

Fiber Optic Disaster Safety Monitoring Systems

FODSMOS-2021

KOR Patent#10-1698835

KOR Patent#10-1924423

KOR Patent#10-1698836



- Monitoring of Displacement, Deflection, Tilt, Acceleration, Water depth/level/flood/tsunami by a System
- To alarm at emergency and prevent disaster
- Simple to install and operate
- No electricity, passive element only
- Remote monitoring up to 10KM current /260KM near future
- To extend lifetime of the structure under the safety monitoring



Innovative Fiber Optic Security & Safety Systems Manufacturer

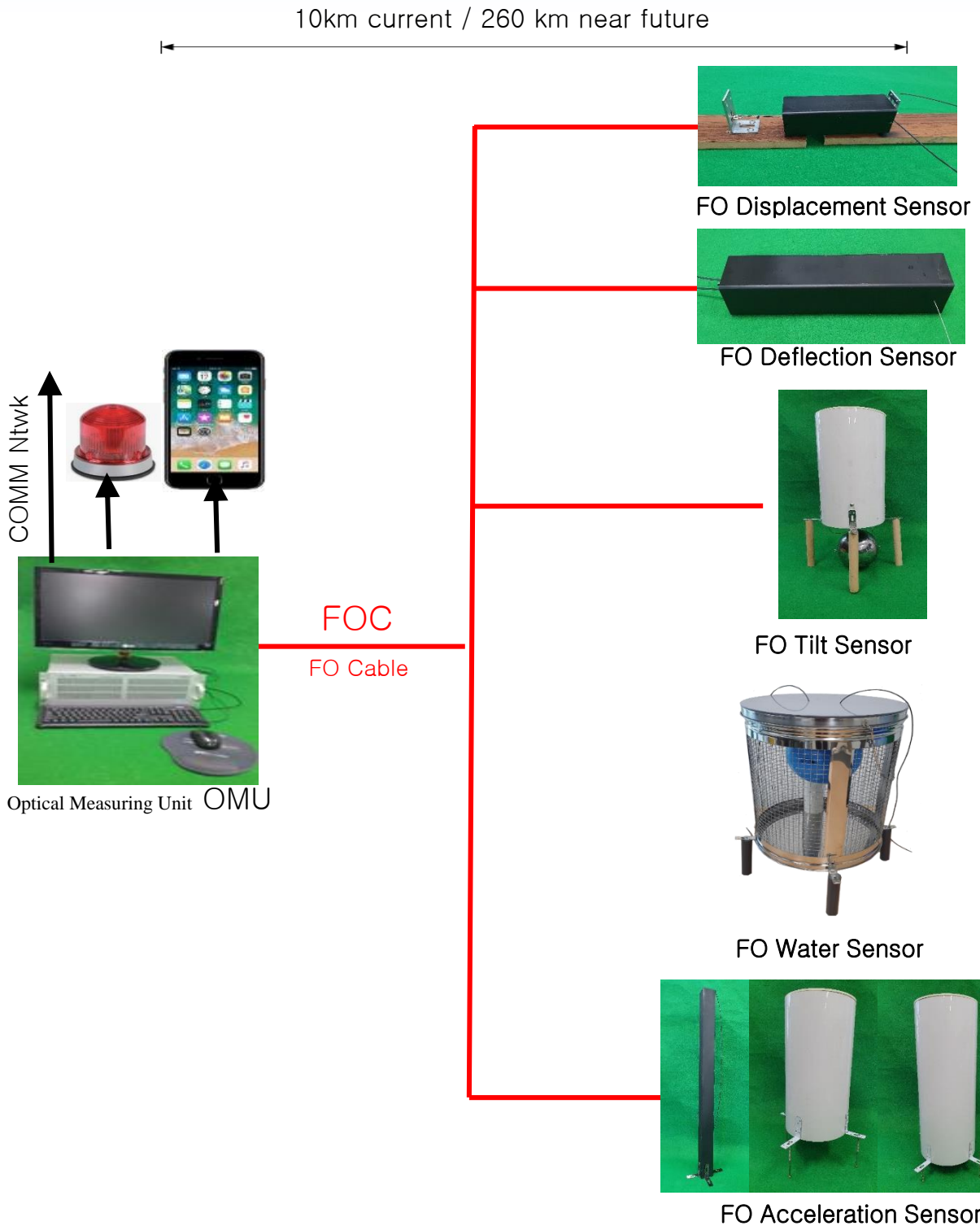
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With the FODSMOS (Fiber Optic Structural Safety Monitoring System), a Fiber Optic Sensor suitable for any safety parameter among displacement, deflection, tilt, acceleration, water depth/level/flood/tsunami etc. is attached selectively to each location whose behavior or status is inherently related to the safety status of such a large structure as long bridge, dam, tunnel, tower, tall building etc. to receive periodically Infrared Laser Pulses from and return the Pulses affected by the Sensor status to the OMU (Optical Measuring Unit) which can be located via FOC (Fiber Optic Cable) remotely up to 10KM currently / 260KM near future. In turn from the Optical Loss between Tx Pulses and Rx Pulses, the OMU measures the designated safety parameter and displays/stores the measured value and in case of emergency triggers alarm and transmits emergency message through SNS and/or safety network.



