Visible broadband continuum generation in nano-scale silica-air waveguides

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Abstract: Single-mode supercontinuum spanning (and largely confined to) the visible spectrum is generated from the nanosecond pulses output of a 532-nm microchip laser, using tens of millimeters of nano-tapered fibres or photonic crystal fibre cores.

1. Introduction

Photonic crystal fibre (PCF) cores and tapered conventional fibres can both confine light to small waveguides surrounded by air. The reduced zero dispersion wavelength (ZDW) enables spectacular nonlinear interactions at Ti:sapphire-laser wavelengths for ~2 µm diameters[1,2]. Shorter ZDWs are possible for further-reduced diameters, but coupling into PCFs soon becomes impractical and the narrowest tapered fibres with reported nonlinear results were ~1 µm diameter. Tong et al recently formed submicron-diameter "silica wires" by drawing with a sapphire rod[3]. As we reported at OFC in February[4], this cumbersome process is unnecessary: we made uniform waists with diameters down to 280 nm by conventional tapering in a bare flame, with up to two orders of magnitude lower loss than [3] and transitions at input and output. We also tapered PCF cores to similar dimensions, the taper transitions facilitating input coupling. Previously-unattained dispersion properties of both waveguides enabled generation of single-mode supercontinuum light spanning the visible spectrum down to 400 nm, from as little as 20 mm of fibre, using a frequency-doubled Nd:YAG microchip laser (JDSU Nanogreen, 0.6 ns pulses, ≤1 kW peak power coupled into fibre; some residual 808 nm CW diode-laser output remains).

2. Nano-tapered fibres

Uniform nano-scale taper waists of predetermined length (up to 100 mm) and diameter (down to 280 nm; taper ratio 450:1) were made in Corning SMF-28 by a variable flame-brush technique. The losses of samples are given in Table 1 and compared with [3]; ours have much lower loss (despite including the losses of the transitions) and longer waists.

Table 1. Loss / waist length of tapered fibres

waist diameter, nm	waist length, mm	wavelength, nm	loss, dB/mm	loss from [3], dB/mm
950	90	1550	0.0014	0.21
890	90	1550	0.0017	0.29
360	30	633	0.0083	0.21
280	30	633	0.011	0.38

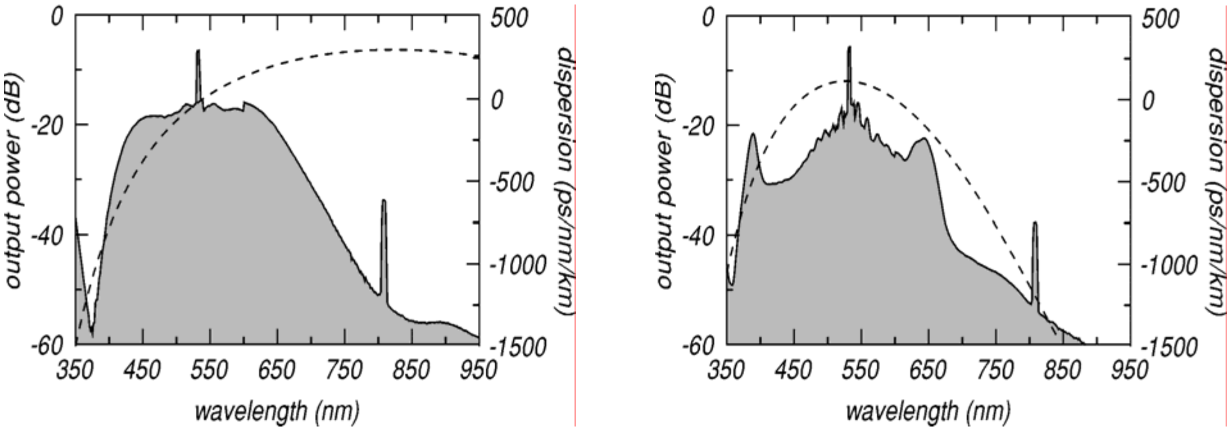

Fig.1. Supercontinuum and (broken lines) dispersion spectra from taper waists with diameters and lengths (left) 950 nm and 90 mm, and (right) 520 nm and 20 mm, respectively.

