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Development and comprehensive investigation of a lightweight FBG accelerometer for small structure acceleration measurements

Muhammad Rais Rahim, MD Mofazzal Hossain and Mohd Firdaus Hassan*

Faculty of Mechanical & Automotive Engineering Technology, Universiti Malaysia Pahang Al-Sultan Abdullah, 26000 Pekan Pahang, Malaysia

E-mail: firdaus@umpsa.edu.my

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Abstract

Despite their sensitivity potential, diaphragm-type fiber Bragg grating accelerometers with inertia mass are often too complex and large, limiting their suitability for measuring small structures. Designing a suitable accelerometer for small structures, where its weight must be less than one-tenth of the measured structure, is challenging. This paper introduces a compact, simplified, and fabricable non-inertia mass FBG accelerometer (FBGA-SD), featuring a longer FBG tunnel and a through-hole for monitoring. The proposed FBGA-SD is 16 × 16 × 10 mm, weighing 4 grams. Numerical and experimental results show good agreement, though amplitude sensitivity differs by 50%. The experimental sensitivity is 9.64×10^{-2} pm g^{-1}, while transient response analysis gives 4.79×10^{-2} pm g^{-1}, valid for 10–100 Hz excitation frequencies and up to 10.5 m s^{-2} base acceleration.

Keywords: diaphragm-type FBG accelerometer, vibration, transient response analysis, lightweight FBG accelerometer, non-inertia mass

1. Introduction

The fabrication of the fibre Bragg grating (FBG) is based on the exposure of ultraviolet (UV) light to the optical fibre's core, which results in a permanent change in refractive index, creating the fixed index modulation [1–5]. When light propagates through the core and passes through the gratings, the FBG reflects a portion of narrowband light at a specific wavelength called the Bragg wavelength [2]. Recent advances in the development of FBG sensors are driven by their numerous advantages, which include their small size and lightweight nature, fast response, multiplexing capability, high sensitivity, long-term reliability, corrosion resistance, immunity to electromagnetic interference, and capability of transmitting signals over long distances without additional amplifiers [6, 7]. These advantages have led to the use of FBGs as accelerometers. FBGs technology has been continuously improved for use as an accelerometer in various applications, such as structure health monitoring, measurements, and seismic wave detection fields [8–11]. As technology progresses, researchers have developed a multi-dimensional FBG accelerometer [12] to meet the requirements of applications like robotics and aerospace. Due to its deficiency in comparison to commercially available accelerometers, in terms of durability, sensitivity, analytical and numerical modelling, and manufacturability, the FBG accelerometer is still being studied and developed.

Beam-type (FBGA-B) [9, 12–14] and cylindrical-type (FBGA-C) [8, 10, 11, 15] are the two most frequent types

* Author to whom any correspondence should be addressed.