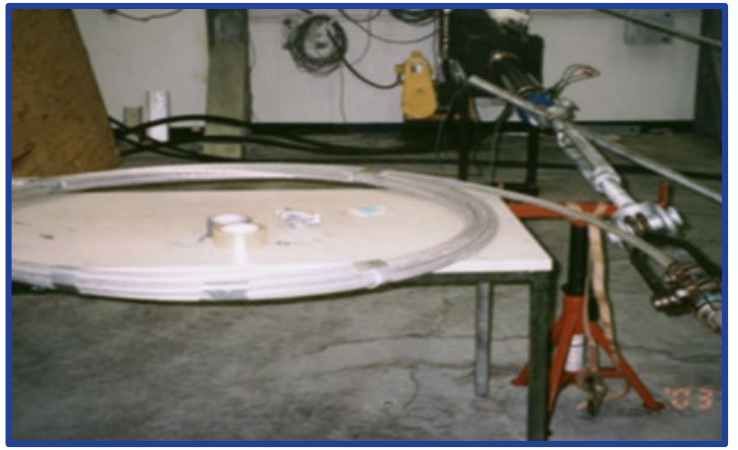
OPGW Strain Monitoring

Power line/OPGW monitoring in Hydro-Quebec, Montreal



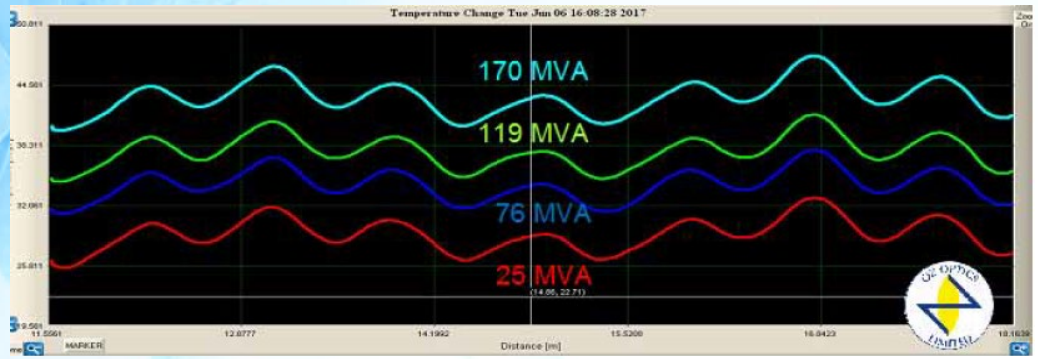


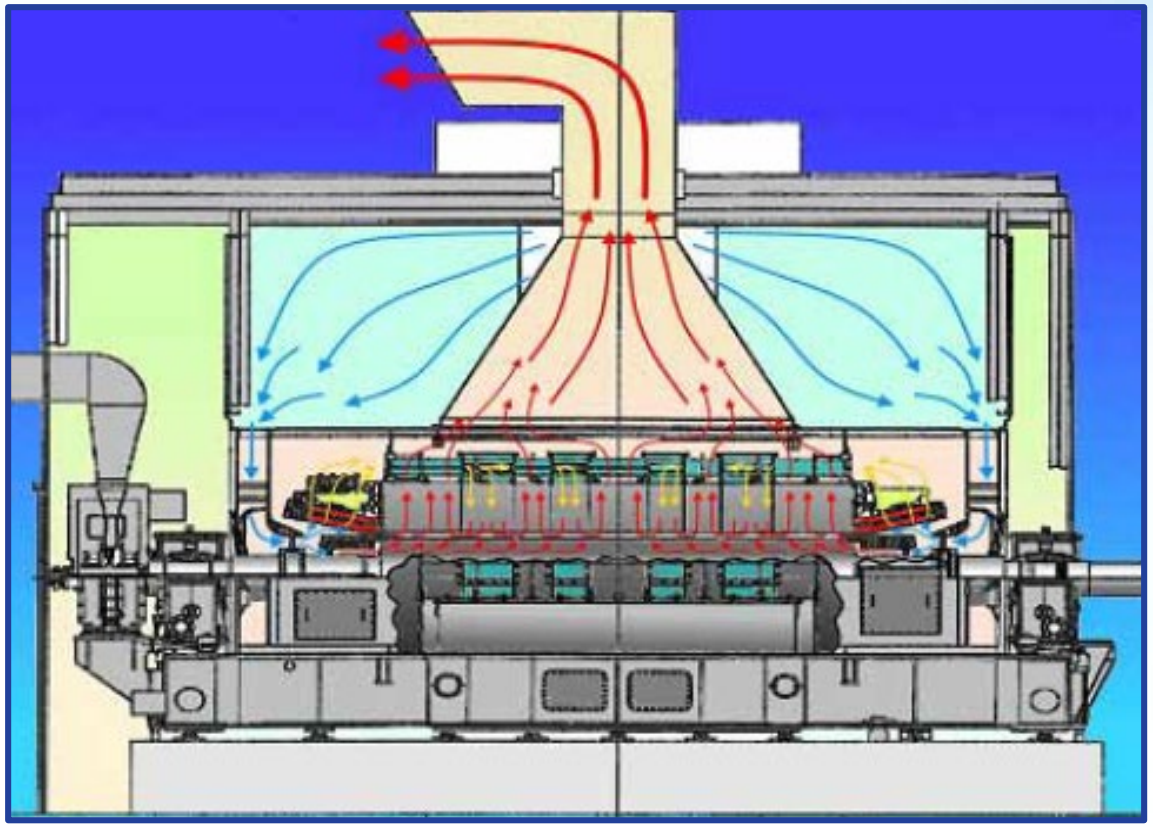




High Voltage Underground Cable with Fiber

Temperature Profile Monitoring of an Air-Cooled Gas Generator