d Fiber Optic Displacement Sensor



8 Fiber Optic Displacement Sensor



W Fiber Optic Water Sensor

t **Fiber Optic Tilt Sensor**

a1 **Fiber Optic Acceleration Sensor - 1 axis**



a2 **Fiber Optic Acceleration Sensor - 2 axis**

a3 **Fiber Optic Acceleration Sensor - 3 axis**

Performance Specification

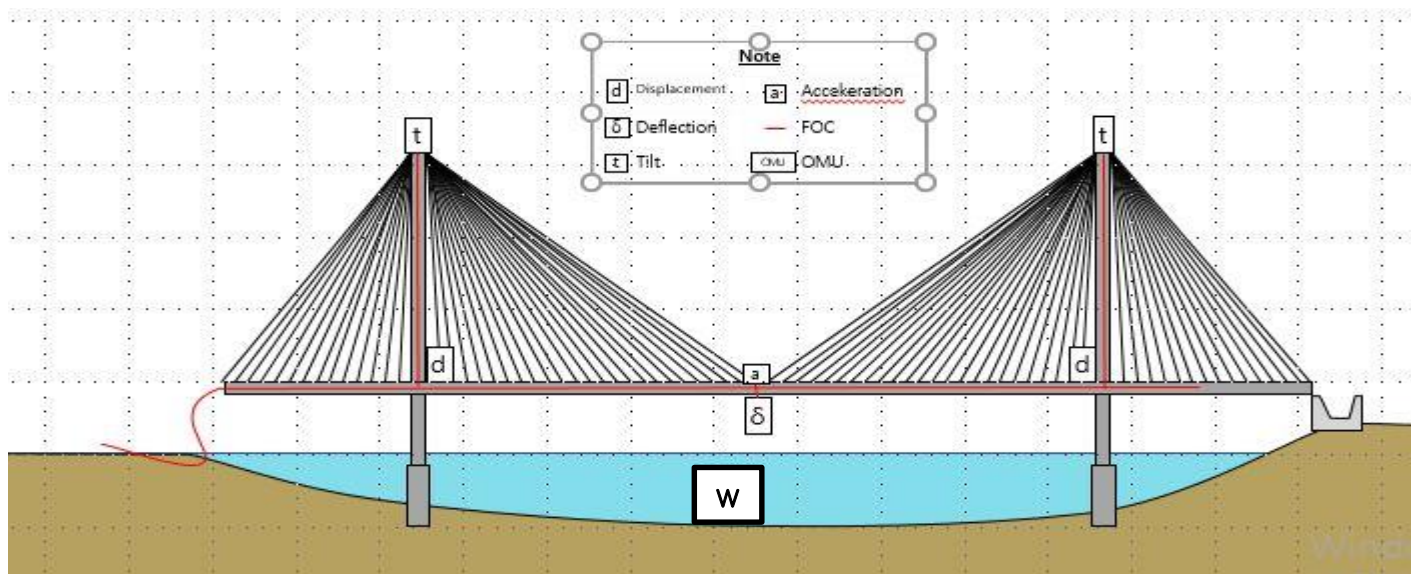
Sensor Type	Displacement (d)	Deflection (δ)	Water depth, (h) Including water level, Flood, Tsunami	Tilt (Θ, Φ)	Acceleration (Strength, Dyn Range)			Others
Max Range, R	1,000mm	Span L < 400M : 0 to L/400 L > 400M : δc-1,000 to δc δc deflection limit	100M	(±30°, 360°)	(±2 g , 120dB) 1axis, 2axes 3axes or Per specific structural requirement			Cable Elongation/Tension/Te mperature Per specific structural requirement
					1 axis	2 axes	3 axes	
Dimension, mm	75x75x3R	75x75x3R	500Φ x 800	270Φ x 450	75x75x1,200	270Φx450	270Φx600	Slight change per site condition
Weight, kg	5kg @ R=200mm	15kg @ R=500mm	30	40	10	15	20	Slight change per site condition
Accuracy	±1% FS							
Maximum FOC Length	10KM current / 260KM near future							
Sensor Material	Passive elements only (FO Cable / Anti-resistant metal)							
Power Consumption by Sensor	0 Watt							
Sensor Operating Temp	-40℃ ~ +60℃							
Environmental	Environment – proof (immune to temp, humidity, wind. Vibration, lightening, EMI, sunshine etc.), To work on the earth/Under-ground/Under-water							
Expected Life Time	15 yrs or over							



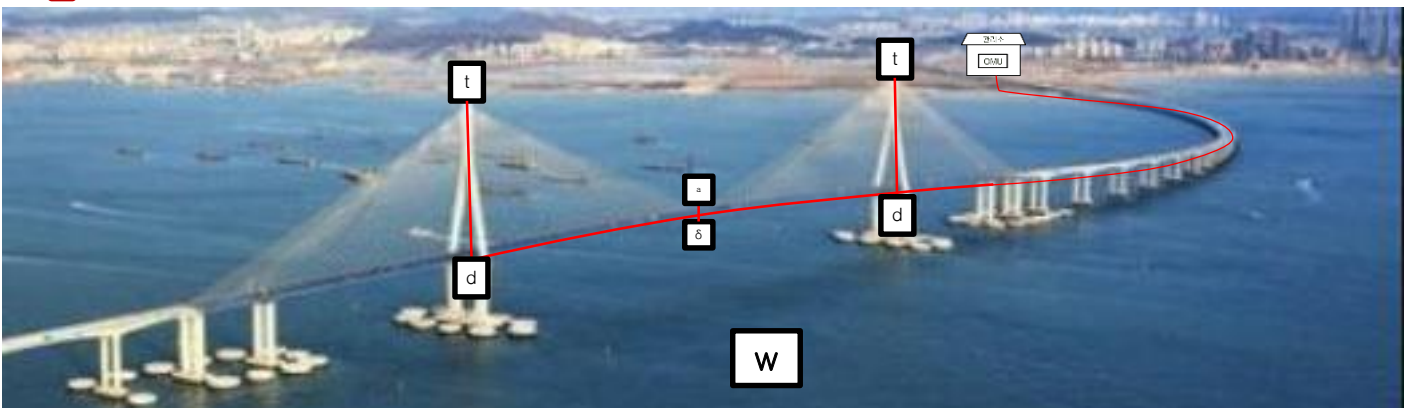
Attach a Fiber Optic Deflection Sensor to the Bridge Plate Middle and connect it with TW (Tension Wire) and with FOC (Fiber Optic Cable) to the remote OMU (Optical Monitoring Unit) which measures, displays and stores the deflection in real time and transmits emergency message through SNS and/or safety network.

The TW shall be first connected to fixed bridge points or solid ground and further be treated to provide fixed point for the Sensor not to be affected by temperature change and wind disturbances.

Other Safety Parameter such as Cable Elongation/Tension/Temperature can be further measured in parallel with the Cable Deflection Measurement additionally upon the site request.



