**Phase-Controlled Magnetic Mirror for Wavefront Correction**

**Goddard Space Flight Center, Greenbelt, Maryland**

Typically, light interacts with matter via the electric field and interaction with weakly bound electrons. In a magnetic mirror, a patterned nanowire is fabricated over a metallic layer with a dielectric layer in between. Oscillation of the electrons in the nanowires in response to the magnetic field of incident photons causes a re-emission of photons and operation as a “magnetic mirror.” By controlling the index of refraction in the dielectric layer using a local applied voltage, the phase of the emitted radiation can be controlled. This allows electrical modification of the reflected wavefront, resulting in a deformable mirror that can be used for wavefront control.

Certain applications require wavefront quality in the few-nanometer regime, which is a major challenge for optical fabrication and alignment of mirrors or lenses. The use of a deformable magnetic mirror allows for a device with no moving parts that can modify the phase of incident light over many spatial scales, potentially with higher resolution than current approaches. Current deformable mirrors modify the incident wavefront by using nano-actuation of a substrate to physically bend the mirror to a desired shape.

The purpose of the innovation is to modify the incident wavefront for the purpose of correction of fabrication and alignment-induced wavefront errors at the system level. The advanced degree of precision required for some applications such as gravity wave detection (LISA — Laser Interferometer Space Antenna) or planet finding (FKSI — Fourier-Kelvin Stellar Interferometer) requires wavefront control at the limits of the current state of the art.

All the steps required to fabricate a magnetic mirror have been demonstrated. The modification is to apply a bias voltage to the dielectric layer so as to change the index of refraction and modify the phase of the reflected radiation. Light is reflected off the device and collected by a phase-sensing interferometer. The interferometer determines the initial wavefront of the device and fore optics. A wavefront correction is calculated, and voltage profile for each nanowire strip is determined. The voltage is applied, modifying the local index of refraction of the dielectric under the nanowire strip. This modifies the phase of the reflected light to allow wavefront correction.

This work was done by John Hagopian and Edward Wollack of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16008-1

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**Frame-Transfer Gating Raman Spectroscopy for Time-Resolved Multiscalar Combustion Diagnostics**

**John H. Glenn Research Center, Cleveland, Ohio**

Accurate experimental measurement of spatially and temporally resolved variations in chemical composition (species concentrations) and temperature in turbulent flames is vital for characterizing the complex phenomena occurring in most practical combustion systems. These diagnostic measurements are called multiscalar because they are capable of acquiring multiple scalar quantities simultaneously. Multiscalar diagnostics also play a critical role in the area of computational code validation. In order to improve the design of combustion devices, computational codes for modeling turbulent combustion are often used to speed up and optimize the development process. The experimental validation of these codes is a critical step in accepting their predictions for engine performance in the absence of cost-prohibitive testing.

One of the most critical aspects of setting up a time-resolved stimulated Raman scattering (SRS) diagnostic system is the temporal optical gating scheme. A short optical gate is necessary in order for weak SRS signals to be detected with a good signal-to-noise ratio (SNR) in the presence of strong background optical emissions. Time-synchronized optical gating is a classical problem even to other spectroscopic techniques such as laser-induced fluorescence (LIF) or laser-induced breakdown spectroscopy (LIBS). Traditionally, experimenters have had basically two options for gating: (1) an electronic means of gating using an image intensifier before the charge-coupled-device (CCD), or (2) a mechanical optical shutter (a rotary chopper/mechanical shutter combination).

A new diagnostic technology has been developed at the NASA Glenn Research Center that utilizes a frame-transfer CCD sensor, in conjunction with a pulsed laser and multiplex optical fiber collection, to realize time-resolved Raman spectroscopy of turbulent flames that is free from optical background noise (interference). The technology permits not only shorter temporal optical gating (down to <1 µs, in principle), but also higher optical throughput, thus resulting in a substantial increase in measurement SNR.

The new technology is an experimental method (or scheme) for isolating true Raman spectral signals from flames using a single CCD detector. It does not use an image intensifier or a mechanical shutter. Individual electrical or optical devices employed in this method are not
The microstrain gauges under study have been found to contribute significantly as safety monitors in lithium-ion cells that are designed even with hard metal cases. Although the metal cans do not undergo changes in material property, even under worst-case unsafe conditions, the small changes in thermal properties observed during charge and discharge of the cell provide an observable change in resistance of the strain gauge. Under abusive or unsafe conditions, the change in the resistance is large. This large change is observed as a significant change in slope, and this can be used to prevent cells from going into a thermal runaway condition. For flexible metal cans or pouch-type lithium-ion cells, combinations of changes in material properties along with thermal changes can be used as an indication for the initiation of an unsafe condition.

Lithium-ion cells have a very high energy density, no memory effect, and almost 100-percent efficiency of charge and discharge. However, due to the presence of a flammable electrolyte, along with the very high energy density and the capability of releasing oxygen from the cathode, these cells can go into a hazardous condition of venting, fire, and thermal runaway. Commercial lithium-ion cells have current and voltage monitoring devices that are used to control the charge and discharge of the batteries. Some lithium-ion cells have internal protective devices, but when used in multi-cell configurations, these protective devices either do not protect or are themselves a hazard to the cell due to their limitations. These devices do not help in cases where the cells develop high impedance that suddenly causes them to go into a thermal runaway condition. Temperature monitoring typically helps with tracking the performance of a battery. But normal thermistors or thermal sensors do not provide the accuracy needed for this and cannot track a change in internal cell temperatures until it is too late to stop a thermal runaway.

The microstrain gauges under study have shown remarkable changes in resistance with changes in temperature that show a very close tracking to the current used to charge and discharge the lithium-ion cells. As the cells are charged, there is a very slight increase in temperature at the end of charge, and the same during the discharge process. Although normal thermistors do not show a big change in temperature, the strain gauges have been able to track with great accuracy the thermal changes in the cells during these processes. Although strain gauges have been used to track pressures internal to cells in battery chemistries that use pressure vessels such as the Ni-hydrogen cells, they have not been used to track resistance changes due to temperatures. Existing thermal sensors do not have the sensitivity to be able to track small changes in internal temperatures of the cells, so monitoring systems cannot detect changes fast enough to be able to provide any protection. With lithium-ion cells, when the thermal sensors

The purpose of this innovation is to use microstrain gauges to monitor minute changes in temperature along with material properties of the metal cans and pouches used in the construction of lithium-ion cells. The sensitivity of the microstrain gauges to extremely small changes in temperatures internal to the cells makes them a valuable asset in controlling the hazards in lithium-ion cells. The test program on lithium-ion cells included various cell configurations, including the pouch type configurations.

The thermal properties of microstrain gauges have been found to contribute significantly as safety monitors in lithium-ion cells that are designed even with hard metal cases. Although the metal cans do not undergo changes in material property, even under worst-case unsafe conditions, the small changes in thermal properties observed during charge and discharge of the cell provide an observable change in resistance of the strain gauge. Under abusive or unsafe conditions, the change in the resistance is large. This large change is observed as a significant change in slope, and this can be used to prevent cells from going into a thermal runaway condition. For flexible metal cans or pouch-type lithium-ion cells, combinations of changes in material properties along with thermal changes can be used as an indication for the initiation of an unsafe condition.

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Thermal Properties of Microstrain Gauges Used for Protection of Lithium-Ion Cells of Different Designs

Commercial uses include lithium-ion batteries used in a human-rated environment, such as in automobile applications.

Lyndon B. Johnson Space Center, Houston, Texas

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