Fiber Bragg Grating (FBG) sensors as flatness and mechanical stretching sensors

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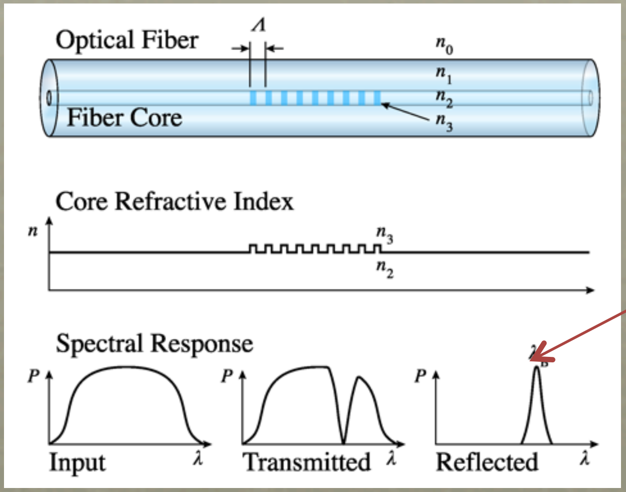
TOPICS

- What FBGs are
- The GE1/1 Chambers case
- The idea
- Very preliminary and encouraging results

WHAT FBGS ARE

A Fiber Bragg Grating (FBG) is a type of distributed Bragg reflector constructed in a short segment of optical fiber that reflects particular wavelengths of light and transmits all others. This is achieved by creating a periodic variation in the refractive index of the fiber core, which generates a wavelength-specific dielectric mirror. A fiber Bragg grating can therefore be used as a strain measurement tool, since variation of the Bragg grating translates into different light frequency response. The sensitivity of FBG in terms of strain (relative elongation w.r.t the initial position) is of the order of 0.1 micron.



What is useful is the light reflected by the grating

What FBG sensors are

Fiber Bragg Grating (FBG) sensors have been so far mainly used in high energy physics as high precision positioning and re-positioning sensor and as low cost, easy to mount and low space consuming temperature sensors. FBGs are also commonly used for very precise strain measurements (see reference below).

References:

The Omega-like: A novel device using FBG sensors to position vertex detectors with micrometric precision *L. Benussi et al. Nucl.Phys.Proc.Suppl. 172*

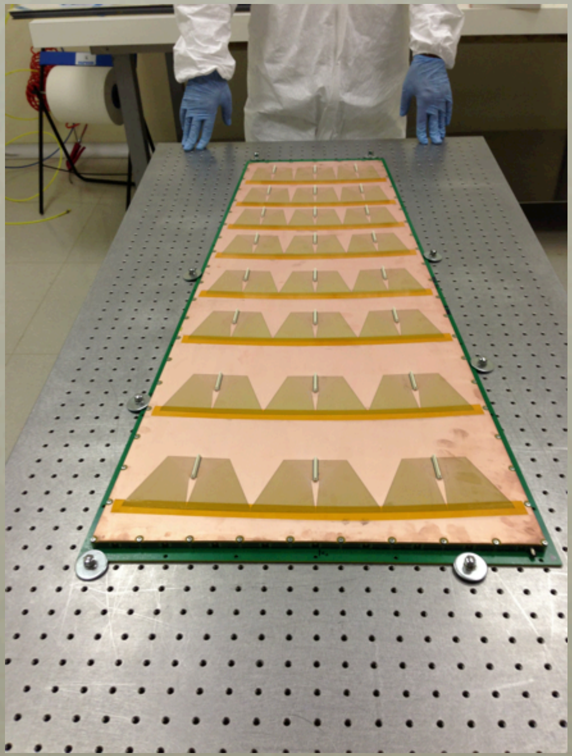
SiOx coated plastic fiber optic sensor for gas monitoring in RPC *S. Grassini et al. PoS RPC2012 (2012) 072*

Use of fiber optic technology for relative humidity monitoring in RPC detectors *M. Caponero et al. PoS RPC2012 (2012) 073, JINST 8 (2013) T03003*

Micrometric position monitoring using fiber Bragg grating sensors in silicon detectors *E. Basile et al Proceedings Villa Olmo 2005*