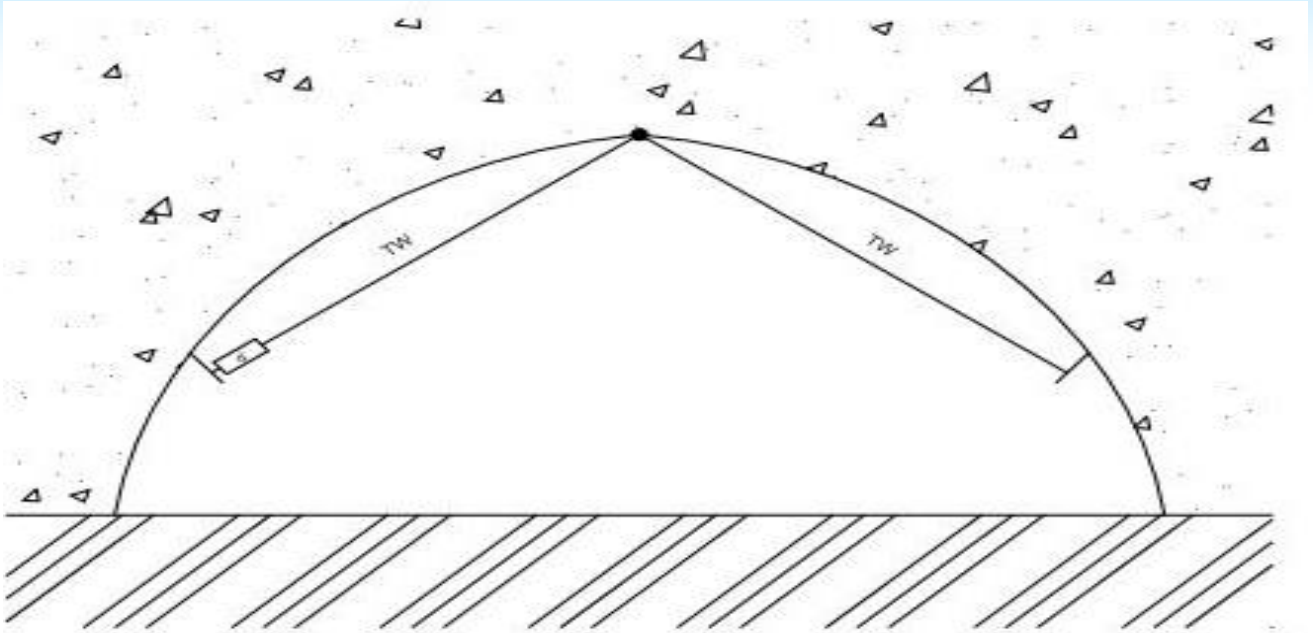
Incheon Bridge Safety Monitoring System (Ex)



Attach FO Displacement Sensor at Connecting Portion or Crack, FO Deflection Sensor at the Bridge Plate Middle, FO Tilt Sensor on the Main Tower top, FO Acceleration Sensor at the Bridge Plate Middle, put FO Water Sensor for monitoring of water depth & level and flood/tsunami alarming etc. and connect each FO Sensor via FO Cable to the remote OMU which measures, displays and stores each Safety Parameter in real time and transmits the corresponding emergency message through SNS and/or safety network.

General Suspension Bridge

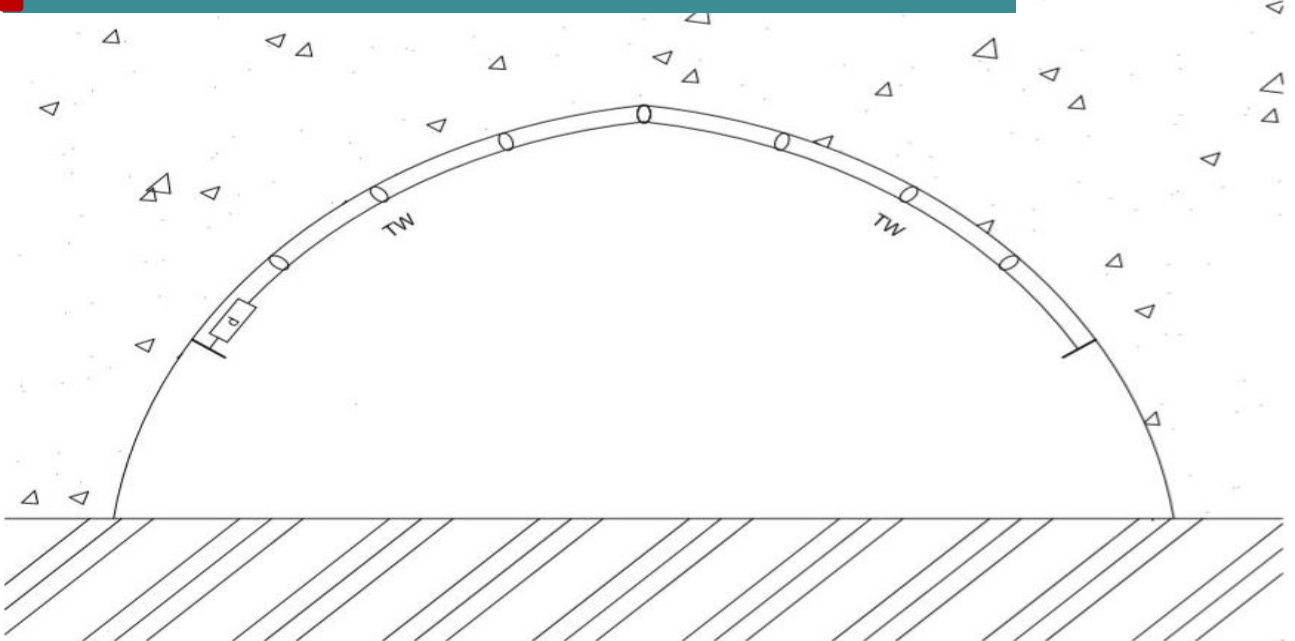




Attach a FO Displacement Sensor sit on one side wall of the tunnel and mount a TW via the Tunnel Ceiling Top to the other side wall of the tunnel.

