Novel fabrication method of highly-nonlinear silica holey fibres

Kazunori Mukasa, Marco N. Petrovich, Francesco Poletti, Andrew Webb, John Hayes, Adriaan van Brakel, Rodrigo Amezcua Correa, Lionel Provost, Jayanta Sahu, Periklis Petropoulos and David J. Richardson

University of Southampton, Optoelectronics Research Centre (ORC), Highfield, Southampton, Hampshire, SO17 1BJ, U.K.
Tel +44 (0)23 8059 3139 Fax +44 (0)23 8059 3142
e-mail kam@orc.soton.ac.uk

Abstract: In this paper we present a novel and simple method of producing small core holey fibres with nonlinearity close to the maximum value achievable in silica. The fibres are based on a three-hole structure, where the core is suspended on three thin struts. An effective mode area of 1.6μm^2, attenuation loss better than 0.20dB/m and a gamma of 60W^{-1}/km^{-1} at 1.55μm were achieved. The potential for practical applications of such fibres is discussed.

OCIS codes: (060.2280) Fiber design and fabrication, (060.2400) Fiber properties, (190.4370) Nonlinear optics, fibers

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1. Introduction

Highly nonlinear (HNL) fibres are useful for a wide range of applications, including optical processing and supercontinuum generation. Due to the high index contrast between silica and air, holey fibres (HFs) can achieve very small mode field areas (≈1.5μm^2) and thus much higher effective nonlinearity (γ) than conventional fibres [1]. The highest nonlinearity reported in a silica HF at 1.55μm is γ≈70W^{-1} km-^{1} [2]. Fabrication of such fibres is however challenging: a small pitch (Λ≈1μm) and a large air filling fraction are required in order to achieve high γ values [2]; furthermore, a significant number of rings of holes (≥ 6) is required in order to maintain the confinement loss low. Here we propose an alternative design of a HF, which can achieve high γ, while being considerably easier to fabricate. The fibre is composed of only three holes and has a core suspended on thin struts (fig. 1); we term this structure *suspended core* holey fibre (SC-HF). By virtue of the simple design, the preform can be fabricated by a drilling technique, which has a clear advantage on the more labour-intensive stack-and-draw technique generally used for HF fabrication. In this paper we describe the fabrication and properties of silica SC-HFs and the procedures that are required for achieving low loss.

2. Fabrication of silica suspended core holey fibres

A microstructured perform was obtained from a high-purity silica VAD rod by precision ultrasonic drilling (fig 1). The bores were subsequently mechanically polished, which allowed reducing the average surface roughness from ≈2μm to ≈0.2μm. The preform was drawn into fibre via a two-step process, where the holes were expanded to the

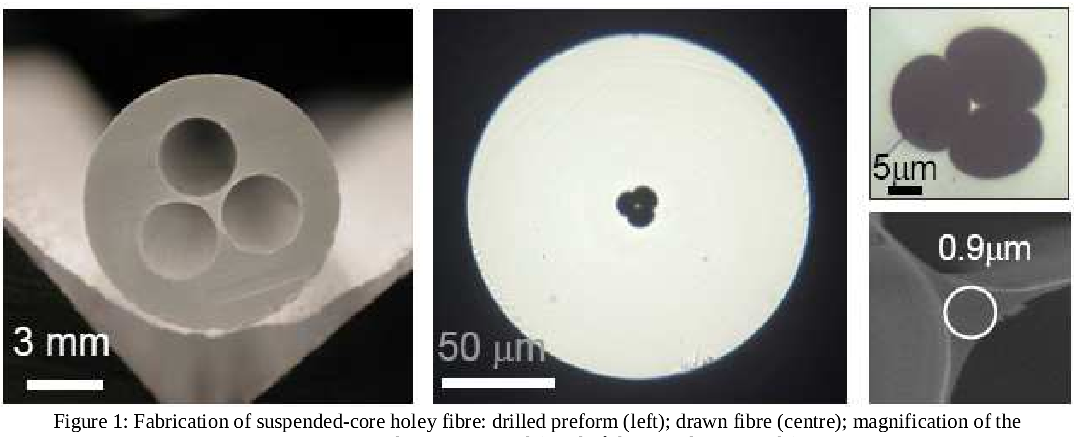

Figure 1: Fabrication of suspended-core holey fibre: drilled preform (left); drawn fibre (centre); magnification of the microstructured region (top right) and of the core (bottom right).

target size. The air holes measure ≈11µm in the radial direction, and the struts are ≈8µm long and ≈50nm thick in their thinnest section, which ensures that confinement loss is negligible (<10^{-6}dB/m). Two fibres with different core diameters, d, of 0.8 (fibre A) and 0.9µm (fibre B) were produced. By virtue of the simple structure, very stable fibre drawing conditions were easily attained and fibres with excellent and consistent geometry could be fabricated in ≈hundred meter lengths.