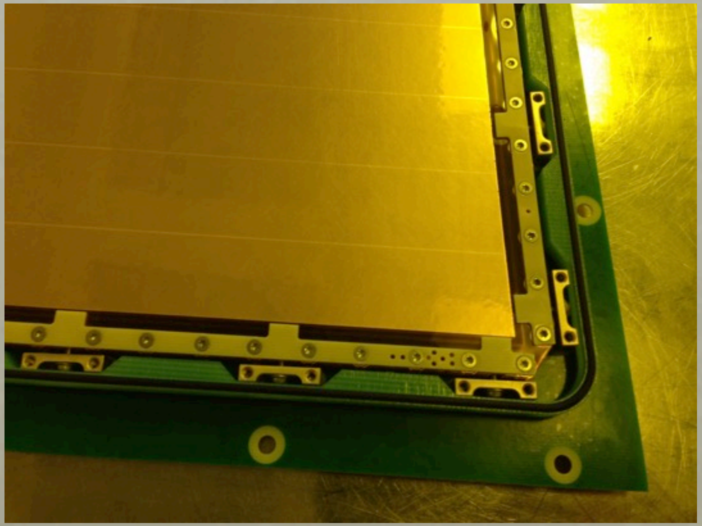
The GE1/1 chambers case

- The GE1/1 CMS upgrade consists of 144 GEM chambers of about 0.5 m^2 active area each and based on the triple GEMs technology, to be installed in the very forward region of the CMS end-cap. The large active are of each GE1/1 chamber consists of a single GEM foil (the GE1/1 chambers represent the largest GEM foils assembled and operated so far) to be mechanically stretched in order to secure its flatness and the consequent uniform performance of the GE1/1 chamber across its whole active surface.



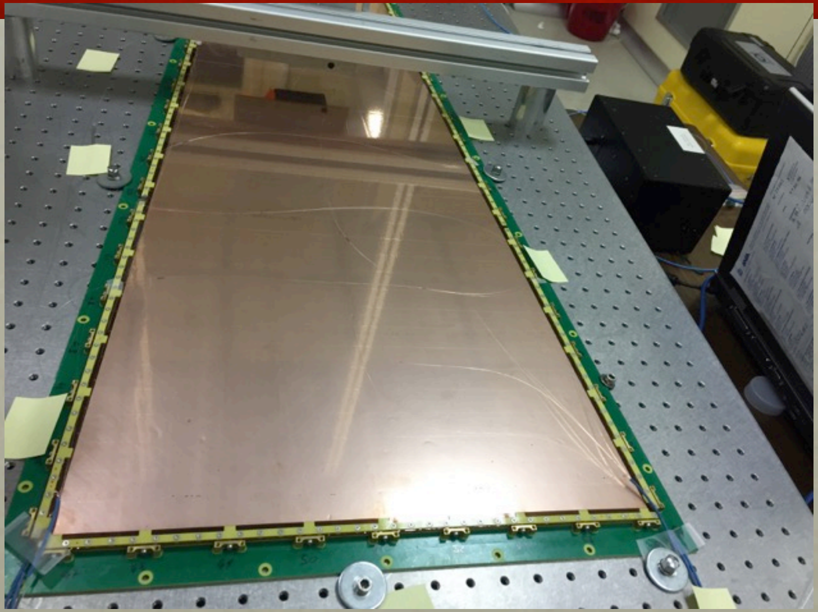
The GE1/1 Chambers case

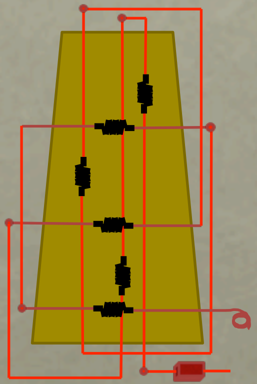
The GE1/1 chamber assembly procedure foreseen that foils will to be stretched by means of 55 screws placed around the chamber's lateral frame. These screws will pull the internal frame that keeps together the three GEMs. This brand new technology allows to assemble the whole chamber with any single drop of glue, speeding up sensibly the assembly time (couple of hours without the usual glue hardening time) and permitting to easily replace GEM foils that can be damaged during the assembly by simply disassembling the GEM stack. However this "glue-less" technology needed to be fully validated and one of the main concern raised by the CMS referees was to secure that the three GEMS are stretched in the same way up to the same operational tensile load.