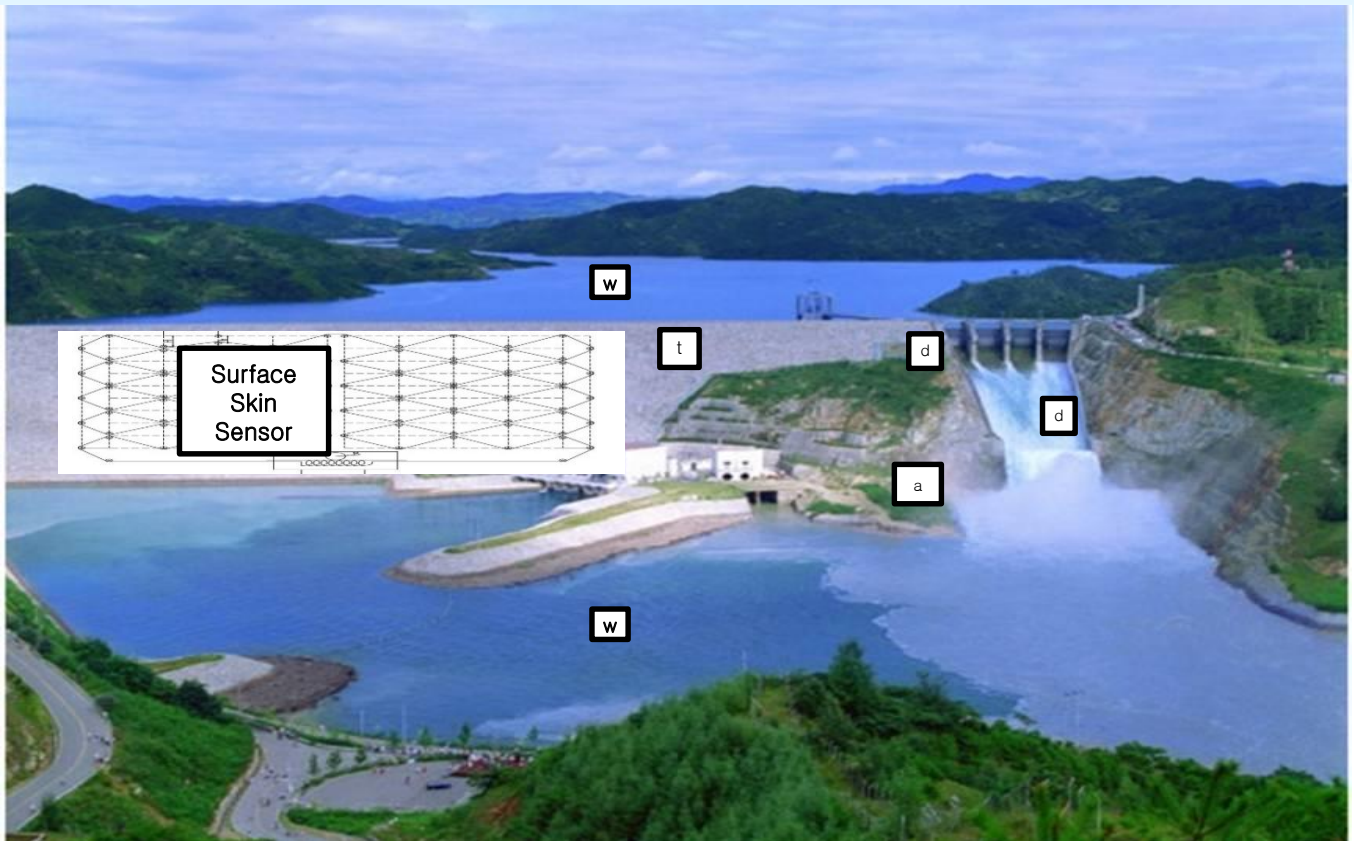
Any variation of the TW length shall be sensed by Sensor to let the remote or nearby OMU measure, displays and store the measure Deflection value in real time and transmit the corresponding emergency message through SNS and/or safety network.

Tunnel Curvature Variation Measurement



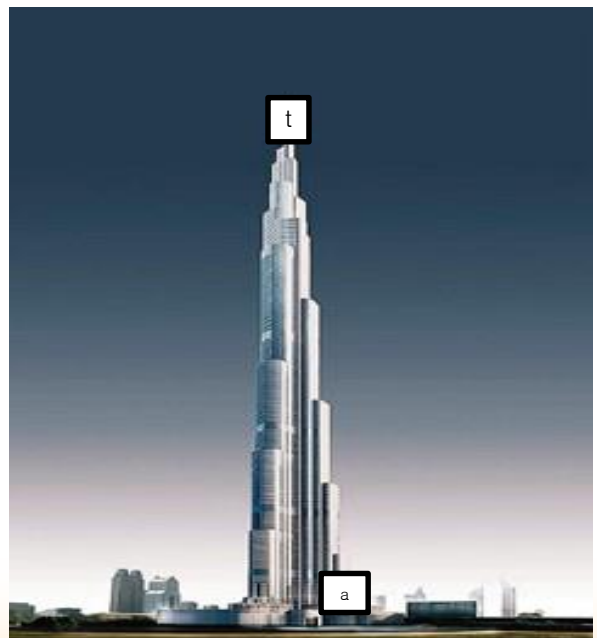
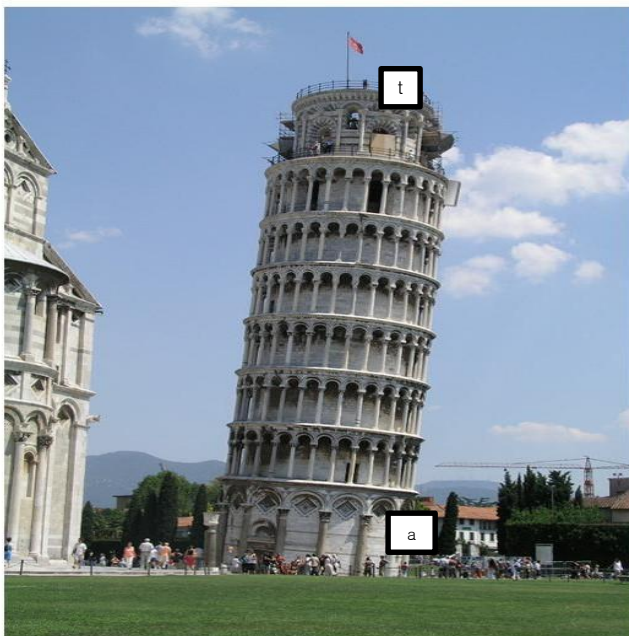
Attach a FO Displacement Sensor sit on one side wall of the tunnel and mount a TW through a series of guide rings along the Tunnel surface curvature to the other side wall of the tunnel.

Any variation of the TW length shall be sensed by Sensor to let the remote or nearby OMU measure, displays and store the measure the Tunnel Curvature Length value in real time and transmit the corresponding emergency message through SNS and/or safety network.



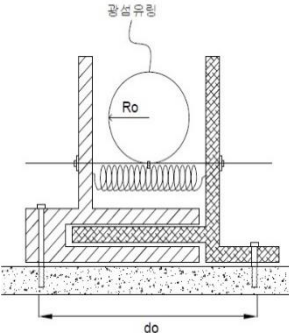
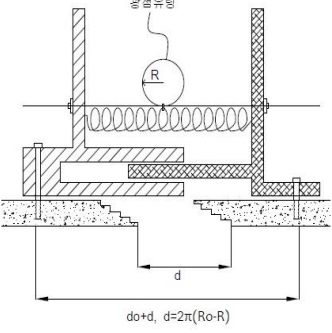
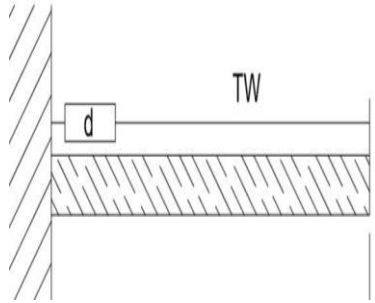
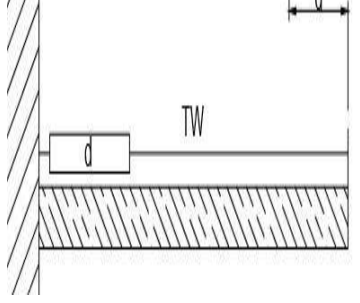
Cover the entire dam surface with the Skin Sensor and attach FO Tilt Sensor put FO Displacement Sensor across cracks and junctions and FO Acceleration Sensor on the Dam foundation so as to sense tilt, displacement and quake and FO Water Sensor in the lake to measure water depth/level and instantly alarm at flood and tsunami and acceleration sensor to the lake shall cause tsunami to be instantly alarmed by the FO Water Sensor for people to escape earlier. Connect each of FO Sensors via FO Cable to the remote OMU at Guard House near by the Dam to display and store each measured value and transmit the corresponding emergency message through SNS and/or safety network network.