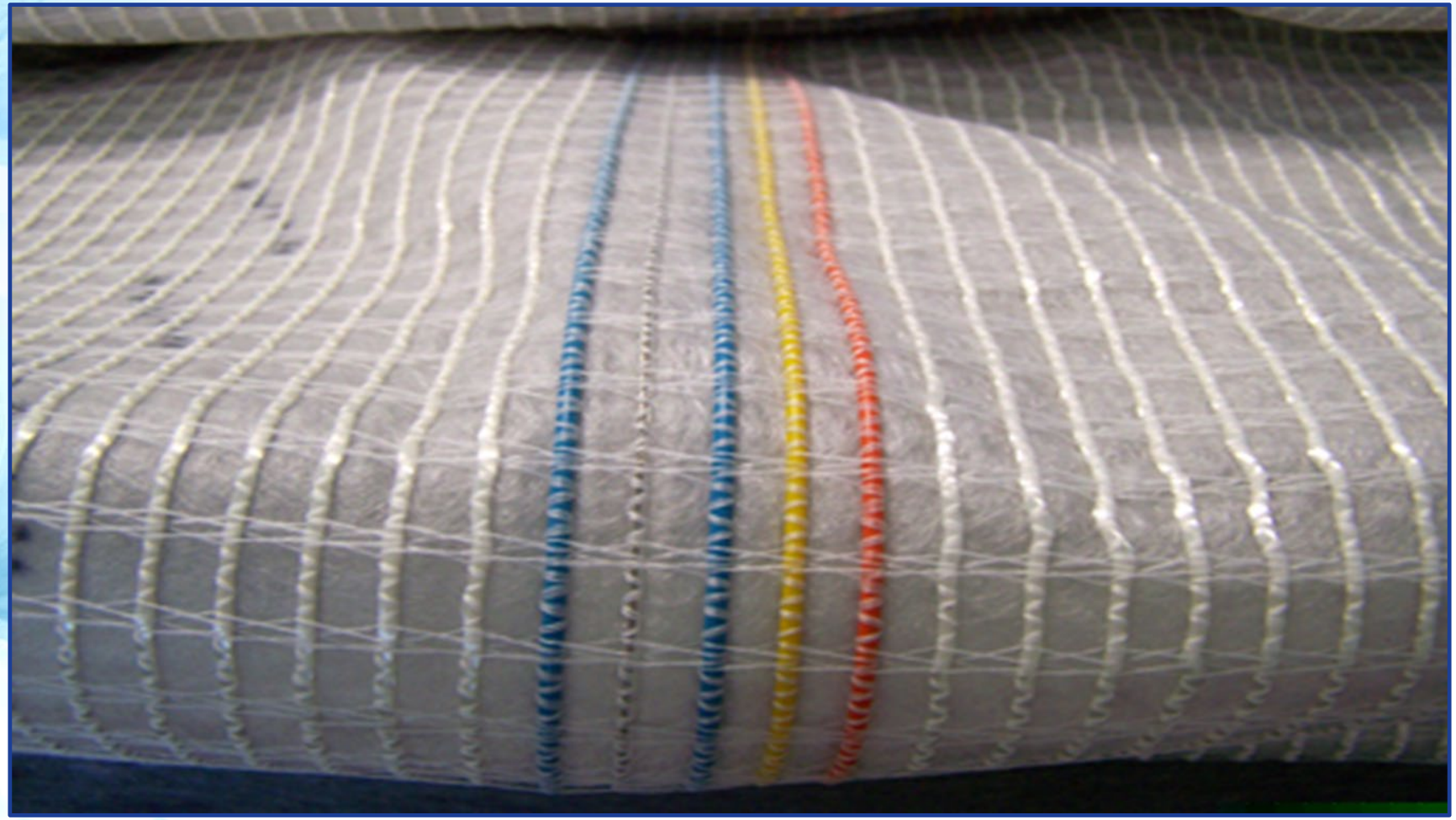




Concrete Beam/Highway Monitoring

Concrete beam/Highway monitoring on HW40/University of Sherbrooke,
Dr. Brahim Benmokrane

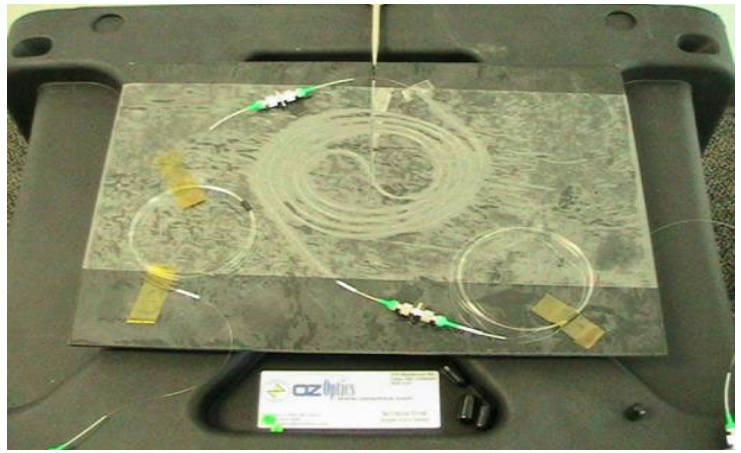
GeoDetect With Embedded Fibers

