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MICROMETRIC POSITION MONITORING USING FIBER BRAGG GRATING SENSORS IN SILICON DETECTORS

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Abstract

We show R&D results including long term stability, resolution, radiation hardness and characterization of Fiber Grating sensors used to monitor structure deformation, repositioning and surveying of silicon detector in High Energy Physics.

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1 INTRODUCTION

FBG sensors are widely used in telecommunication as optical filters. For the first time we have used FBG sensors as optical, low-noise, high-resolution strain gauges to monitor structure deformation, repositioning, and surveying silicon (pixel and microstrips) detectors for HEP experiments at hadron machines. We show R&D results including long term stability, precision, resolution, radiation hardness and characterization.

2 FBG SENSORS

Fiber Bragg Grating (FBG) sensors have been used so far as telecommunication filters, and as optical strain gauges in civil and aerospace engineering [1], and, only recently, in HEP detectors [2]. The BTeV [3] detectors utilize FBG sensors to monitor online the position of the straw tubes, pixels, and microstrip. The optical fiber is used for monitoring displacements and strains in mechanical structures such as the straw tube-microstrip support presented here. A modulated refractive index along the FBG sensor produces Bragg reflection at a wavelength dependent on the strain in the fiber (Fig.1), permitting real-time monitoring of the support. According to these properties, an FBG sensor is going to be plced in the M0X structure between the Rohacell foam and the CFRP shell. Sensors will be located in spots of maximal deformation, as predicted by FEA simulation. Figure 2 shows long-term behaviour of FBG sensors while monitoring micron-size displacements, compared to monitoring via microphotographic methods.

3 LONG-TERM STABILITY AND RADIATION HARDNESS

The optical fiber is used for monitoring displacements and strains in mechanical structures such s the presented straw tubes-microstrip support. A wavelength selective light diffraction grating (Fig.1) along the FBG sensor is placed in the fiber, and it permits an on-time monitoring of the support. Fig.2 shows long-term behaviour of FBG sensors while monitoring micron-size desplacements, compared to monitoring via photografic methods.
Sensors have been tested for radiation damage. Fig.3 shows spectral response up to a neutron fluence of $1.6 \cdot 10^{13}$ 14-MeV neutrons/cm^2, corresponding to 6 months BTeV integrated dose.

4 THE OMEGA-LIKE REPOSITIONING DEVICE

FBG sensors have been also applied to instrument a novel repositioning device with micrometric resolution. The Omega-like device (shown as prototype in Fig.4,5) follows the displacement of the pixel detector designed for the BTeV experiment at the Fermila Tevatron which, at each accelerator store, has to be moved out and in of the beamline. Fig.6 shows a Finite Element Analysis of the Omega-like device. FBG sensor are located on area of largest strain in order to maximize sensitivity. Preliminary results show how a repositioning precision of about $10\,\mu$m is reached. Work is in progress to reach the required $3\,\mu$m precision.

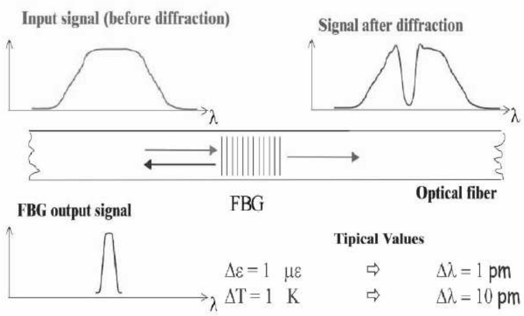

Figure 1: Principle of FBG sensors operation. A laser pulse is injected in the fiber and reflected selectively according to the grating pitch. Strain $\Delta\varepsilon$ changes the grating pitch thus changing the wavelength of reflected pulse. The sensors is also sensitive to temperature changes.

