

Terahertz Waveguides: A Study of Microwires and Porous Fibres

by

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Contents

Contents	iii
Abstract	vii
Statement of Originality	ix
Acknowledgments	xi
Conventions	xv
Publications	xvii
List of Figures	xxi
List of Tables	xxvii
Chapter 1. Introduction and Motivation	1
1.1 THz waveguides	2
1.2 Thesis overview	6
1.3 Summary of original contribution	8
Chapter 2. Review of THz generation, detection and waveguides	11
2.1 Introduction	12
2.1.1 Objective and framework	15
2.2 Generation and detection of THz pulses	15
2.2.1 Terahertz sources	16
2.2.2 Terahertz detectors	17
2.2.3 THz radiation generation and detection based on photoconductive antennas	20
2.3 Terahertz waveguides	23
2.3.1 Metallic waveguides	25
2.3.2 Dielectric Waveguides	35
2.4 Chapter Summary	55

Chapter 3. THz microwires	61
3.1 Introduction	62
3.1.1 Objective and framework	62
3.2 Optical Nanowires	62
3.3 Dielectric properties of the bulk materials in THz	64
3.4 Microwires	72
3.4.1 Electric and magnetic field distributions	74
3.4.2 Power fraction and effective area	79
3.5 Signal degradation in THz microwire	83
3.5.1 Loss mechanisms	84
3.5.2 Dispersion mechanisms	95
3.6 Chapter Summary	102
Chapter 4. THz porous fibres: concept and modelling	105
4.1 Introduction	106
4.1.1 Objective and framework	106
4.2 Sub-wavelength air-hole in a dielectric waveguide	107
4.3 Concept of THz porous fibre	109
4.4 THz characteristics of porous fibre	121
4.4.1 Power fraction and effective area	121
4.4.2 Loss and confinement	124
4.4.3 Dispersion	130
4.5 Chapter Summary	135
Chapter 5. Porous fibres: design, fabrication and cleaving	139
5.1 Introduction	140
5.1.1 Objective and framework	143
5.2 Porous fibre fabrication based on extrusion	144
5.3 Cleaving of extremely porous polymer fibres	150
5.3.1 Semiconductor dicing (SD) saw	151
5.3.2 Focused ion beam (FIB) milling	155
5.3.3 UV 193 nm laser	156
5.4 Modelling of fabricated porous fibres	160
5.5 Chapter Summary	164

Chapter 6. THz characterization of porous fibres	167
6.1 Introduction	168
6.1.1 Objective and framework	171
6.2 Characterization of waveguides	171
6.3 Porous fibre characterisation	172
6.3.1 First characterisation technique	173
6.3.2 Second characterisation technique: probing the evanescent field . .	181
6.4 Chapter Summary	197
Chapter 7. Conclusion and future work	203
7.1 Introduction	204
7.2 Thesis summary and author's contribution	204
7.3 Potential future directions	207
7.3.1 Mode profile of THz microwire and porous fibre	207
7.3.2 THz beam coupling into THz microwire and porous fibre	207
7.3.3 Bending loss of the THz microwire and porous fibre	208
7.3.4 THz microwire as a biosensor	208
7.3.5 THz porous fibre as a biosensor	209
7.4 Chapter summary	209
Appendix A. Derivation microwire equations	211
Appendix B. Data processing algorithms	217
B.1 Conventional THz-TDS analysis program	218
B.1.1 Main mfile	218
B.1.2 Functions	219
B.2 THz waveguide analysis program	224
B.2.1 Main mfile	224
B.2.2 Functions	227
B.3 Microwire	229
B.3.1 Main mfile	229
B.3.2 Functions	230
B.4 Porous fibre	233
B.4.1 Main mfile	234

Appendix C. Equipment for THz measurements	243
Bibliography	245
Glossary	259
Acronyms	261
Biography	263

Abstract

This Thesis reports the development of fibres to guide terahertz (THz) or T-ray radiation. It demonstrates the theoretical studies of THz microwires (air-clad solid core fibres) and a new form of waveguide: the *porous* fibre. Porous fibre has an arrangement of sub-wavelength featured air-holes in the cross-section, resulting in improved confinement of the propagating mode while retaining the low loss characteristic compared to air-clad sub-wavelength waveguide or microwires. Porous fibres also offer lower frequency dependent loss and dispersion compared to microwires. Furthermore, introducing asymmetrical discontinuity leads to high birefringence, which is comparable to recently achieved high birefringence in photonic crystal fibres.