The transmission loss spectra, measured over ≈100m lengths, are shown in figure 2. The SC-HF was fusion spliced to a conventional HNLF in order to achieve a stable and efficient launch. The loss at 1.55µm is 0.18dB/m. Preform polishing was found to produce a factor of 2-3 improvement of the fibre loss. The relatively low value of loss and its weak wavelength dependence (proportional to about $\lambda^{-1.1}$ excluding the OH absorption bands) suggests that the limiting loss mechanism in our fibres is scattering from capillary waves frozen-in during fibre drawing as described in reference [3].

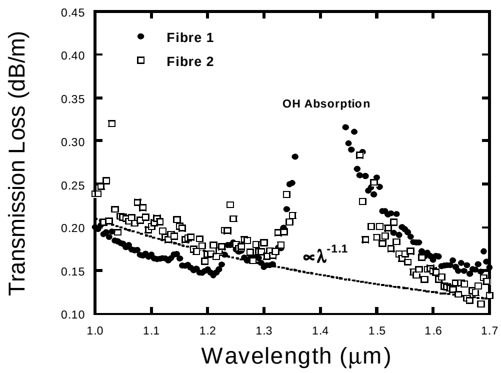

Figure 2: Fibre loss spectra of SC-HFs

3. Device applications of SC-HFs

The effective fibre nonlinearity, γ, of fibres 1 and 2 is 49.7$W^{-1}km^{-1}$ and 60.4$W^{-1}km^{-1}$ respectively at 1.55µm (fig.3 shows the result for fibre 1). We also measured a modal birefringence of 2-3x10^{-4}. SC-HFs can therefore be used as a polarization maintaining high non-linear fibre. The wavelength dependent dispersion, calculated for SC-HFs with different core sizes (0.6-1.2µm) is shown in fig.4. Both fibre 1 and 2 have large normal dispersion at telecom wavelengths, making them suitable for dispersion compensation. The dispersion is positive below ≈1µm and in the visible, where SC-HFs can be used for supercontinuum generation. Furthermore, a large fraction of the optical field is located in the air holes. Our calculations show that over 30% (fibre1) and 25% (fibre2) of the power is transmitted in air at 1550nm, making SC-HFs extremely attractive for evanescent-wave chemical sensing of gases and liquids.

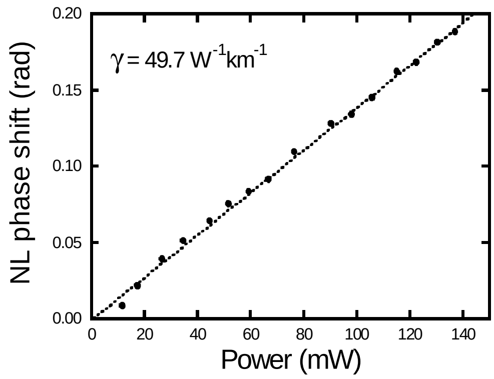

Figure 3: Effective nonlinearity of fibre 1 measured by SPM

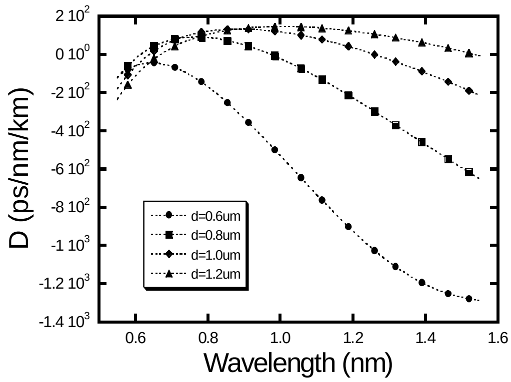

Figure 4: Dispersion calculated for SC-HFs with different core diameters

4. Conclusion

Suspended core holey fibres were fabricated from VAD silica using a drilling technique. Relatively low loss was achieved by polishing the bores in the preform. These fibres have nonlinearity close to the maximum obtainable in silica HFs, but are much easier to produce than previously reported HNL-HFs fabricated by stacking.

5. Acknowledgment

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6. References

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