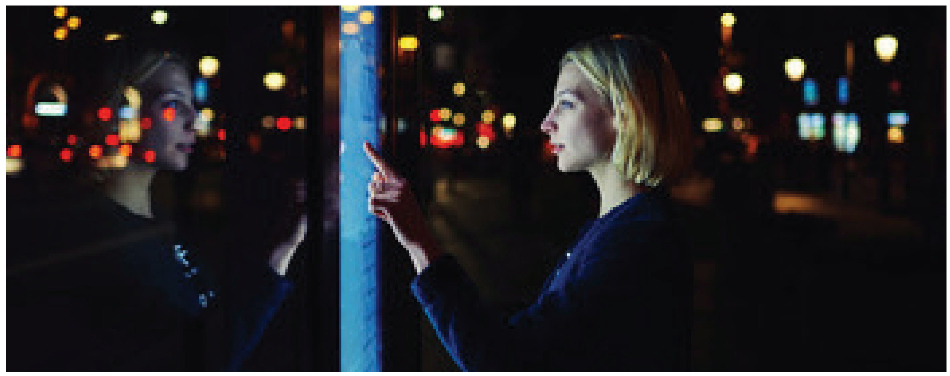
Innovation in Smart Cities via Sensory Fibre

The article discusses the sensing characteristics embedded in optical fibre that are set to create a new trend in monitoring the health of utility network, civil infrastructure as major elements of Smart cities...



Fibre sensing technologies mentioned in this article are for Utility/Structural/Infra health monitoring that STL can leverage being in fibre business. This feature details on the sensing characteristics embedded in optical fibre that are set to become trendsetters in monitoring the health of civil infrastructure, especially for upcoming technologies like bullet trains & smart cities for utility pipelines, dams, tunnels, bridges, residential & commercial complexes. One great add-on value with such fibre is that it not only serves as sensor but also acts as a communication media to send down the signals to central command centres.

Sensing via Optical fibre technology

Sensory fibres can be classified on the basis of Light characteristics (such as intensity, wavelength, phase or polarisation; whether sensing segment is inside or outside of fibre, and local, if it is quasi or fully distributed). Fibre optic sensors are majorly of two types: intension-metric and interfero-metric. Intension metric sensors rely on variations of the radiant power transmitted through an optical fibre. For examples a micro-bend sensor is a common intension-metric sensor, while interfero-metric sensors rely on measured induced phase change in light propagating through the optical fibre such as Fabry-Perot and Bragg grating.

The optical fibre sensing distribution can be of two types: spatial and fully distributed sensing techniques. For spatially distributed way of monitoring use technique Fibre Bragg Gratings (FBG) and for fully distributed sensing technique Raman DTS (Distributed temperature sensor) and Brillouin Optical Time Domain Reflectometry (BOTDR) can be used even for infra more than 100 Km with the ability to measure temperature & strain at thousands of point in a single fibre.

Major measurable parameters of these sensors include:

- **Stress:** When considering the safety of a structure, the maximum stress in a member due to live load, earthquake, wind, or other unexpected loadings must be checked not to exceed the allowable stress of a member. In allowable stress design of steel structures, if the maximum stress in a member reached the yield stress, the member is considered to be analogous to failure. Therefore, to guarantee the safety of a structure and its users, the maximum stress in a member must be monitored. In this case, the reliability of the evaluated safety depends on the number and location of point sensors.

- **Strain:** It is noticeable that due to the deformation measured is the average value measured, the strain variation or stress distribution of a beam can be considered by using several fibre optic sensors, and by means of these sensors the maximum strain or stress in a beam can be measured. The strain sensors consist of a fibre Bragg grating sandwiched between layers of carbon composite material and are about 50 mm long and 0.5 mm thick. The accuracy and sensitivity of the sensors are dependent upon the optical system.

- **Temperature:** Thermal expansion is an important factor in all types of structures where differential heating may occur, either from environmental effects, such as the solar heating of pavements and bridge decks, or from service conditions, such as in nuclear-reactor, pressure vessels or furnaces. The thermal expansion coefficient will be a variable quantity depending on materials. The Bragg wavelength λB , is related to the grating period, Δ , and the effective refractive index of the fibre eff n by λB eff = 2 nΔ . Subjecting the fibre to a change of temperature causes eff Δn and therefore λ to change.