Furthermore, this thesis involves the first successful fabrication of highly porous polymer fibres, with both symmetrical and asymmetrical discontinuities, via an extrusion process. In order to achieve rapid and reproducible waveguide cross-sections three different cleaving techniques—based on the use of a semiconductor dicing saw, focused ion beam milling, and a 193 nm ultraviolet laser—have been investigated for cleaving of polymer porous fibres.

Finally, two different techniques have been utilised for characterisation of porous fibres. The first approach leads to the first experimental verification of frequency dependence of effective refractive indices of polymer porous fibres and microwires. The second approach exploits a micromachined photoconductive probe-tip for sampling of the THz pulse along the waveguide, from which the frequency dependent absorption coefficient and refractive index are determined. Moreover, the evanescent field distribution of porous fibres as a function of frequency is measured for the first time.

Statement of Originality

This work contains no material that has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Shaghik Atakaramians and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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12 January 2011

Signed

Date

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Conventions

Typesetting This thesis is typeset using the L^AT_EX₂ε software. T_EXnicCenter is used as an effective interface to L^AT_EX.

Referencing The Harvard style is used for referencing and citation in this thesis.

Spelling Australian English spelling is adopted, as defined by the Macquarie English Dictionary (Delbridge 2001).

System of units The units comply with the international system of units recommended in an Australian Standard: AS ISO 1000—1998 (Standards Australia Committee ME/71, Quantities, Units and Conversions 1998).

Physical constants The physical constants comply with a recommendation by the Committee on Data for Science and Technology: CODATA (Mohr and Taylor 2005).

Frequency band definition It is preferable to refer to the spectral band from 0.1 to 10 THz as ‘T-rays’, according to an argument by Abbott and Zhang (2007). T-rays have frequencies that correspond to the so-called ‘Terahertz-gap.’ Thus in the field, when we refer to ‘terahertz radiation’ this is an alternative form for T-rays. In this context, the term ‘terahertz radiation’ is understood as meaning ‘radiation in the terahertz-gap’ or T-rays and the word ‘terahertz’ is not to be confused with the units of terahertz that span three decades from 10¹² Hz.

Publications

Journal Articles

1. **Atakaramians S.**, Afshar V. S., Nagel M., Rasmussen H. K., Bang O., Monro T. M., and Abbott D., “Direct probing of evanescent field for characterization of porous terahertz fibers,” *Appl. Phys. Lett.*, **vol. 98**, 121104, 2011.
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3. **Atakaramians S.**, Afshar V. S., Nagel M., Ebendorff-Heidepriem H., Fischer B. M., Abbott D., and Monro T. M., “THz porous fibers: design, fabrication and experimental characterization,” *Optics Express*, **vol. 17** (19), pp. 14053–14062, 2009.
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2. **Atakaramians S.**, Franke H., Abbott D., Monro T. M., and Fumeaux C., “Application of full-wave electromagnetic solvers to micro/nano-structured fibres,” *ACOLS/ACOFT*, Adelaide, Australia, pp. 473-474, December 2009.
3. Ebendorff-Heidepriem H., Afshar V. S., Warren-Smith S. C., Zhang W. Q., Ruan Y., **Atakaramians S.**, and Monro T. M., “Fibres with subwavelength features: fabrication and novel guidance properties,” *ACOLS/ACOFT*, Adelaide, Australia, pp. 28-29, December 2009.
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5. **Atakaramians S.**, Afshar V. S., Nagel M., Ebendorff-Heidepriem H., Fischer B. M., Abbott D., and Monro T. M., “Experimental validation of low dispersion and high birefringence properties of THz polymer porous fibers,” *The 18th International Conference on Plastic Optical Fibers*, Sydney, Australia, September 2009.
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List of Figures

