

Accepted Manuscript

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PII: S0263-2241(18)30861-3

DOI: <https://doi.org/10.1016/j.measurement.2018.09.033>

Reference: MEASUR 5891

To appear in: *Measurement*

Received Date: 6 June 2018

Revised Date: 8 September 2018

Accepted Date: 12 September 2018

Please cite this article as: I. Floris, S. Sales, P.A. Calderón, J.M. Adam, Measurement uncertainty of Multicore Optical Fiber sensors used to sense curvature and bending direction, *Measurement* (2018), doi: <https://doi.org/10.1016/j.measurement.2018.09.033>

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Measurement uncertainty of Multicore Optical Fiber sensors used to sense curvature and bending direction

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Abstract

This paper describes a study of the influence of strain measurement uncertainty on sensing curvature and bending direction, considering one of the most widely used fiber geometries for sensing applications (7-core Multicore Fiber) with different core spacings (distance between outer cores and fiber axis). The Monte Carlo method was proposed to simulate the real measurement process and 33 simulations with 10^6 iterations were performed to determine the laws of propagation of strain measurement uncertainty in calculating curvature and bending direction. The outcomes, which show the strong influence of strain uncertainty and core spacing on the precision of Multicore Fiber sensors, can be used to support the design of new sensors or new fiber geometry and to predict their achievable performance.

Keywords: Fiber Bragg Grating; Multicore Fiber Optic; Curvature Sensing; Shape Sensing; Monte Carlo Simulation; Error Analysis.

1. Introduction

Recent developments in Optical Fiber Sensor (OFS) technology have made these sensors attractive for a number of medical [1], industrial and general engineering applications [2–5]. The reasons for these developments are the unique advantages of OFSs over electrical sensors, including their compactness and light-weight, immunity to electromagnetic interference (EMI), resistance to harsh temperatures, chemicals and radiation and intrinsic safety.

Multicore Fiber (MCF) Sensors for high-precision curvature sensing have many applications in Mechanical, Civil, Aerospace, and Medical Engineering. For example, an ultrasensitive multicore optical fiber-based vector bending sensor has been developed for continuously monitoring the verticality of buildings, towers, bridge piles, and other infrastructures [6], a curvature sensing multicore fiber displacement sensor has been used for tunnel monitoring [7] and a two-axis temperature-insensitive accelerometer has been developed based on an MCF curvature sensor [8].

Moreover, 3D shape analysis of elastic rod in shape sensing medical robot system have been performed with strain gauges [9] and flexible foil sensors based on strain gauge rosettes have been developed for surface reconstruction [10] and applied to respiratory monitoring [11]. Compared with electrical strain gauges, OFS are inherently electrical safe and not affected by electro-magnetic signal.

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