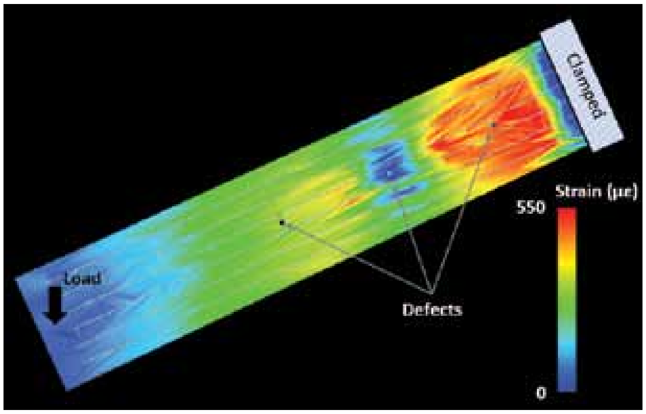
Structural and thermal measurement

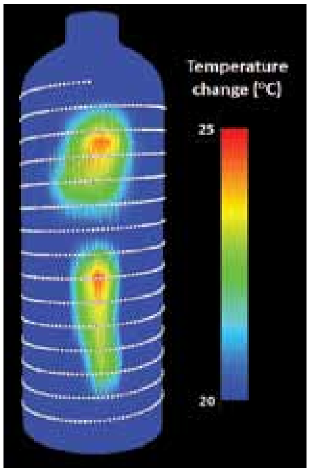
Luna Innovations' fiber optic measurement technique can help increase quality and safety in automotive design

The current shift in the automotive market toward electric vehicles is resulting in a move to offset battery pack weight by using carbon composite designs. This is resulting in a fundamental shift in measurement requirements of stress, strain and temperature. Standard sensor technologies such as resistive foil gauges for strain measurements and thermocouples for temperature, while readily available, are inherently limited in their ability to provide full-field information. Luna Innovations is applying its technological advantage in fiber optic measurement systems to distributed sensing applications. Luna has developed a fiber optic-based, fully distributed measurement technique that provides a much more detailed view of the strain and temperature gradients within a system. This technology enables low-cost, fully distributed sensing capabilities with millimeter spatial resolution and high dynamic range. The sensors themselves are small, lightweight, immune to EMI, radiation-resistant, and can be embedded in or adhered to a material's surface. These capabilities lead to new insights into materials that can result in better designs.

Carbon composites are being widely tested for use in both vehicle body panels as well as frames. Due to their non-homogeneity, performance properties are characterized through extensive and complex physical and mechanical testing with single point sensors. By definition, these do not provide an accurate full-field strain profile during testing. As an alternative, with a single optical fiber sensor, an entire body panel can be instrumented and tested in both static and fatigue loading. The sensor can be run in a grid pattern across the panel, resulting in the ability to measure strain gradients at a very high spatial resolution. This enables weak points of potential failure to be located and monitored. With a better understanding of the overall panel strength, its design can be optimized for cost savings without sacrificing structural integrity.

In addition, once a design has been finalized, the fiber sensor can be embedded into the panel or frame itself during the manufacturing process. This adds a previously inaccessible dimension to structural validation checks, either periodically or after a crash. A baseline strain profile of the body panel can be taken before the panel is shipped with the embedded sensor. During regular vehicle check-ups, the sensor can be scanned for changes in structural integrity over time. More importantly, after a crash, the strain profile can be measured for the effect of impact damage to the vehicle. This would now be a more objective method for verifying structural integrity, potentially resulting in improved safety.





TOP: Strain distribution in a carbon composite panel with a single embedded 5m fiber sensor. The panel is clamped at the root and loaded vertically downward at the tip. Strain gradients due to intentional defects are clearly visible

ABOVE: Temperature distribution on a vessel wrapped with a single 5m fiber sensor, with heating elements applied to two regions on the vessel

Obtaining a high accuracy temperature profile of each individual cell within an electric vehicle's battery pack would greatly improve the efficiency of the battery in terms of power output, as well as active control and regulation through the battery management system. Instead of being limited by the need to select individually specific temperature measurement locations and grappling with thermocouple electrical leads that threaten to short-out the battery pack, electrically immune fiber sensors can be installed between cells to traverse the entirety of the battery pack. Temperature measurements can therefore be reported from all cells, and could also include multiple measurements per cell. This greatly helps in optimizing the design of the battery pack, and ultimately reduces the risk to the customer.