Design and study of mechanical transducers for an optical-fiber accelerometer based on polarization effects

Pierre Tihon, Patrice Mégret, Marc Wuilpart, Olivier Verlinden

PII: S0263-2241(16)30478-X
DOI: http://dx.doi.org/10.1016/j.measurement.2016.08.017
Reference: MEASUR 4295

To appear in: *Measurement*

Accepted Date: 12 August 2016

Design and study of mechanical transducers for an optical-fiber accelerometer based on polarization e ects

Pierre Tihon[a,] , Patrice Mégret[b], Marc Wuilpart[b], Olivier Verlinden[a]

[a] *Department of Theoretical Mechanics, Dynamics and Vibration, University of Mons, Boulevard Dolez 31, 7000 Mons, Belgium*
[b] *Department of Electromagnetism and Telecommunications, University of Mons, Boulevard Dolez 31, 7000 Mons, Belgium*

Abstract

This paper presents di erent mechanical transducers designed to perform acceleration measurements with an optical fiber. The transducer subjected to a vibration deforms the fiber, inducing a birefringence variation that leads to the modulation of the light state of polarization. The di erent transducers are numerically and experimentally studied. In particular, the resonance frequencies and sensitivities are compared. For accelerations applied along the sensing axes, resonance frequencies from 1500 Hz to 3950 Hz are measured, with sensitivities that range from 4 10^{4} rad (m s^{2}) to 1 10^{3} rad (m s^{2}). However, lower-order vibration modes exist, that lead to high transverse sensitivities. A method to reduce these transverse sensitivities is presented.

Keywords: Accelerometer, optical fiber, transducer, state of polarization

1. Introduction

Vibration measurements are of high importance in structural health monitoring. Vibrations applied on a mechanical structure such as a bridge or an airplane wing can lead to the appearance of damage. Furthermore, the characteristics (amplitude, frequency range) of a vibration generated by a mechanical device can be influenced by the presence of damage. Vibration measurements are therefore useful for maintenance purposes.

Several studies have investigated the design of accelerometers based on optical fibers [1, 2, 3, 4, 5]. Optical fibers are small and lightweight. They can be used in harsh environments, in the presence of high temperature, aggressive chemicals or electromagnetic fields. They allow furthermore to perform distributed measurements (the measurand value can be obtained continuously along the fiber) or quasi-distributed measurements (the measurand value can be obtained at several locations along the fiber).

Di erent light properties can be used to perform the measurement: power, phase (in interferometric techniques), wavelength (mainly used with the Bragg gratings technology) or state of polarization (SOP). The approach presented in this paper is based on the SOP measurement. Polarization-based sensors do not require highly stable and narrow-band laser sources, which is the case for interferometry techniques. Moreover they show a low temperature sensitivity, contrary to Bragg gratings sensors.

In order to perform the acceleration measurements, a mechanical transducer must be used. The transducer converts the acceleration into fiber deformation, which induces a birefringence variation within the fiber. The aim of this paper is to propose and study di erent transducer designs. Numerical and experimental results will be presented to compare the resonance frequencies and sensitivities associated with the transducers. Accelerations applied along or perpendicular to the sensing axis will be investigated, in order to determine the nominal or the transverse sensitivities respectively.

A first transducer based on a flexible aluminium beam is presented to validate the technique. As it is cumbersome, a smaller, parallelepipedic transducer based on two steel parts linked by a silicone resin is proposed. However, numerical simulations show that the transducer response for transverse vibrations is higher than for vibrations parallel to the sensing axis. It is then proposed to fix the transducer on an U-shaped basis in order to reduce the transverse sensitivity.

First results about the aluminium beam sensor were presented in [6]. The nominal sensitivity was measured and simulated with the Abaqus software. In this paper the sensor response to a transverse excitation will also be numerically studied (the vibration modes and transverse sensitivities will be determined).

The parallelepipedic transducer without the U-shaped basis has already been presented in [7]. The nominal sensitivity and the resonance frequencies were measured and computed with Abaqus. In this paper, the transverse sensitivities will also be computed. Due to the high values obtained, the U-shaped basis has been designed. The behaviour of the parralelepipedic sensor fixed on the U-shaped basis will be investigated in this paper.

2. Background and experimental Set-up

Birefringence occurs in an optical fiber when its circular symmetry is broken. In this case, there exist two orthogonal states of polarization called eigenmodes, that propagate with di erent speeds. Due to the speed di erence, the optical phase

Corresponding author
Email address: pierre.tihon@umons.ac.be (Pierre Tihon)