The idea

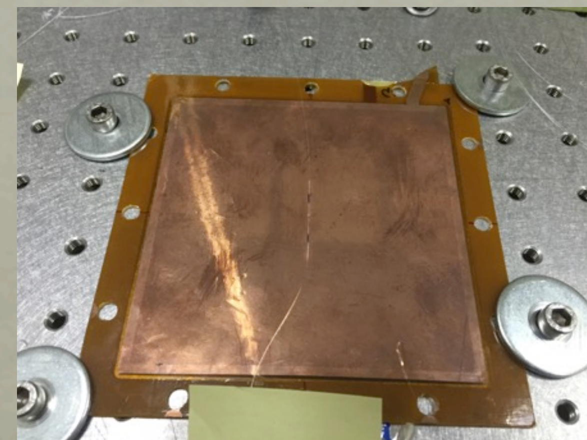
In order to confirm the GE1/1 assembly technology we glued a network of FBG sensors (fig. 4) on the three GEMs of a full scale GE1/1 prototype. The sensors active region is 1 cm long and the six sensors on the same foil are connected serially and read the the DAQ system. The sensors on the three foils are glued with the same pattern in the three layer. This allow to immediately compare the response of sensors located in the same corresponding point in the three different GEMs.

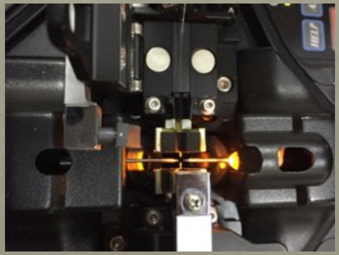


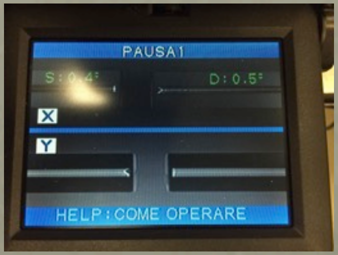


The Idea

Due to the extremely high sensitivity of FBG the thermal dilatation of the materials used need to be corrected. This is done by means of a FBG glued on the surface of a 10X10 GEM stretched into a small RF4 frame firmly fixed on the working bench. The response of the FBG on this small GEM allow us to cope the thermal effect since it is in the same temperature environment.







Very Preliminary and Encouraging Results

The test has been done in the following steps. During each step the FBG were continuously monitored and the data recorded:

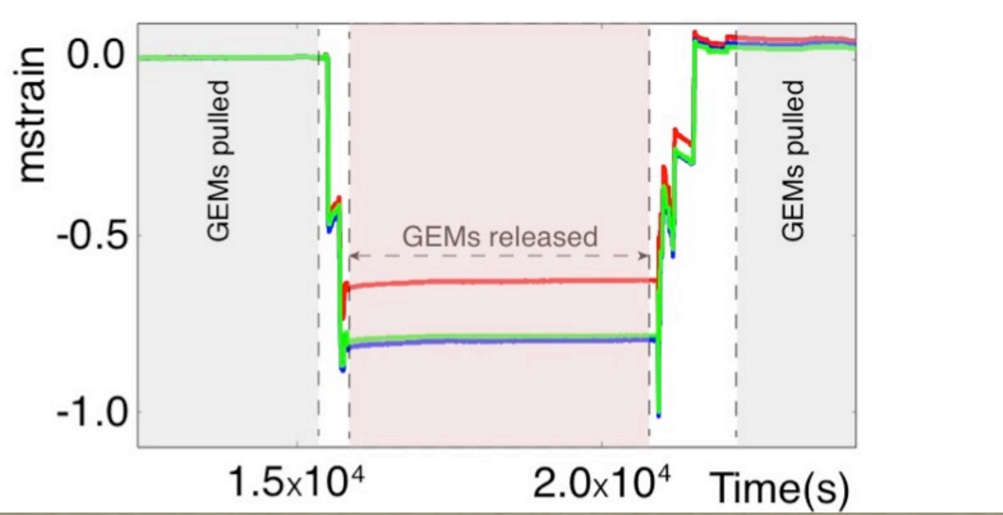
1) The chamber normally assembled with the GEM stack pulled to the nominal load

