

SENSORS

FIBER SENSORS PROVIDE 'WEIGH-IN-MOTION' INFORMATION

Advanced fiber sensor technology funded partly by MDA may have found a concrete application. The next step will be testing it in asphalt.

Intelligent Fiber Optic Systems, Inc. (IFOS, Sunnyvale, CA), is currently working with a state transportation department to test how well fiber-optic sensors embedded in concrete can provide "weigh-in-motion" information. A truck can drive over a concrete roadway equipped with sensors that relay the vehicle's gross weight and speed instantly and accurately to local or remote command centers. Such a sensor system can augment current weigh station networks and would obviate the need for truck idling time and perhaps even the need for weigh stations themselves. This would save transportation firms millions of dollars in wasted driver time and spent fuel, and save transportation departments precious budgetary resources in money and people.

The IFOS multi-sensor system is called I*Sense™ and some of its underlying technology was funded in Phase I and Phase II SBIR contracts by MDA and MDA's predecessor, BMDO, as early as 1995. The interest of the organization at that time was to investigate high-speed fiber Bragg grating (FBG) filters and other optical signal processing technology such as wavelength switching devices, with the intent of improving processing speed for optical sensors and potentially also for optical computing and telecommunications. The use of fiber systems as strain gauges and structural health monitoring evolved from that early work.

An FBG sensing system is extremely sensitive to almost any change in its environment, whether that be strain, temperature, pressure, displacement, or acceleration. The reason why is because of the way an FBG sensor works: any stretching or compression due to an external force changes the spacing of the grating—like

a Venetian blind being stretched out or squashed—and thus alters the center of the wavelength of the light reflected from the grating. In short, its reflectivity spectrum changes, and that change can be detected.

Placing multiple FBG sensors on a single strand of fiber is a tricky problem, since each sensor must have its own wavelength segment so that various signals do not overlap. As an FBG sensor undergoes strain, signals shift in wavelength within their bandwidth range. The



Feeling the pressure. IFOS' I*Sense multisensor system calculates environmental changes at high speed.

complete sensor system has an optical source that continuously monitors the sensors. The resulting reflection spectra are analyzed by an advanced photonic spectral analyzer and an interface module that records wavelength shifts.

In sum, the more sensors on a single strand, the harder it is to control. Accuracy in the light source and detection module is paramount, as is the specific wavelength-division-multiplexing technique used. The higher degree of accuracy often forces a low sampling rate. However, IFOS specializes in maintaining very high (kilohertz speed) sampling rates.

Fiber sensors are not new. Their advantages over traditional electronic sensors have to do with the fact that fiber is immune to electromagnetic interference, is lightweight, is electrically passive, can be multiplexed, has near-infinite lifespan, and can be embedded or laminated

into materials to operate in harsh environments. In many cases, their operation and maintenance is actually more cost-effective than a traditional counterpart.

The advantage of the IFOS I*Sense product suite is that IFOS takes customer requirements and then provides a tailored, complete sensing solution of both hardware and software. A customer wanting to measure the total weight of a truck as it passes over a section of highway doesn't need or want to know complex spectrum analysis—just the measured weight.

Weigh stations aren't the only commercial application of this previously exotic technology. Fiber sensors can be deployed in hard-to-reach places such as on oil and gas pipelines, to measure corrosion levels and possible intrusions on mile after mile of pipeline sections. Every day that a pipeline is shut down for inspection can cost millions of dollars, and the longer the pipeline, the more likely a shutdown. This is the kind of inspection process that can be done with fiber sensors remotely and automatically.

Weigh-in-motion trials on concrete surfaces have proven successful. IFOS intends to tackle the more complex problem of sensing asphalt surfaces, which are subject to more frequent changes in strain, temperature, and pressure. Most of the world's road surfaces are paved with asphalt, not concrete. For customers with any environmental sensing problems, IFOS welcomes inquiries on the I*Sense suite of products, services, and pricing.

—A. Gruen

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