Output spectra from two samples pumped by the 532 nm microchip laser, with calculated dispersion spectra, are plotted in Fig. 1. The first's ZDW is very near 532 nm and the second is dispersion-flat around that wavelength, enabling supercontinuum generation despite the waveguides' short length and the low peak power.

3. Submicron PCF cores

The PCF (core diameter 3.1 µm) was provided by BlazePhotonics[5]. 90-mm lengths were tapered "fast-and-cold", Fig. 2, successfully preserving the microstructure while reducing the core diameter to as little as 300 nm (taper ratio 10:1). Dispersion curves (not calculated) should resemble those of conventional taper waists. Tapering losses could not be measured accurately because the untapered fibre is multimode, but were around 0.5 dB. Typical output spectra are plotted in Fig. 3.

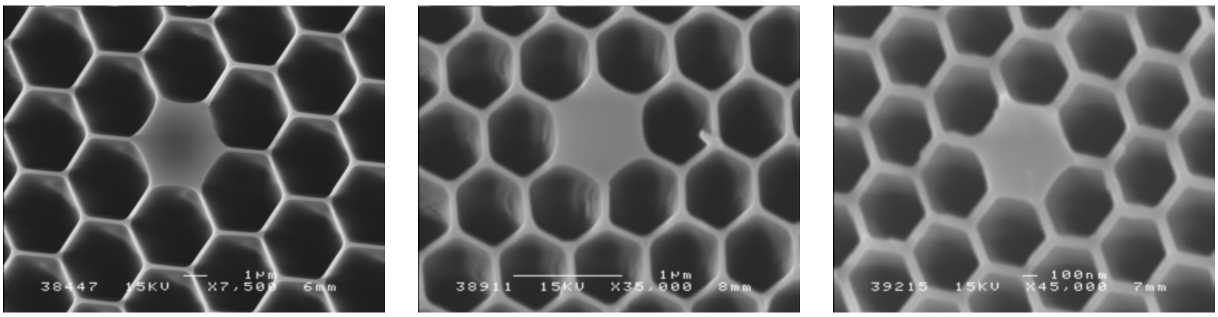

Fig.2. SEM images of tapered PCF cores with diameters 3.1 (untapered), 0.7 and 0.5 µm (left to right, to different scales).

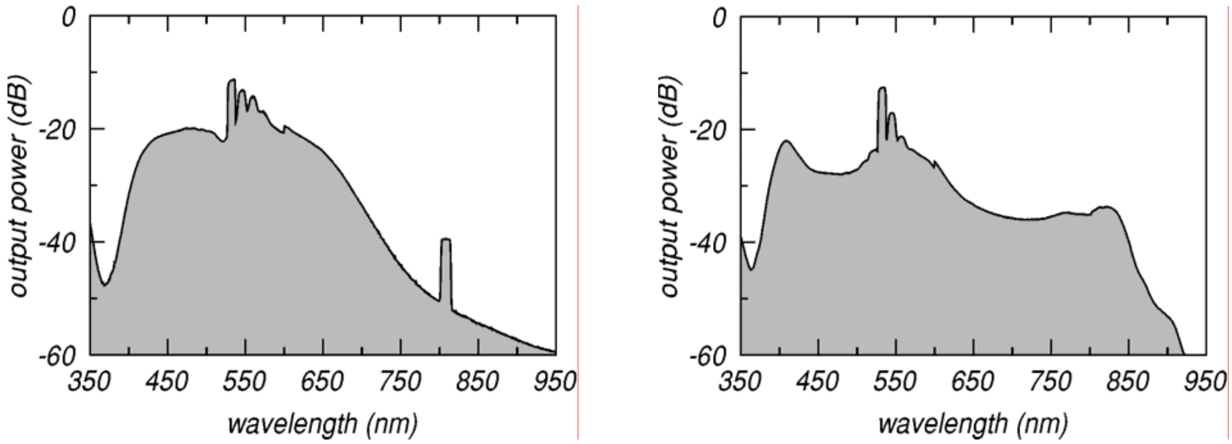

Fig.3. Supercontinuum spectra from 90 mm of PCF cores with diameters (left) 700 and (right) 500 nm.

4. Conclusion

This is the first report of nonlinear processes in air-silica waveguides of nano-scale diameter, and indeed of any form of optical transmission along PCFs with submicron pitch. The resulting compact light source has applications in, eg, optical coherence tomography, spectroscopy and optical device measurement.

5. References

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