Soft-glass microstructured optical fibres for nonlinear applications.

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Contents

Abstract

The objective of this thesis is to explore the potentials of using soft-glass (non-silica) based microstructured optical fibres (MOFs) for nonlinear optical applications. The high linear and nonlinear refractive indices of soft glasses and the ability to tailor the dispersion properties of MOFs have made them an ideal platform for developing nonlinear optical applications. Soft glasses also provide the possibilities of developing waveguides with mid-infrared transmission capability. In addition, the advances in fabricating MOFs with sub-wavelength structures and high refractive index contrast mean that nonlinear processes in these fibres can no longer accurately explored using conventional theories (namely scalar theories). A full vectorial theory is thus required, and this thesis drives forward some applications of recently developed generalised nonlinear theory. In this work, the author studies soft-glass MOFs from two aspects. The first aspect is to develop soft-glass MOFs for new frequency light generation using the scalar theories. The second aspect is to explore new nonlinear phenomena in sub-wavelength scale high-index-contrast waveguides, which includes soft-glass MOFs, using a full vectorial theory. The goal of studying these two aspects is develop a general theory that can explain and accurately predict all nonlinear effects in all types of waveguides.

Progress towards two novel nonlinear light sources is described, namely a femtosecond near-transform-limited tunable light source based on a fibre optical parametric oscillator (FOPO) and a broadband highly coherent supercontinuum (SC) source in the mid-infrared. The advantages of soft-glass MOFs have never previously been employed to enhance the performance of FOPOs. Also the bandwidth

and coherence of SC sources have never been optimised simultaneously, utilising the advantages of soft-glass MOFs. In this work, a genetic algorithm based fibre design approach is developed and applied to design and optimise fibres for these devices. The extrusion technique is used to fabricate fibre preforms. Simulations and experiments are performed to demonstrate SC generation and new frequency light generation in the final fibre.

The Kerr nonlinearity and nonlinear polarisation interactions are studied in a full vectorial framework. A continuous self-phase-modulation method was used to measure the Kerr nonlinearity of soft-glass MOFs, which confirmed the validity of the full vectorial theory. After that, new polarisation behaviours including polarisation self-switching were discovered and studied.

The outcomes of the works demonstrate the efficiency of using soft-glass MOFs for nonlinear applications. As described in Part I, for the FOPO, only a few millimetres of fibres were used to achieve near transform limited output with high conversion efficiency across a large frequency separation. For the supercontinuum source, a broadband continuum spectral output that was only limited by the transmission window of the glass and highly coherent was obtained. The supercontinuum experiments indicated the fabricated fibres had behaved as expected with the consideration of fabrication distortion.

As described in Part II, the work on the nonlinear effects with the full vectorial theory indicates that the Kerr nonlinearities of soft-glass MOFs can be significantly larger than they were previous predicted. New nonlinear polarisation behaviours including polarisation self-switching can take place in soft-glass MOFs with milliwatt level of power which indicates significant differences in the nonlinear processes that involved in FOPO and SC light sources should be observed with soft-glass MOFs.

Combining the full vectorial theory with FOPOs, supercontinuum sources and other nonlinear applications will lead to a better understanding the physics of the nonlinear processes behind these applications as well as further increase the efficiency of using soft-glass MOFs for these nonlinear applications and discover new

applications.

Declarations

I, Wen Qi Zhang certify that this work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution 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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List of Publications

JOURNAL:

1. Wen Qi Zhang, H. Ebendorff-Heidepriem, Tanya M. Monro, and Shahraam Afshar V., "Fabrication and supercontinuum generation in dispersion flattened bismuth microstructured optical fiber," Opt. Express **19**, 21135–21144 (2011)

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1. Wen Qi Zhang, Max A. Lohe, Tanya M. Monro, Shahraam Afshar V.,"Nonlinear polarization self-flipping and optical switching," in International Quantum Electronics Conference/Conference on Lasers and Electro-Optics Pacific Rim, OSA Technical Digest (CD) (Optical Society of America, 2011), pp.152–154

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with the International Workshop on Dissipative Solitons, 2009, pp. 374–375.

6. Shahraam Afshar V., Wen Qi Zhang, H. Ebendorff-Heidepriem, Kamran Eshraghian, Tanya M. Monro, "New frontiers in nano-scale highly nonlinear photonic circuits for System on System (SoS) Integration" Proceedings of the International SoC Design Conference (ISOCC) 2009: pp.1–4

7. Shahraam Afshar V., Wen Qi Zhang, and Tanya M. Monro, "Experimental Confirmation of a Generalized Definition of the Effective Nonlinear Coefficient in Emerging Waveguides with Subwavelength Structures," in Conference on Lasers and Electro-Optics/International Quantum Electronics Conference, OSA Technical Digest (CD) (Optical Society of America, 2009), paper CThBB6

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9. Wen Qi Zhang, Jay E. Sharping, Richard T. White, Tanya M. Monro and Shahraam Afshar V., "Towards Microstructured-Fibre-Based Optical Parametric Oscillators for Ultra-Short-Pulse Sources in the Near-Infrared," in Proceedings of the Australasian Conference on Optics, Lasers and Spectroscopy and Australian Conference on Optical Fibre Technology in association with the International Workshop on Dissipative Solitons, 2009, pp.501-502.

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