Tower / Tall Building

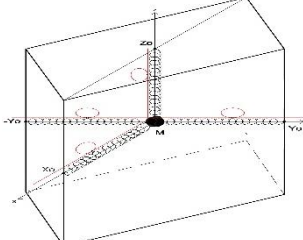
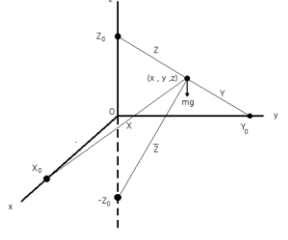
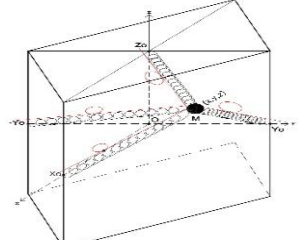


Put a FO Tilt Sensor on the top of tower or tall building to sense the Tilt and FO Acceleration Sensors on to tower or building and the basement. Connect each Sensor via FO Cable to the remote or nearby OMU to measure, display and store the tilt value in real time and transmit the corresponding emergency message through SNS and/or safety network.

Principle of displacement/deflection measurement, KOR Patent#10-1698835

		<p>A Fiber Optic Displacement Sensor (FODS) positioned parallel with the gap of any crack or connection portion is constructed with a spring and FO ring to stretch or shrink and result in Optical Loss change accordingly.</p> <p>According to the KOR Patent#10-1698835, The relation between the Optical Loss L and the Displacement d can be characterized by the following Equation</p> $d = 2\pi(Ro - (\alpha - \beta \ln L)/L)$
<p>Longitudinal Displacement</p>		<p>where Ro, Lo, α and β are constant independent from the Optical Loss L.</p>
		<p>Suppose to measure the deflection of a suspension bridge. To do this, first attach a FO Displacement Sensor to the girder plate middle and mount a TW (Tension Wire) between two neighboring pillars or two other locations on the ground.</p> <p>Next put the TW under vertically force - balanced condition to be floated at fixed position vertically overcoming temperature change or wind disturbance. Finally the System shall measure the deflection without being affected by the temperature change or wind disturbance.</p>
<p>Transverse Displacement (Deflection Measurement)</p>		

Principle of acceleration measurement, KOR Patent#10-1698836

		
<p>FO Acceleration Sensor, Origin</p>	<p>Coordinate</p>	<p>FO Acceleration Sensor, Acceleration</p>

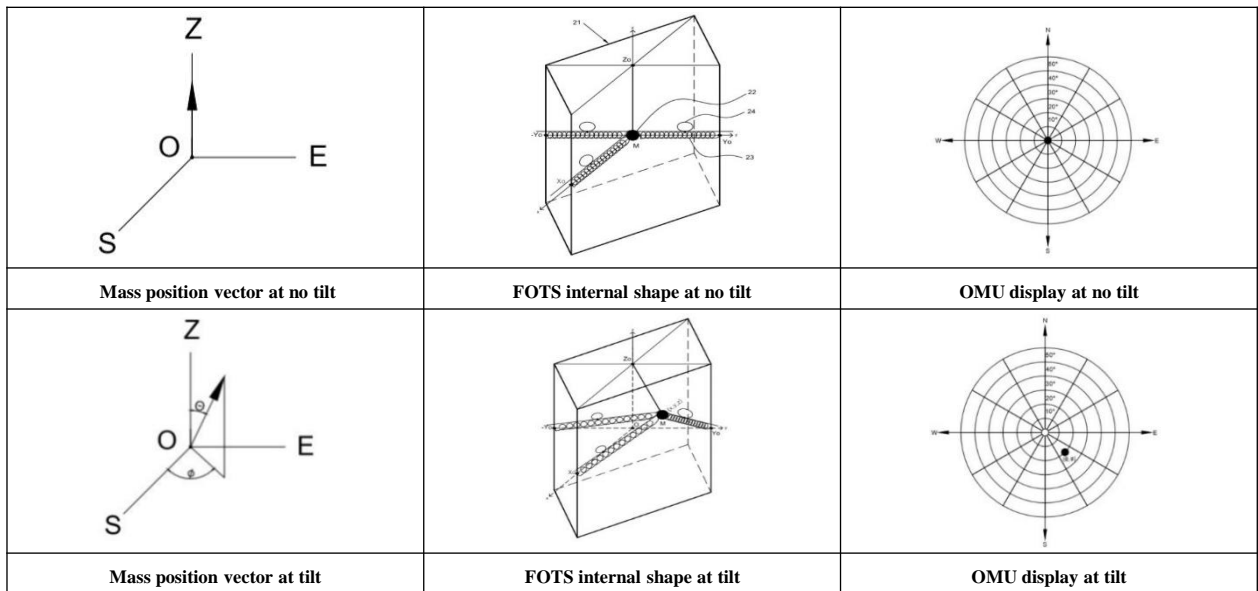
Above Figures show in FO Acceleration Sensor that a mass is connected with four springs / FO rings. The mass is positioned at the center at no acceleration but moves to other position at receiving an acceleration. Each of four FO rings are via a FO Cable connected to the remote OMU to receive periodically Infrared Laser Pulses from and return the Pulses affected by each FO Ring. In turn from each Optical Loss between Tx Pulses and Rx Pulses, the OMU measures each displacement and determines each of 3D accelerations with the help of the following patented Equations

$$a_x = \frac{k}{4mX_0} (2X^2 - 2X_0^2 + 2Y_0^2 - Y^2 - \overline{Y^2}) \quad - \text{Eq(1)}$$

$$a_y = \frac{k}{4mY_0} (Y^2 - \overline{Y^2}) \quad \text{----- Eq(2)}$$

$$a_z = \frac{k}{4mZ_0} (2Z^2 - 2Z_0^2 + 2Y_0^2 - Y^2 - \overline{Y^2}) - g \quad - \text{Eq(3)}$$

where k is the elastic constant of the springs, g is the gravity, m is the mass and Y, X, \overline{Y} , Z are the spring length respectively.

