Scalable Multi-Parameter Fiber Bragg Grating Interrogation System for Condition Based Maintenance

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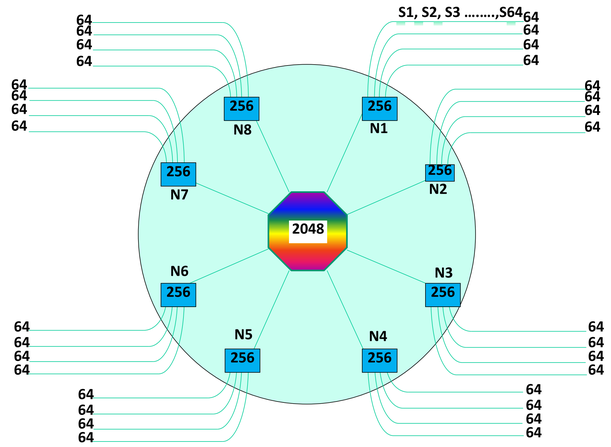
Introduction

IFOS has developed a broadband fiber optic sensor system architecture as a basis for dynamic structural state sensing (S3) and condition based maintenance (CBM). The architecture is scalable to support 2048 electromagnetic interference immune sensors for harsh environment applications. Each interrogation node supports 16 subsections with all sensors within a subsection interrogated simultaneously at sampling rates ranging from Hz to MHz. The 256-sensor architecture can be scaled to support over 2048 sensors by either increasing the number of fibers 8-fold for a node or increasing the number of nodes.

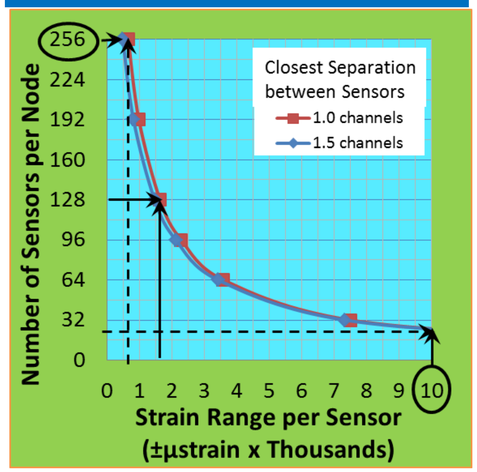


Potential Applications: Ships & Rotorcraft

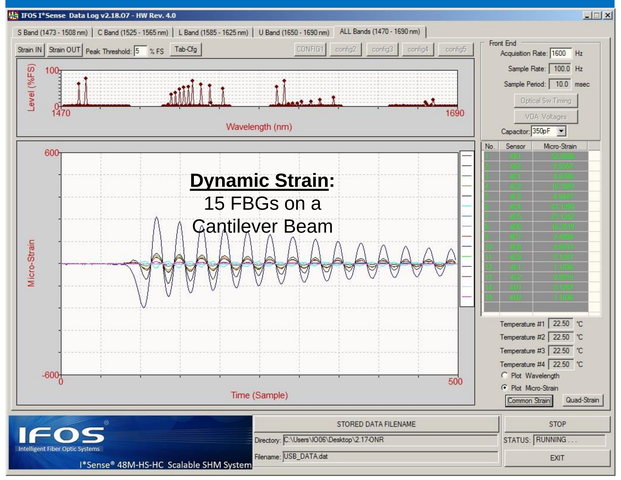
The same broadband sensors could provide monitoring of quasi-static loads, low frequency vibrations (to 100s Hz) for characterization of primary boat/blade motions during impact events with real-time strain state, and monitoring to MHz of high frequency acoustic emissions for damage detection. For rotorcraft, miniaturization and ruggedization are especially important and can be achieved with a < 200 cm^3 version supporting a reduced number of sensors with large (10,000 microstrain) strain range.