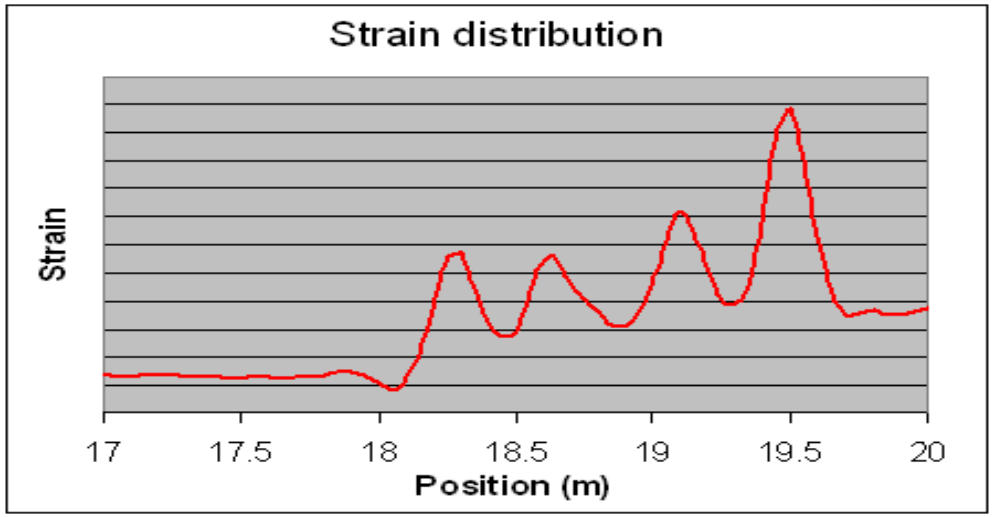


Christchurch Northern Corridor (CNC) – Measuring settlement with fibre optics

Crack Detection

Crack detection in University of California, Irvine, Dr. Maria Feng, 19th International Conference on Optical Fiber Sensors, Perth (Australia, 14-18 April 2008).





