Metrological Evaluation of Optical Fiber Grating-Based Sensors: An Approach Towards the Standardization

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(Invited Paper)

***Abstract*—This paper discuss a set of tools for metrological evaluation of optical fiber grating sensors, including uncertainty analysis of the measurements. Background and definitions about basic specifications of the optical fiber grating sensors, such as response curve, calibration curve, sensitivity, resolution, repeatability, reproducibility and conformity are presented. Besides, the paper proposes the procedures to identify, quantify, and express uncertainties in optical fiber grating sensor measurements based on the International Standard Organization's Guide to the Expression of Uncertainty in Measurement. In order to illustrate the application of the approach, two fiber grating measuring systems were evaluated under the light of the methodology. The proposed route is a pragmatic step towards the standardization of optical fiber sensors.**

***Index Terms*—Optical metrology, sensor certification, uncertainty in measurement.**

I. Introduction

In recent years, optical fiber grating sensors based on fiber Bragg gratings (FBGs) and long period gratings (LPGs) have been widely investigated and several industrial applications of such transducers have been reported [1]–[6].

Grating sensors present some advantages that supported their development and stimulated its dissemination in many knowledge areas. These sensors have small physical size and low weight, features that make them appropriate for massive scale production of integrated optics and optoelectronic equipments. Besides, fiber grating sensors are normally made with dielectric materials which confer them electrical and chemical passivity, being appropriate for applications in hostile or corrosive environments or with risk of explosion. The grating sensors exhibit also electromagnetic immunity, low response time, as well as the possibility of wavelength encoding. Furthermore, these devices can present superior metrological characteristics when compared to conventional sensors [7]. However, the worldwide acceptance of this photonic technology requires the development of standards and guidelines for specification and testing based on optical metrology [8]. Technical and performance characteristics of the measuring system are fundamental to compare and select solutions. Anyway, mistakes still happen because there is great variety in the formulation and interpretation of such characteristics. Although of the extremely importance, there are just a few of works that report standard methods to determine quantitatively and qualitatively the optical fiber sensors performances.

In 1995 was published the first standard draft on generic specification for optical fiber sensors [9], shortly followed by the publication of the first draft for a specific type of optical fiber sensor (an optical fiber gyroscope) in 1996 [10]. In 1998, López-Higuera reports a brief attempt to unify criteria about basic specifications for optical sensors in general [7]. A specific guideline for the use of optical fiber sensors containing the definition of basic terms and the description of important sensor features was only released in 2009 [11]. This guideline brings important definition, but it does not detail any practical method to quantify the main metrological characteristics of the optical fiber sensor. Complementary literature has been reported in order to provide further details on this specific subject. For instance, also in 2009, a guideline for FBG strain sensor was published [12]. This guideline was developed to supply technical and scientific instruction, procedures for documentation and decision-making aids for manufacturers, distributors and users. A calibration for optical FBG strain sensors according to this guideline have already been reported [13].

Other important issue that must be addressed is the reliability in the measurement performed by optical fiber grating-based sensors, which is influenced by random and systematic errors. An accurate and precise measurement result can only be obtained if the error sources are identified, quantified and taken into account in the sensor response. Although calibration process can be used to compensate systematic effects, random effects cannot be completely eliminated. Such effects must be quantified and included in the sensor response by means of a doubt range called *uncertainty*, which reflects the lack of exact knowledge of the *result of the measurement*. Therefore, the *result of the measurement* after correction for recognized systematic effects is still only an estimate of the true value of the *measurand*, because of the *uncertainty* arising from random effects as well as from imperfect correction of systematic effects. Clearly *uncertainty* analysis is necessary, but this is often a not

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