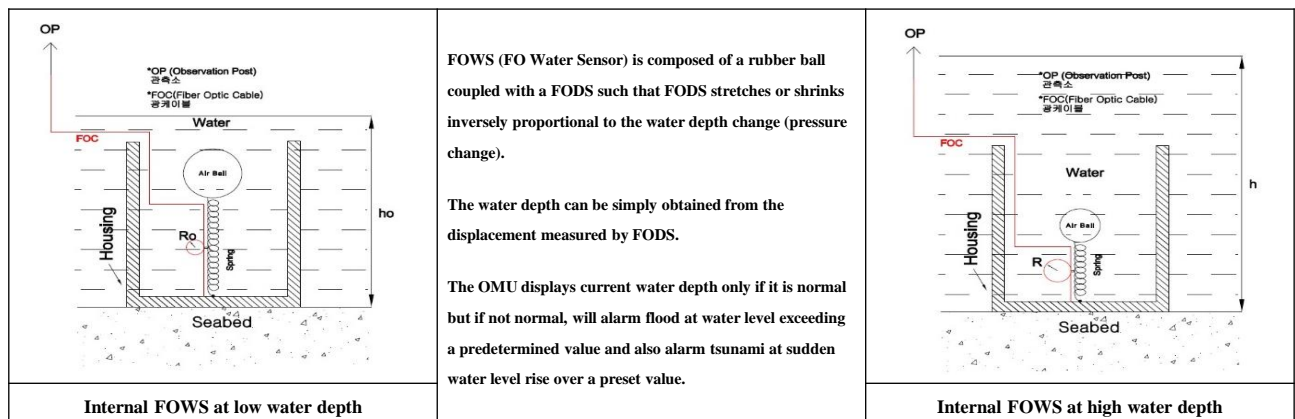


The FO Tilt Sensor is configured in the same as FO Acceleration Sensor except the vertical spring/FO ring is replaced by a wire of length Z_0 . Under tilt, the mass inside the FO Tilt Sensor moves to other position (x, y, z) which can be easily calculated from the above three Eqs(1-3) with the help of well known $F = ma$.

In turn from the values of x, y, z obtained, the tilt angle θ and azimuth ϕ can be obtained according to the KOR Patent#10-1698836 as

$$\theta = \arccos \frac{z}{\sqrt{x^2 + y^2 + z^2}} = \arccos \frac{z}{\sqrt{2zZ_0}} = \arccos \sqrt{\frac{z}{2Z_0}} \text{ ----- Eq(4)} \quad \phi = \arctan x/y \text{ -----Eq(5)}$$

Principle of remote monitoring of water depth/level and flood/tsunami alarming by KOR Patent #10-1924423

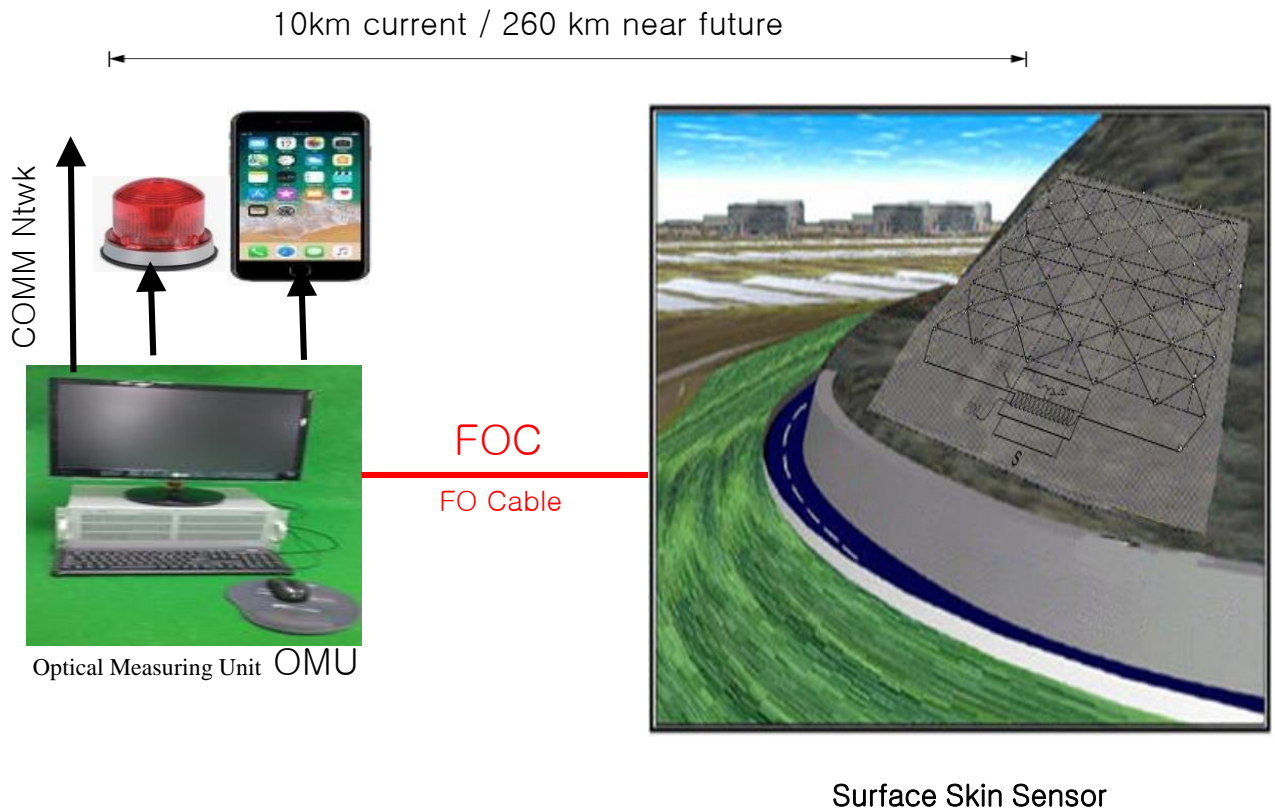


Optical Monitoring Unit, Model OMU-nP



- Operation mode : Normal, Test, Emergency, Setting, Stop
- Sensing mode : cutting and/or excess force
- Location Accuracy : $\pm 1\text{m}$, $\pm 15\text{m}$, $\pm 25\text{m}$, Optional
- No of Optical Ports : n (maximum 8)
- Sensing mode : cutting , excess force , selectable
- External connection port : PC interface
- Fiber Optic test function : semi-OTDR
- Auto-logging : event data (alarm, action, status, setting value etc)
- Monitor : 8.4" LCD color built in or 17" LCD external
- Interface : dry contacts, serial or LAN
- Acceptable output devices : warning light, signal phone
- O/S : Window 10
- Dimension : 19" 4U (177×483×300 mm)
- Operating condition : indoors
- Power : AC220V $\pm 10\%$ 50/60Hz, 100Watt approx

