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Fibre Bragg Grating and No-Core Fibre Sensors

Springer

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ISSN 2191-5423 ISSN 2191-5431 (electronic)
SpringerBriefs in Physics
ISBN 978-3-319-90462-7 ISBN 978-3-319-90463-4 (eBook)
https://doi.org/10.1007/978-3-319-90463-4

Library of Congress Control Number: 2018939013

Printed on acid-free paper

This Springer imprint is published by the registered company Springer International Publishing AG part of Springer Nature
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Alhamdulillah… Praised be to Allah s.w.t… Peace and Blessing be to Prophet Muhammad s.a.w…

While preparing this book, we were in contact with numerous researchers, academicians, and professionals. They have contributed toward the understanding and thoughts of physics and fibre sensors. In particular, we wish to express our sincere appreciation and gratitude to Prof. Dr. Jalil bin Ali from Faculty of Science UTM, Assoc. Prof. Dr. Hazri bin Bakhtiar from Laser Centre UTM, Nurul Amirah bt Yusof from Ministry of Health Malaysia, Muhammad Hakeem Anaqi, and Muhammad Hazeeq Arfan for their motivation, support, and patience. Last but not least, we like to thank our family members and friends for their endless support. Without their continued support and interest, the completion of this book would definitely impossible and keep in imaginary nature.

This book serves to design, construct, and analyze the optical FBG and NCF sensing system in indoor and outdoor environment, within different refractive indexes, under different solutions, and different temperatures. The FBG and NCF sensing system has been analyzed, the performance has been investigated, and the characteristics of the system have been reported. The performance of the system has been investigated in terms of Bragg wavelength shift, no-core wavelength, FWHM, and intensity. The fundamentals of FBG and NCF have been discussed in details. At the end, the model design of FBG and NCF sensing system has been developed successfully.

This book consists of six chapters, namely Introduction, Operational Principles of Fibre Bragg Grating and No-Core Fibre, Theory, Methodology, Research Finding, and Conclusion. The overview and motivations of this book are discussed in Chap. 1, which includes its objective. The principles of FBG and NCF are discussed in Chap. 2, which includes the writing techniques and preparation techniques of FBG and NCF. The historical perspective of FBG and NCF is also discussed in this chapter. In Chap. 3, the theoretical part of FBG and NCF is given. This includes the coupled mode theory analysis, operational principles of FBG and NCF, and characteristics of both FBG and NCF. Chapter 4 explains the experimental set-up and methodology used in the experiments, in order to prepare this book. Results, analysis, discussion, and evaluation of the performance of FBG and NCF sensing system are discussed in Chap. 5. Bragg wavelength shift and no-core wavelength are among the main criteria discussed in this book. At the end, the conclusions of this work are described in Chap. 6.

Hopefully, this book may lead to the fundamental study on FBG and NCF, especially in sensing field.

Johor Bahru, Malaysia

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Acknowledgements

The author wishes to extend the highest appreciation to Laser Center and Department of Physics, Faculty of Science, Universiti Teknologi Malaysia, for providing the research facilities toward the success of this project. Sincere appreciation also extends to all beloved friends and families who have provided assistance in various occasions, motivation, and supports. Without their continued support and interest, the completion of book would have been definitely impossible. Thank you very much.

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Prof. Dr. Jalil Ali received his Ph.D. in Plasma Physics from Universiti Teknologi Malaysia in 1990. At present, he is affiliated with Laser Center, Ibnu Sina Institute for Scientific & Industrial Research and Physics Department, Universiti Teknologi Malaysia as Professor of Photonics. During 1987–2010, he has held numerous faculty and research positions including the Dean/Director, Bureau of Innovation and Consultancy. He has authored/co-authored more than 300 research papers for international journals, 11 books, and a number of book chapters. His areas of interests are photonics, optical solitons, fibre couplers, nano waveguides, fusion energy, and so on. He is UTM's delegate member for African-Asian Association for Plasma Training (AAAPT). He also holds memberships of OSA, SPIE, and the Malaysian Institute of Physics.

Abbreviations

CMT	Coupled mode theory
DNA	Deoksiribonukleid acid
EMI	Electromagnetic interference
FBG	Fibre Bragg grating
FBGs	Fibre Bragg gratings
FOS	Fibre optic sensor
FOSs	Fibre optic sensors
FWHM	Full width at half maximum
HiBi	High birefringent
NA	Numerical aperture
NCF	No-core fibre
OSA	Optical spectrum analyzer
TLS	Tunable laser source

Symbols

a	Core radius
b	Wavelength position at 0 °C
B	Magnetic field
d	Power dip
dB	Decibel
E	Electric field
k	Propagating constant
$\vec{k}$	Propagating constant vector
$\vec{k}_1$	Modal wavevector of the forward-propagating wave
$\vec{k}_2$	Modal wavevector of the backward-propagating wave
$\vec{k}$	Grating momentum vector
L	Grating length
MHz	Mega Hertz
M_p	Fraction of fibre mode power
N	Number of grating plane
nm	nanometer
n_{cl}	Cladding refractive index
n_{co}	Core average index
n_{eff}	Effective refractive index
n_o	Average refractive index
n_1	Refractive index of fibre core
n_2	Refractive index of fibre cladding
$pm/°C$	picometer per degree Celsius
R	Reflectivity
$R(L,\lambda)$	Reflectivity in the function of length and wavelength
s	Fringe visibility of the index change
T	Temperature
z	Distance along the fibre longitudinal axis
α	Thermo-expansion coefficient
ξ	Thermo-optic coefficient

ε	Permittivity
μ	Permeability
ε_z	Strain
Ω	Coupling coefficient
Λ	Grating period
Λ_g	Grating spacing
Λ_{pm}	Phase mask period
λ	Wavelength
λ_B	Bragg wavelength
λ_{in}	Incident light
$\lambda_{B,0}$	Nominal Bragg wavelength
λ_{NCF}	NCF wavelength
λ_o	Initial wavelength
δL	Change of length
δn_{eff}	Change of refractive index
Δk	Detuning wavevector
Δn	Dept of index modulation
ΔT	Temperature change
$\Delta\lambda_B$	Bragg wavelength shift
$\Delta\lambda_{NCF}$	NCF wavelength shift
°C	Degree Celsius
°F	Degree Fahrenheit
%	Percentage

Abstract

A prototype of fibre Bragg grating (FBG) and no-core fibre (NCF) sensing system has been designed, constructed, developed, and evaluated. Indoor and outdoor FBG temperature sensor system has been developed where the commercial FBG has been tested under controlled environment (lab based) and uncontrolled environment (outdoor based). The sensitivity of the system has been evaluated in different refractive indexes of solutions, different placements of sensor, under focused and unfocused elements and under different temperatures. The NCF has been incorporated into the FBG and the performance of the system has been evaluated. The combination of FBG and NCF can be used as a very useful tracking system, especially for the temperature and surrounding refractive index (SRI) sensing. For the purposes, TLS was used as the broadband light source and the output spectra been displayed through the OSA, where both transmission and reflection spectra of the system have been analyzed. The performance of FBG and NCF has been investigated in terms of Bragg wavelength shift, no-core wavelength, FWHM, and power dip. The sensitivity of FBG and NCF were calculated using the related formula, based on the data taken. Results show that the sensitivity of FBG and NCF system is directly proportional to the temperature change and SRI number, for both indoor and outdoor environment. Thus, a prototype FBG and NCF sensing system has been developed successfully.