1.1	Terahertz band in the electromagnetic spectrum	3
1.2	Thesis outline and original contribution	7
<hr/>		
2.1	Primary methods of generation, and detection of single-mode THz pulses .	14
2.2	THz generation in non-linear media	17
2.3	THz generation from accelerating electrons	18
2.4	THz generation from lasers	19
2.5	Coherent detection of THz radiation	20
2.6	Generation of THz radiation from a PC antenna	21
2.7	Schematic diagram of a dipole, strip-line and bow-tie PC switches	22
2.8	Detection of THz radiation from a PC antenna	23
2.9	Circular and rectangular cross-section metallic waveguides	27
2.10	Parallel-plate waveguide and interconnect	28
2.11	Bare metal wire experimental setup	31
2.12	Sommerfeld wire experimental set-up I	32
2.13	Sommerfeld wire experimental set-up II	32
2.14	Metallic slit waveguide experimental set-up	34
2.15	Single dielectric ring (pipe) waveguide and the experimental set-up	38
2.16	Hollow-core microstructured band-gap fibre	41
2.17	THz Bragg fibres	44
2.18	Bragg fibre experimental set-up	46
2.19	Hollow-core microstructured Kagomé fibres	47
2.20	Sub-wavelength air-clad dielectric fibre experimental arrangement	51
2.21	Solid-core microstructured fibre and the experimental arrangement I	53
2.22	Solid-core microstructured fibre and experimental arrangement II	54
2.23	Schematic of a dielectric slit rectangular and tube waveguides, and electric field enhancement	54

3.1	Optical nanowires	63
3.2	Glass and polymer samples	65
3.3	T-Ray 2000 TM system	66
3.4	Experimental setup	67
3.5	Determination of the THz dielectric properties from reference and sample pulses	71
3.6	Dielectric properties of the glass and polymer materials	72
3.7	Normalised electric fields of the fundamental mode	75
3.8	Normalised magnetic fields of the fundamental mode	76
3.9	Normalised Poynting vector distribution of the fundamental mode	77
3.10	Normalised Poynting vector distribution of the fundamental mode	78
3.11	Enhancement of the electric field in the lower refractive index medium	80
3.12	Power fraction and effective area of microwires	82
3.13	Scalar and vectorial effective area of a PMMA microwire	83
3.14	Dielectric waveguide	86
3.15	Effective loss of COC, PMMA, F2, SF6, SF57 and bismuth microwires	88
3.16	Contribution of transverse- and z -components of electric field on α_{eff}	89
3.17	Bend loss and critical bend radius of microwires	92
3.18	Correlation of the bend loss and effective area	93
3.19	Total loss: effective material and bend losses	95
3.20	Comparison of our results with Chen <i>et al.</i> (2006)	96
3.21	Material dispersion of the polymer and glass samples	98
3.22	Effective refractive indices, phase velocity and group velocity of PMMA and bismuth microwires	100
3.23	Waveguide dispersion of PMMA and bismuth microwires	101

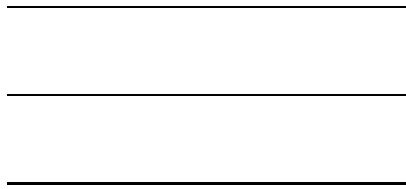
4.1	The electric field enhancement inside the central bore of a hollow core fibre	108
4.2	Power profile distribution of a porous fibre with triangular lattice	112
4.3	Numerical simulation steps of the full geometry of a PMMA porous fibre	114