- **Crack Monitoring:** The existing condition of many important concrete structures can be accessed through the detection and monitoring of cracking. Conventionally, crack detection and monitoring have been carried out by visual inspection. The procedure is time consuming, expensive, and yet unreliable. An optical fibre is embedded in the concrete element in a "zigzag"

Sterlite

shape and before the formation of cracks, the light intensity distribution along the fibre is measured. When a crack opens in the structure, fibre bend to stay continuous and consequently light intensity is changed.

- **Cable and Fibreglass reinforced plastic (FRP) monitoring:** With the development of the fibre optic sensing techniques, the applications of fibre optic sensors have been extended from the laboratory test to in site experiments. Some kinds of fibre optic sensors have been applied to the health monitoring of FRP and cable structures in recent years. They employed fibre optic sensors to monitor the strains of steel, FRP (fibre reinforced polymer), pre-stressing tendons, post-tensioning cables and etc. They can measure strain and temperature in arbitrary regions.

- **Bridge Monitoring:** The applications of fibre optic sensors to bridge monitoring are focused in measurement of short and long-term parameters of bridges. One of these bridges is the Mounted Bridge. Up to 100 fibres optic sensors were mounted inside the bridge and six locations were monitored in order to assess the strains at the centre of the bridge and the shear strains close to one of the supports of bridge. Another monitoring is presently being used in the construction of the bridge over River Ave, in Portugal. In this bridge, besides the Bragg grating sensors, conventional resistive strain gauges in concrete, reinforcing and pre-stressing steel and etc. were added.

- **Moisture Monitoring:** Corrosion can occur internally without this being evident from the outside. This is often due to the ingress of water corroding the reinforcements, which is hastened by the salts and chloride ions dissolved in it.

  At the moment, fibre optic based humidity sensor has been developed and used for the measurement of moisture absorption in concrete. The sensor was fabricated using a fibre Bragg grating coated with a moisture sensitive polymer. The sensor itself exploits the inherent characteristics of the fibre Bragg grating.

- **Welding Residual Stresses Monitoring:** This feature is combined with excellent stability and also with the possibility of having several optical fibres. As result of their features, a kind of sensors constitutes a very powerful tool for the analysis of welding transient and residual stresses. Under the assumption of a perfect bonding between the plate and the sensor, we are actually measuring transient and residual strains in the material being welded.

Other parameters may include curvature/bend sensors, electric and magnetic Field sensors, torsion/twist sensors, transversal loading sensors, refractive index sensors, vibration sensors, and multi-parameter sensing.

Fibre at the right time

Many of the newly proposed smart cities in India are Greenfield. In retrofit cities it is difficult to work out on monitoring of existing infra but in new cities it becomes quite easy to deploy the fibre along with deployment of existing infrastructure. In some case wireless sensors are also used in multiple applications of Smart cities but continuously powering them is big constraint, and putting these sensors across 100 Km of infra is not pragmatic.

Major implementation areas can be bridges, buildings, tunnels, wind turbines, Railway infrastructure, upcoming bullet trains project and utility pipelines in India.

Applications

Fibre optic sensors are used in several areas such as

- Measurement of physical properties such as strain, displacement, temperature, pressure, velocity, and acceleration in structures of any shape or size.

- Monitoring the physical health of structures in real time.

- **Buildings and Bridges:** Concrete monitoring during setting, crack (length, propagation speed) monitoring, pressurising monitoring, spatial displacement measurement, neutral axis evolution, long-term deformation (creep and shrinkage) monitoring, concrete-steel interaction, and post-seismic damage evaluation.

- **Tunnels:** Multipoint optical extensometers, convergence monitoring, shot Crete / prefabricated vaults evaluation, and joints monitoring damage detection.

- **Dams:** Foundation monitoring, joint expansion monitoring, spatial displacement measurement, leakage monitoring, and distributed temperature monitoring.

- **Heritage structures:** Displacement monitoring, crack opening analysis, post-seismic damage evaluation, restoration monitoring, and old-new interaction.

(The article has been authored by Madhukar Srivastava - Business Head, Vikram Singh Mains -Business Analyst & Deepak Sharma, Head - Solutions from Telecom Services Business)