2) The GEMs have completely released and left for several our in this configuration

3) The GEMs have been pulled again up to the nominal load

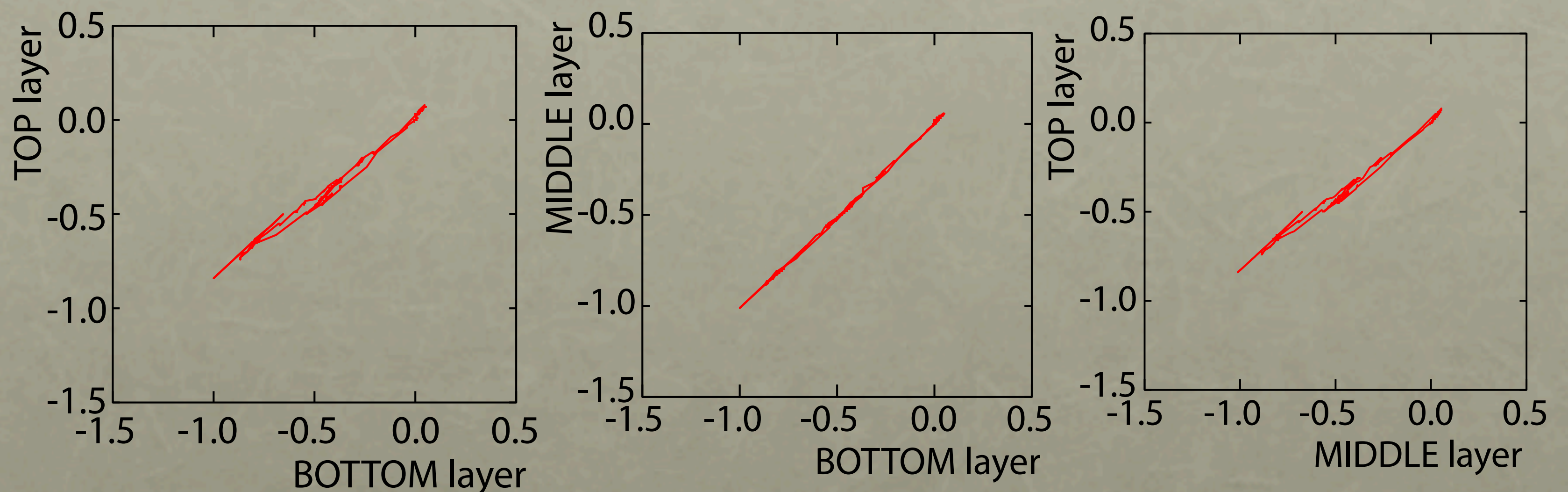
Very preliminary and encouraging results

The steps visible correspond to the actions during the un-screwing and screwing of the stack during the test. The red curve corresponding to the on the TOP GEM (TOP MIDDLE and BOTTOM mean the GEM foil position in the stack) of the stack have a sensible offset once the foil is loose due to the random position that in that point the GEM assumed with respect to the other two. As to the underlined that once the stack has been pulled to the nominal load again the sensors have almost recovered their initial length. It is immediate to observe that the sensors were reacting immediately in the same way.



Very preliminary and encouraging results

In the three lover plots of are shown the correlations of the three sensors response shone in the upper plot. It is almost useless to underline that the correlation of the sensors is almost perfect. Very similar plots can be obtained with all the other sensors. These results allow us to fully validate the no-glue technology assembly for the GE1/1 chambers.



Preliminary Considerations

- With the use of FBG sensors we successfully demonstrated that, the novel glue-less technique adopted to assemble the GE1/1 chambers for the LS2 update of CMS is reliable and secure the correct tensioning of the three GEM foils. Several tests are ongoing using the same FBG sensors to optimize the tensile load and the GEM foils planarity.
- Further test are ongoing to confirm other important parameters as the optimal tensile load to be applied to the GEMs, the maximum planarity obtainable for the GEMs without applying a load outside the "Young region" for the GEM.