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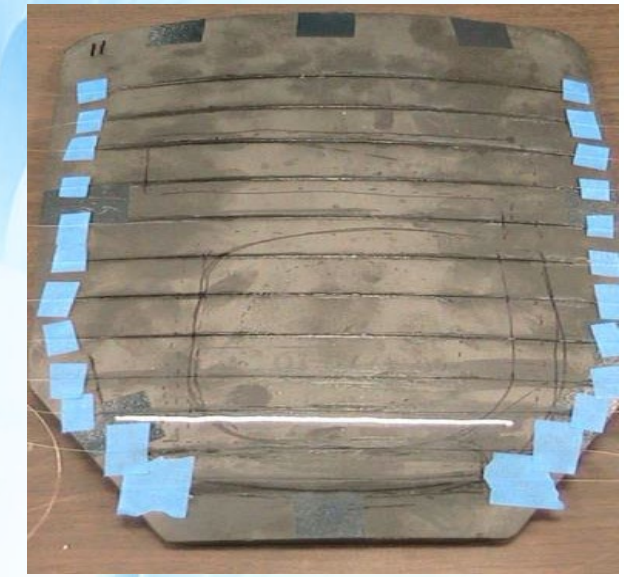
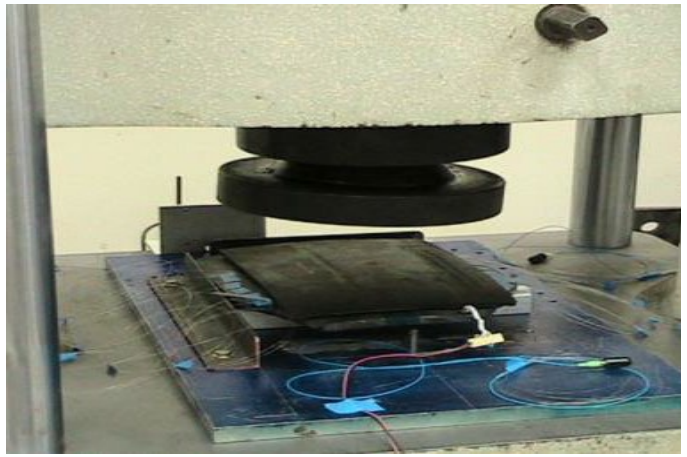
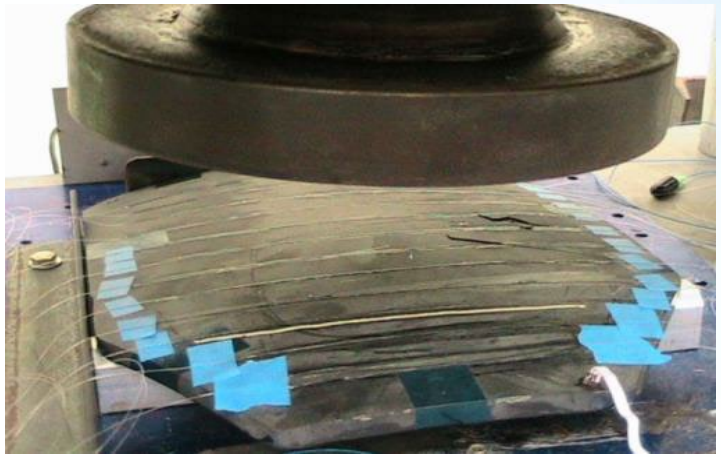
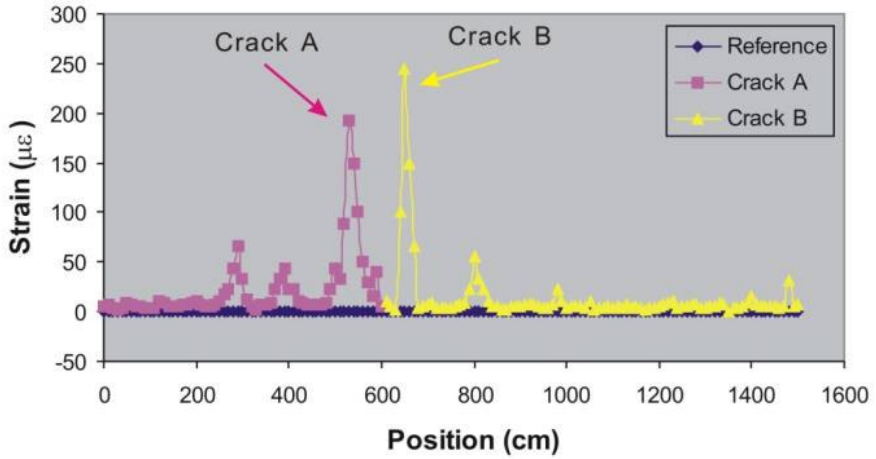