4.4	Electric and magnetic field distributions of the fundamental mode	116
4.5	Numerical simulation steps of a quarter geometry of a PMMA porous fibre	118
4.6	Impact of the solution region dimension on the porous fibre parameters . .	119
4.7	Impact of the finite-element dimensions on the porous fibre parameters . .	120
4.8	Effective refractive index of three porous fibres and a microwire as a func- tion of core diameter	122
4.9	Power fraction of three porous fibres and a microwire as a function of core diameter	123
4.10	Effective area of three porous fibres and a microwire as a function of core diameter	125
4.11	Effective material loss of three porous fibres and a microwire as a function of core diameter	126
4.12	Normalised effective area versus effective material loss of three porous fibres and a microwire	127
4.13	Sketch of a bent waveguide	128
4.14	Fraction of power radiated for a porous fibre and microwire as a function of effective material loss for two different bend radii	129
4.15	Signal degradation due to the frequency dependence of the host material loss for a porous fibre and microwire	130
4.16	Different shapes of sub-wavelength air-holes in porous fibres and their nor- malised power distribution	131
4.17	Effective material loss of porous fibres with symmetrical and asymmetrical shaped sub-wavelength air-holes	133
4.18	Normalised group velocity of four porous fibres (symmetrical and asym- metrical sub-wavelength air-holes) and a microwire	134
4.19	Modal birefringence of four porous fibres (symmetrical and asymmetrical sub-wavelength air-holes) and a microwire	136
<hr/>		
5.1	Cross-section of porous preforms and fibres fabricated employing stacking and structured molding approach	142
5.2	Preform extrusion process	145
5.3	Designed die exit cross-sections	146

5.4	Photograph of the cross-sections of the extruded polymer porous preforms	148
5.5	Fibre drawing tower and porous fibre cross-sections	149
5.6	SEM images of cleaved end-face of PMMA porous fibres using a conventional blade and heating up the blade before hand	152
5.7	Images of SD saw machine	153
5.8	SEM images of SD saw cleaves	154
5.9	Images of FIB milling machine	155
5.10	SEM images of FIB milling cleaves	156
5.11	Schematic of the UV cleaving setup	157
5.12	SEM images of UV cleaves	158
5.13	Side-view images of UV cleaves	159
5.14	Progression of UV cleave	160
5.15	THz modelling of the <i>ideal</i> and <i>real</i> polymer porous fibres	163

6.1	Standard THz measurement systems employed for characterisation of THz waveguides	170
6.2	Schematic of the THz-TDS setup I for waveguide characterisation	174
6.3	Images of the waveguide holders	175
6.4	Measured THz signals and spectral amplitudes of PMMA porous fibres and a microwire	177
6.5	Effective material loss and effective refractive index of PMMA porous fibres and a microwire	179
6.6	Measured THz signals and spectral amplitudes of PMMA rectangular porous fibres	180
6.7	Absorption coefficients and effective refractive indices of a PMMA rectangular porous fibre	181
6.8	Output coupler for sampling THz pulses	182
6.9	The image of the probe-tip detector	183
6.10	Schematic of the THz-TDS setup for waveguide characterisation	185
6.11	Measured THz signal and spectrum	186
6.12	System parameters variation in time	187

6.13	Spectral amplitude variation in time	188
6.14	Image of a section of the experimental setup	189
6.15	Three methods employed for input coupling into the waveguides	190
6.16	Measured THz signal, spectrum amplitude, and THz properties of a 600 μm COC spider-web porous fibre	193
6.17	Monitoring the alignment of the probe-tip	194
6.18	Measured THz signal, spectrum amplitude, and THz properties of a 540 μm diameter COC spider-web porous fibre	199
6.19	Measured THz signal with and without waveguide in the system	200
6.20	Frequency-dependent radial field distribution of a 600 μm diameter COC spider-web porous fibre	201



List of Tables

2.1	Characteristics of ultrafast photoconductive materials	22
2.2	Summary of key parameters of THz metallic waveguides	57
2.3	Summary of key parameters of THz hollow-core dielectric waveguides	58
2.4	Summary of THz solid-core dielectric waveguides	59
3.1	Composition of heavy metal oxide glasses	65
C.1	List of equipment used at University of Adelaide A	244
C.2	List of equipment used at University of Adelaide B	244