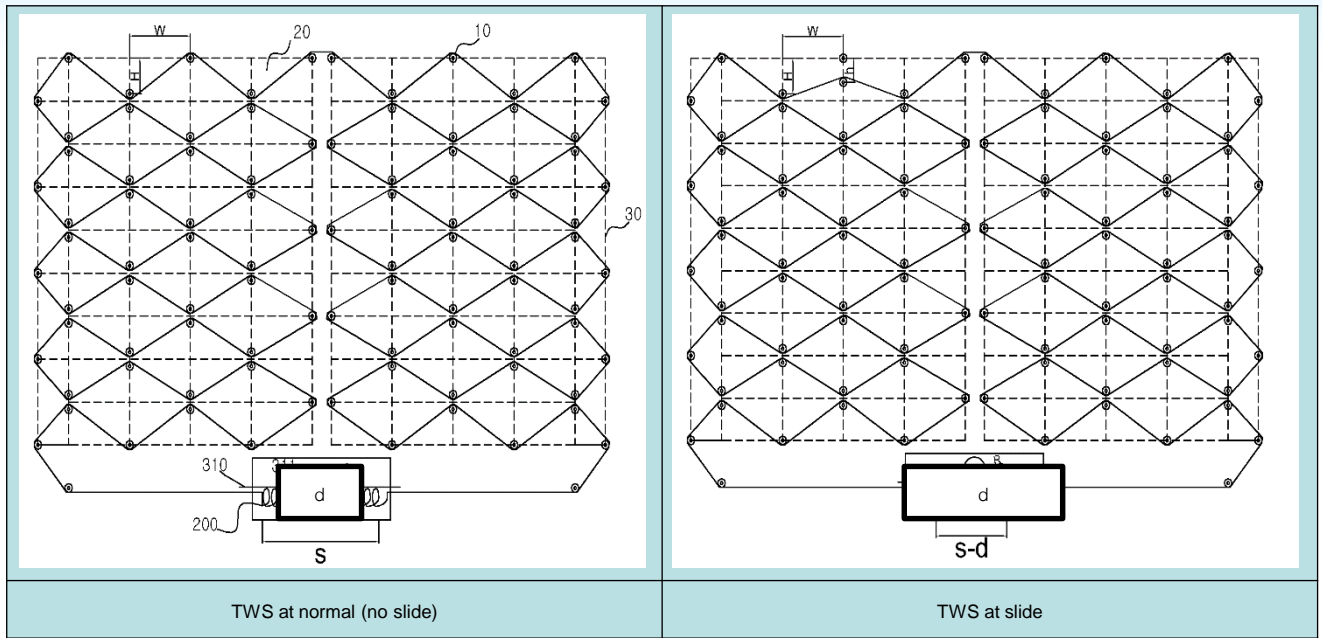
Overview of Surface Skin Sensor



Such a large surface as cutaway surface, steep mountain surface, dam surface, wall surface etc. can be effectively checked by Surface Skin Sensor which is a combination of **FODS** (Fiber Optic Displacement Sensor) and **TWS** (Tension Wire Screen) covering of the surface. FODS shall be connected via FOC (Fiber Optic Cable) to the remote **OMU** (Optical Monitoring Unit) up to 10KM currently / 260KM near future.

The OMU periodically pumps Infrared Laser pulses in to the FODS and receives return pulses from the FODS to measure Optical Loss variation accurately. A tiny surface slide shall force to distrub either chain link or TWS covering and activate FODS coupled. The OMU shall measure Optical Loss from the return pulse strength variation and determine the slide value to trigger alarm at exceeding the predetermined value and transmit the corresponding emergency message through SNS and/or safety network.

Principle of 2 – dimensional surface deformation measurement, KOR Patent#10-1927807



The entire surface vulnerable to slide or fall shall be covered with **TWS** (Tension Wire Screen) which is composed of a tiny stainless wire (typically 1.2mm diameter) in Zig-Zag pattern under tension. Any slide or fall shall disturb the initial TWS pattern so as to activate the **FODS** (FO Displacement Sensor) positioned on the bottom TWS and trigger alarm at exceeding the predetermined limit value.

According to KOR Patent#10-1927807, the sliding h can be characterized by the following equation

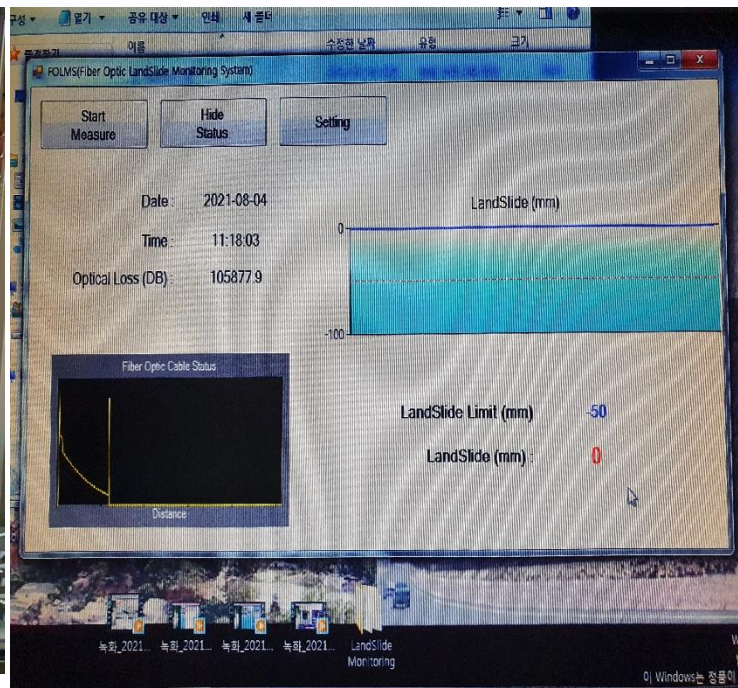
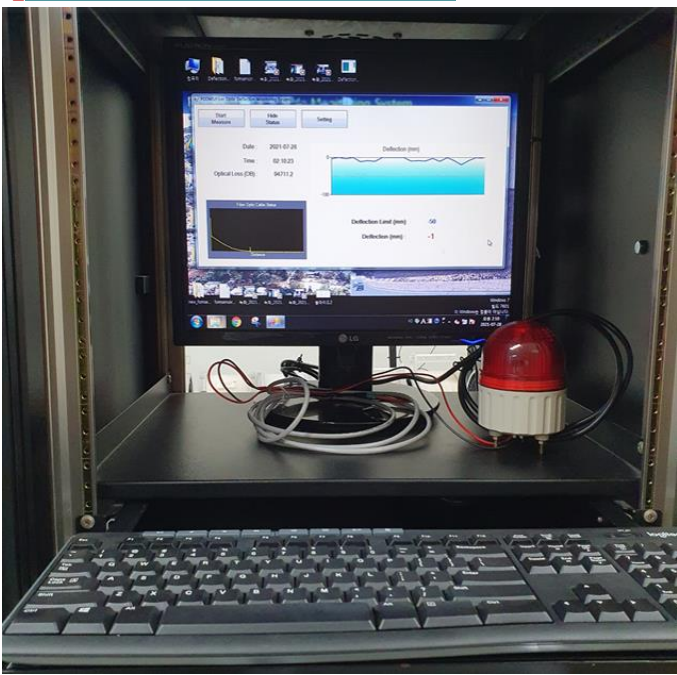
$$h = H - \sqrt{(\sqrt{H^2 + W^2} - \frac{d}{2})^2 - W^2}$$

