DOI 10.5162/EUROSENSORSXXXVI/PT4.274

FOS4CMS: FBG monitoring in the CMS Experiment at CERN

Zoltan Szillasi[1,3], Francesco Fienga[2,3], Vincenzo Romano Marrazzo[2,3], Noemi Beni[1,3], Andrea Iracea[2], Salvatore Buontempo[4,3] and Giovanni Breglio[2,3]
[1] HUN-REN Institute for Nuclear Research (HUN-REN ATOMKI), H-4026 Debrecen, Hungary,
[2] Università degli Studi di Napoli Federico II, Department of Information Technology and Electrical Engineering (DIETI) IT-80125 Napoli, Italy,
[3] European Organization for Nuclear Research (CERN), CH-1211 Geneva, Switzerland,
[4] National Institute for Nuclear Physics (INFN), IT-80126 Napoli, Italy

Corresponding Author's e-mail address: Zoltan.Szillasi@cern.ch

Summary:

This paper provides an extensive overview of more than a decade of continuous data collected by the Fiber Optic Sensing for CMS (FOS4CMS) network, featuring over 1000 Fiber Bragg Grating (FBG) sensors. These FBG sensors have been instrumental in monitoring temperature and strain within the Compact Muon Solenoid (CMS) experiment at the Large Hadron Collider (LHC). Operational since 2009, the monitoring system underwent expansions during LHC Long Shutdowns (LS1 and LS2) and upgrades for LHC Run3.

Keywords: FBG sensor, CMS experiment, CERN, High energy physics

Introduction

In this document, we present data gathered by a network of approximately 1000 Fiber Bragg Grating (FBG) sensors, collectively known as FOS4CMS, pertains to temperature and strain measurements recorded during the operation of the Compact Muon Solenoid (CMS) experiment within the Large Hadron Collider (LHC) when colliding proton beams, as well as during maintenance periods over the course of the past fifteen years. This FBG data collection has been continuous, running 24/7 throughout this time frame. FBG sensors have been strategically positioned to monitor various aspects of the CMS experimental apparatus. paragraphs.

Materials and Methods

The CMS Experiment [1] features a highly intricate and extensive detector system, comprising a substantial superconductive magnetic solenoid capable of generating a magnetic field of up to 3.8T, accompanied by several sub- detectors designed to capture and quantify various elementary particles generated in the LHC collisions. This extensive detector spans dimensions of 21 meters in length, 15 meters in width, and 15 meters in height, residing in a cavern buried 100 meters below ground level. The CMS detector is segmented into distinct components: the primary body (referred to as the "barrel") consists of five disks, while the two extremities (known as the "endcaps") are constructed from four disks, each. Illustrated in Figure 1a, the detectors are composed of layered materials that leverage the distinct characteristics of particles to detect and measure their energy and momentum. The operation of the CMS Experiment is conducted under exceedingly complex environmental conditions, necessitating ongoing monitoring of temperature, structural integrity, relative humidity, and magnetic fields. At present, thorough monitoring covers the entire CMS area, aiming to gather real-time data on all subsystems, particularly crucial for temperature-sensitive equipment and precise thermal conditions.

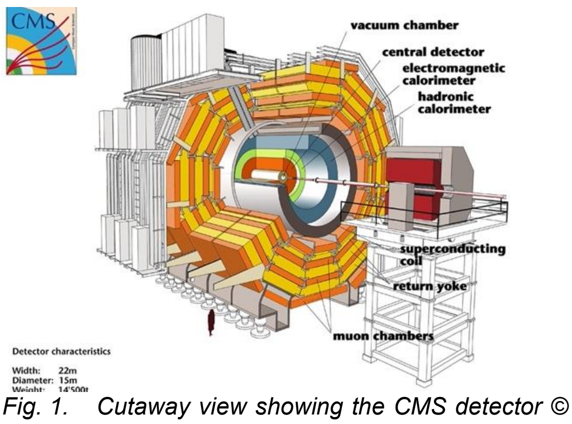

Fig. 1. Cutaway view showing the CMS detector © 2008-2023 CERN.

The existing multitude of detectors and electrical components within the CMS does not readily accommodate the installation of additional monitoring systems. Furthermore, the demanding operational conditions of the LHC, characterized by elevated levels of radiation and magnetic fields, often render conventional electronic sensors unsuitable for ensuring optimal functionality.

A noteworthy attribute of FBG sensors [2] is their spectral encoding, rendering them impervious to electromagnetic noise, optical carrier intensity modulation, and broadband-radiation-induced losses. Ionizing radiation primarily results in wavelength-dependent radiation-induced attenuation in optical fibers, as demonstrated in [3]. These unique characteristics empower the development of extended-distance sensing systems capable of operation in challenging environments, such as the underground experimental facilities at CERN.

Since 2009, our group has led the installation of FBG-based monitoring systems at CERN's underground CMS facility. Initially, the deployment included a gradual increase in the number of temperature and strain sensors, reaching a total of 200, which operated around the clock for a continuous three-year period during LHC collisions. Remarkably, these sensors functioned seamlessly without any interference with the CMS experiment's operational conditions [4].

From February 2013 to March 2015, the LHC underwent Long Shutdown 1 (LS1), during which our FBG monitoring system at the CERN CMS facility expanded. Throughout LHC Run2 (April 2015 to December 2018), the FOS4CMS system, comprising nearly one thousand FBG sensors, provided comprehensive coverage from the outer to inner components of the CMS experiment. Subsequently, during LHC LS2 (April 2018 to April 2022), we further expanded FOS4CMS. With the commencement of LHC Run3 in May 2023, the upgraded FOS4CMS system now monitors the CMS experimental apparatus.

The readout system for these FBGs relies on the Wavelength Division Multiplexing (WDM) technique, employing multiple interrogators whose outputs seamlessly integrate into the CMS Detector Control System [5].

Results

The results will be presented in the paper provides compelling experimental evidence affirming the robust viability of FBG sensors in the intricate and challenging environmental conditions of High Energy Physics (HEP).

The data cover a span exceeding fifteen years, showcasing the remarkable success of FBG measurements within the CMS experiment. Throughout this period, our FBG sensors actively monitored temperatures within the core of CMS, capturing strains in diverse locations during LHC collisions and under the influence of a high magnetic field.

References

[1] CMS collaboration, The CMS experiment at the CERN LHC, JINST 3 (2008) S08004; doi: 10.1234/s10000; doi: 10.1088/1748-0221/3/08/S08004

[2] K. O. Hill and G. Meltz, "Fiber Bragg grating technology fundamentals and overview," Journal of Lightwave Technology, vol. 15, no. 8, pp. 1263-1276, 1997; doi: 10.1109/50.618320

[3] Gusarov, A.; Hoeffgen, S.K. "Radiation Effects on Fiber Gratings". IEEE Trans. Nucl. Sci. 2013, 60, 2037-205; doi: 10.1109/TNS.2013.2252366

[4] M. A. Saccomanno, et al., Long-term temperature monitoring in CMS using fiber optic sensors, Sensors J., IEEE, Dec. 2012, pp. 3392-3398; doi: 10.1109/JSEN.2012.2205989

[5] Z. Szillasi, et al., One year of FOS measurements in CMS experiment at CERN, Phys. Procedia 37 (2012) 79-84; doi: 10.1016/j.phpro.2012.02.360