No. Sensor /Node

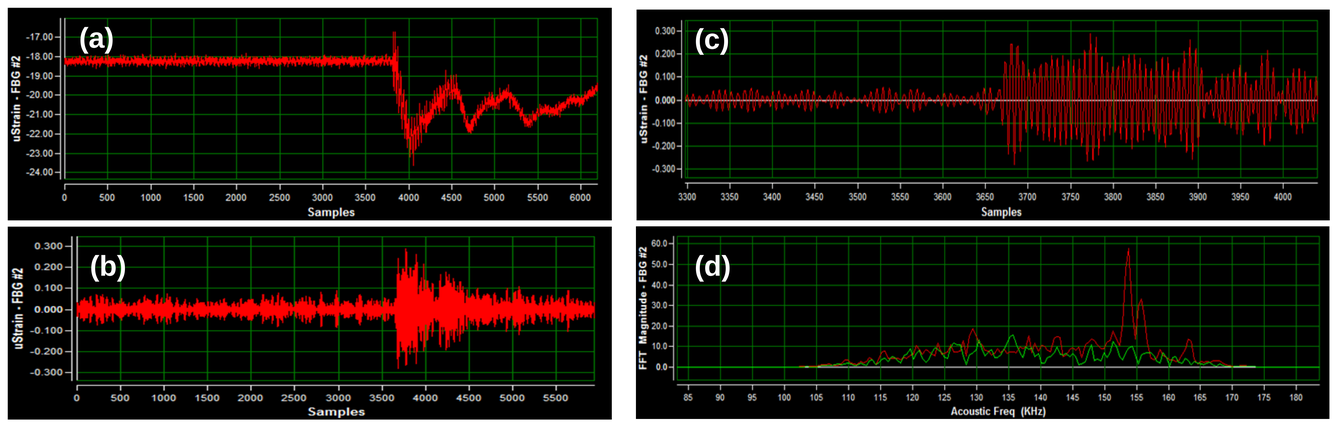


Dynamic Strain Measurements

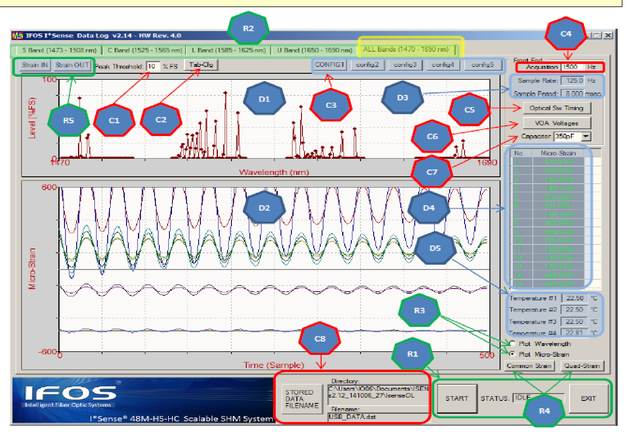


Acoustic Emission (AE) Monitoring for Damage Detection

Broadband detection allows the quasi-static strain change to be captured together with the acoustic emission (AE) event as shown in the pencil break test below on an aluminum coupon: (a) unfiltered strain, (b) with application of a bandpass filter between 105 and 170 kHz, (c) time zoom into the region of multiple AE events, (d) comparison of pre-trigger (green) and post-trigger (red) signals in the frequency domain



Interrogation node supporting up to 256 sensors on 4 fibers with 64 sensors on each fiber
Demo with cantilever beam containing 15 sensors & Software GUI shown below:



Conclusions

Up to many kilometers in length, optical fibers are small-in-diameter, light-in-weight, electromagnetic-interference immune, electrically passive, chemically inert, flexible, and embeddable into different materials. They enable distributed-sensing in harsh environments requiring temperature and radiation tolerance. With appropriate processing and packaging, they can be very robust and well suited to operational demands of harsh environments. The system IFOS has developed supports multi-parameter sensing with dynamic strain and temperature sensors being fundamental and derivative sensors, for parameters such as acceleration and pressure, being incorporated with special packaging. Acoustic emission (AE) detection is demonstrated with a MHz sampling rate version of the interrogator for groups of up to 24 sensors being sampled simultaneously on a single fiber. Example applications include ships, rotorcraft and aerospace vehicles.

Acknowledgments

We thank Dr. Ignacio Perez, ONR Program Officer for Navy SBIR Phase II Contract N00014-11-C-0437, and his colleagues for insightful comments and support.
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