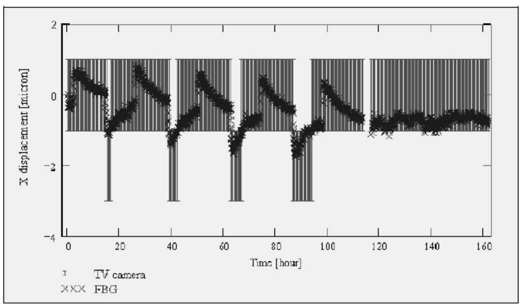

Figure 2: FBG long-term monitoring stability results. FBG output (crosses) is validated by TV camera (bars).

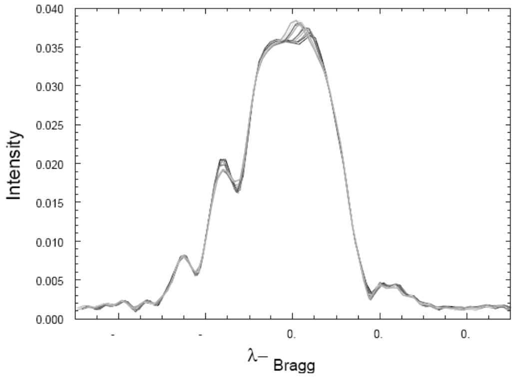

Figure 3: Radiation hardness of FBG sensors. Spectral response up to neutron fluence of $1.6 \cdot 10^{13}$ 14-MeV neutrons/cm^2, corresponding to 6 months BTeV integrated dose. No frequency shift is observed up to max irradiated dose.

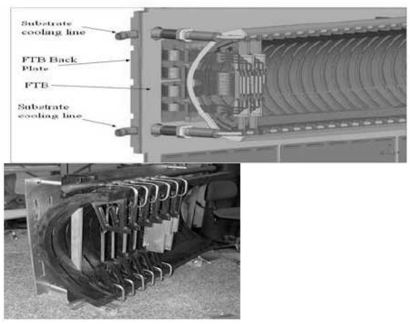

Figure 4: Sketch of BTeV pixel detector and its Carbon Fiber Reinforced Plastic support frame.

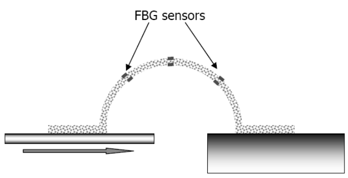

Figure 5: The Omega-like repositioning device, equipped with FBG sensors, follows the pixel support structure in and out of beam, assuring repositioning accuracy.

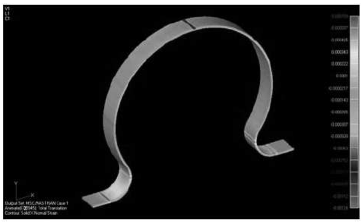

Figure 6: Finite Element Analysis of the Omega-like repositioning system. Sensors are located on the areas of larger mechanical strain in order to maximize sensitivity.

5 CONCLUSIONS

We have used FBG sensor in HEP for the first time as precise, stable, optical devices for micrometric position monitoring of silicon pixel and strips detectors. FBG sensors provide position monitoring with micrometric resolution. Under radiation with doses typical of year-long operation at hadron colliders they show no sign of spectral response shift. We have used sensors to characterize and optimize pixel support structures in Carbon Fiber Reinforced Plastic. Finally, we have proposed a novel device to precisely reposition the pixel detector in and out of the beams at each accelerator store. Preliminary results show a 10μm resolution, improvements are undergoing and we expect to reach the 3μm precision required by the experimental operation.

References

[1] S. Berardis et al., "Fiber optic sensors for space missions" 2003 IEEE Aerospace Conference Proceeding, Big Sky Montana, March 8-15, 2003, pp. 1661-1668.

[2] L. Benussi et al., "Results of Long-Term Position Monitoring by Means of Fiber Bragg Grating Sensors for the BTeV Detector", Frascati preprint LNF-03/15(IR).

[3] Fermilab Experiment E-0897/E-0918, J. Butler, S. Stone co-spokepersons; see www-btev.fnal.gov.