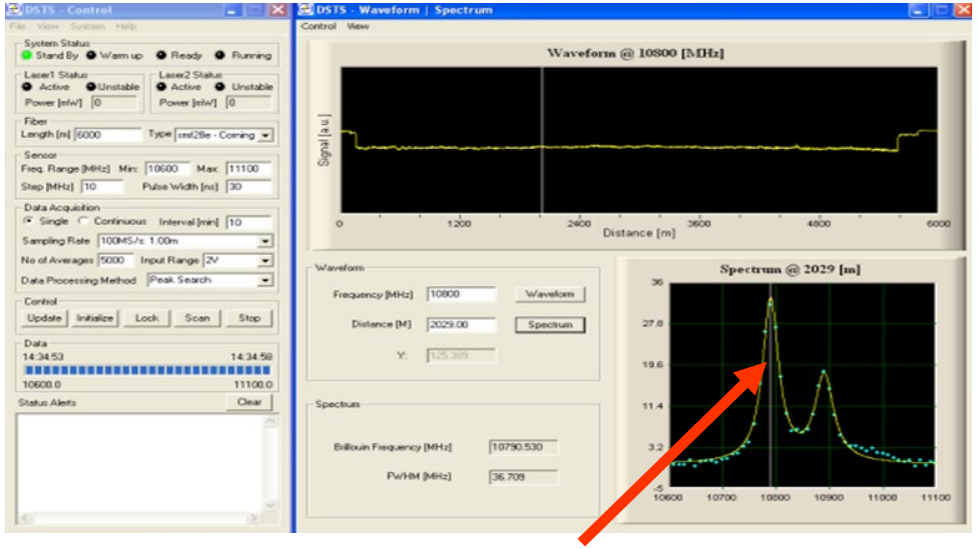




Brillouin Sensor Monitoring of Telecom Fibers

- Detects minor events that are too small to be seen by OTDRs.
- Can replace OTDRs for monitoring fibers.
- Can be used to monitor new or existing fiber installations.
- Permits performance monitoring of fibers above or below ground.
- Avoids unnecessary replacement of old fibers, saving millions of dollars in installation costs.

Yogokawa's results from AT&T's old telecom fiber, very broad Brillouin spectrum, which results in poor resolution and accuracy.



OZ's results from AT&T's old telecom fiber, very narrow Brillouin spectrum, which results in high resolution and accuracy.

The Cost of Catastrophic Failure

- Example: Druzhba Pipeline July 2006
- Small 50 Cubic Meter Leak Results In:
  - Interruption of $100M/Day Pipeline
  - Global Spike in Oil Prices
  - Report of Environmental Catastrophe
  - Months of Investigation and Ecological Monitoring
- Single Point of Failure in 3,000 km Pipeline

The Cost of Catastrophic Failure

- Example 2: Nigerian Pipeline July 2006
- Accidental Leak
- 180,000 Barrels / Day Shutdown
- 180,000 * $74 = $13M per Day
- 10-day Shutdown = $130M
- Brillouin Operation << $1/m/year
- Single Production Shutdown Far Exceeds Lifetime Sensor Operating Costs.

Acknowledgements

- University of California, Irvine, Dr. Maria Feng
- University of Ottawa, Dr. Xiaoyi Bao
- University of Sherbrooke, Dr. Brahim Benmokrane
- TransCanada Pipelines Limited (TCPL)
- C-FER Technologies
- Canmet Materials Technology Laboratory, NRCan
- Hydro-Quebec
- Southwest Research Institute®
- Tencate Geosynthetics
- NZ Transport Agency
- Christchurch Northern Corridor
- CNC Alliance Project

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