Terahertz Waveguides: A Study of Microwires and Porous Fibres

by

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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 LaTeX2e software. TeXnicCenter is used as an effective interface to LaTeX.

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 terahrtez that span three decades from 10^{12} 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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Conference Articles

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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.

6. Fumeaux C., Baumann D., **Atakaramians S.**, and Li E. P., "Considerations on paraxial Gaussian beam source conditions for time-domain full-wave simulations," *25th Annual Review of Progress in Applied Computational Electromagnetics*, California, USA, pp. 401-406, March 2009.

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