where H and W stand for dimension of the cell forming TWS and d stands for the displacement measured by FODS.

Performance Specifications

Item	Specification
1. Sensing Origin	Land Sliding
2. Sensitivity Range	2cm ~ 50cm
3. Resolution	$\pm 2.5\%$, $\pm 1\%$, $\pm 0.1\%$ FS depending on site condition
4. Sensing Surface Unit	50M x 50M, typical
5. Sensing Cell Size	10M x 10M, typical
6. Max Measuring Range	10KM
6. No of Channel per OMU	8ch
7. Channel Capacity	20 x unit surfaces
8. Sensor Power Consumption	0 Watt
9. Sensor Environmental Characteristics	All-weather
10. Sensor Life Time	Half-permanent

OMU Operation



Deflection Sensor Demo



- ⦿ Structure Name and Location
- ⦿ Overall drawing / picture of the Structure requiring safety monitoring system:
- ⦿ Specify type and quantity of each Safety parameter required and its performance
- ⦿ Allowable deflection/elongation, e-f elastic characteristic data of main cable, suspension bridge equation
- ⦿ Required time of the system installation and operation start:
- ⦿ etc.

Benefits by FODSMOS

Human body was created by GOD to be consisted with muscle, bone and nerve so as to sense any external stimulus or internal disease and respond properly. However such a man-made huge structure as bridge, tunnel, dam, tower, tall building, complex building etc. is constructed with cement and rebar only missing sensor is incomplete & unsafe.

Thus the huge structure has to be shut-down at strong wind, storm, heavy snow fall, earthquake etc. and requires check-up by man with the help of Theodolite, X-ray, Laser Beam etc. which does not provide the exact status information at the moment of the danger. Various Electronic measuring devices recently presented for permanent safety monitoring of large structures do not perform as highly reliably as required due to intrinsic technology limitation, complexity of the system and vulnerability by environmental effects.

Fiber Bragg Grating sensor overcomes some of the vulnerability but does not overcome the limitation enough. Recently Fibertron Co., Ltd. presented FOSSMOS (Fiber Optic Structural Safety Monitoring System) employing new **FBL (Fiber Bending Loss)** sensor so as to perform overcoming all the limitation, complexity and vulnerability to maximum satisfaction promising following benefits as

- Monitoring of Displacement, Deflection, Tilt, Acceleration, Elongation, Tilt etc.
by a System to alarm at emergency and prevent disaster
- Simple to install and operate
- No electricity, passive element only
- To minimize maintenance need of the structure

Comparison with other sensors

Item	Electronic Sensors	FBG Sensor	FBL Sensor
System Composition	Sensor-Readout-Data Logger- COM. - Sever	Single Sensor - Monitoring Unit	Various Sensors - Monitoring Unit
Sensor per System	Single	Single	Multiple
Displacement Range	100mm	100mm	1,000mm
Sensor-Monitor Distance	10m	1 km	10km current / 260km near future
Maintenance	Power for sensor/readout/Data Logger	Power for monitor near by sensor	No power
Environmental	Malfunctioning at Humidity, lightning, temperature	Limited at low temperature Degrade at repeated use	Immune to environment
Life time	5 yrs	5 yrs	15 yrs

FOSSMOS (Fiber Optic Safety Monitoring System) originates from the mother product **FOSM** (Fiber Optic Security Mesh) having worldwide proving performance.

Throughout worldwide installations at eminent facilities such as Korean Nuclear Power Plants, Airports, Oil&Gas Reservoirs, Korea Presidential Blue House, Singapore Ministry of Defense, ISTANA, Kuwait MoFA, Saudi ARAMCO/MODA/Palace, **FOSM** (Fiber Optic Security Mesh) was reputed as the unique foolproof – accurate – nuisance alarm free to comply with the purpose of PIDS overcoming the weakness and limitation of other types of sensors .

FOSM (Fiber Optic Security Mesh) operates based on Optical Radar Technology. The system injects Infrared Laser pulses into **FOM** (Fiber Optic Mesh) to identify intrusion from the presence of abnormal Optical echoes caused by either intruder cutting or excess force and pinpoints the intrusion spot on the monitor with audible & visible alarm at Security Control Center.

The fundamental technologies of **FOSM** was invented by Dr. Youn Bae in 1982 while serving as a researcher at Korea Agency for Defense Development (ADD) and later far upgraded gradually to the current level of commercial version by Dr. Bae team under Fibertron Co., Ltd. over 40 years.

FODSMOS which has long been developed by Dr. Bae team to present as new products in late 2020 shall perform in the same excellency as the mother product **FOSM** to the level far beyond of other technology reach. Thus any worry about its performance is actually unnecessary although **FOSSMOS** has no previous installation record yet because it is new,

Fibertron shall provide the brochure and videos to introduce the products first and submit technical proposal / commercial offer per specific site data.

FOSSMOS really wishes to be respected its performance as it is and to get order from the client. Order for a few pilot installations in small scale may be desirable by both Fibertron and client to carry out very quickly for confirming the performance at the operating site and then move forward in growing scale gradually.

