

# Microstructured fibres for nonlinear device applications: progress in design and fabrication

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One particularly promising application area for microstructured optical fibre (MOF) technology is the development of fibre devices based on nonlinear optical effects. Such fibres can be used for applications including optical data regeneration, wavelength conversion, optical demultiplexing, and Raman amplification. The usual measure of fibre nonlinearity is the effective nonlinearity  $\gamma$  [1]. Even though silica is not a particularly nonlinear material ( $n_2 \approx 2.2 \times 10^{-20} \text{ m}^2/\text{W}$ ), the nonlinear properties of silica fibres can be utilized when high light intensities are guided. Microstructured fibres can have a significantly larger NA than solid fibres because the cladding can be mostly comprised of air, and effective nonlinearities as high as  $\gamma \sim 60 \text{ W}^{-1} \text{ km}^{-1}$  are possible in pure silica microstructured fibres [2].

Highly nonlinear microstructured fibres can exhibit a broad range of dispersion characteristics, and in general the magnitude, sign and slope of the dispersion need to be chosen to suit the specific device requirements. Most of the work done to date in this area has relied on trial and error manual optimisation approaches to select the most appropriate fibre design. Recent work in using genetic algorithms to design fibres with ultra-flattened low dispersion around 1550nm will be presented [3]. Dispersion profiles for four optimised designs F1-F4 are shown in Fig.1.

Non-silica or *soft glasses*, are particularly attractive for nonlinear device applications because they can offer values of material nonlinearity ( $n_2$ ) up to two orders of magnitude larger than silica. The combination of microstructured fibre technology and soft glass is attractive for a number of reasons. Single-material fibre designs allow fibres to be drawn from a wide range of glasses. In addition, microstructured soft glass fibres offer extreme nonlinearity through the combination of a large  $n_2$  with tight mode confinement. Note that air/glass fibre designs can overcome the large material dispersion typical of soft glasses at near-IR wavelengths, something that cannot be achieved with conventional fibre designs [4].

Extrusion has been used to fabricate most of the soft glass microstructured preforms made thus far [5]. This technique been used to produce nonlinear fibres from materials including lead-silicate [4], tellurite [6] and bismuth-oxide [7] glasses (see example in Fig.2), and  $\gamma$  values as high as  $1860/(\text{W.km})$  have been achieved [4]. Such fibres promise a route towards nonlinear devices with unprecedentedly low operating powers (10-100 mW) and remarkably short device lengths (0.1-1 m). Progress in the design, fabrication, development and application of non-silica microstructured fibres will be presented.

## References

- <sup>1</sup> G.P. Agrawal, *Nonlinear Fiber Optics*, (1989).
- <sup>2</sup> W. Belardi et al., Paper PD1.2, *Proc European Conference on Optical Communications (ECOC 2002)*, (2002).
- <sup>3</sup> F. Poletti, *Optics Express* 13, 3728-3736 (2005).
- <sup>4</sup> J. Leong et al., Paper PDP22, *Proc. Optical Fibre Communications, Anaheim 2005 (OFC 2005)* (2005).
- <sup>5</sup> K.M. Kiang et al., *Electron. Lett.* 38, 546-547 (2002).
- <sup>6</sup> V.R.K. Kumar et al., *Opt. Express* 11, 2641-2645 (2003).
- <sup>7</sup> H. Ebendorff-Heidepriem et al., Paper ThA4, *Proc. Optical Fiber Communications Conference (OFC 2004)*, (2004).

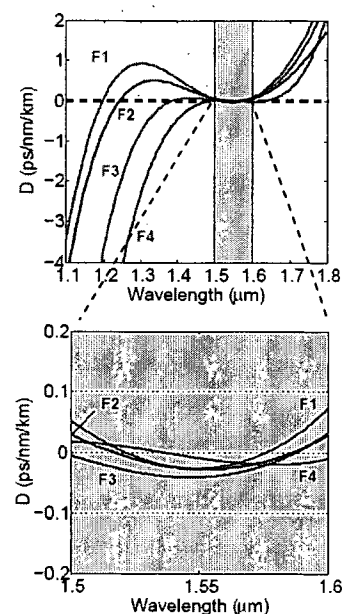


Fig. 1 Silica MOFs optimized for low flat dispersion at 1550nm

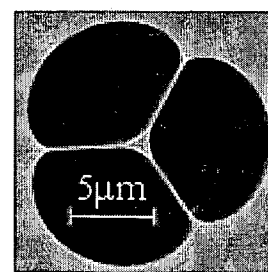


Fig. 2: Extruded nonlinear soft glass fibre