# Tapered dual-core air-clad fiber for generation of polarized supercontinuum

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**Abstract:** A special dual-core tapered fibre is fabricated for generation of supercontinuum (SC) with polarization control. A numerical modal analysis demonstrates a possibility to optimize design of a hybrid 3-in-1 device comprising taper, coupler and polarized SC generator.

## 1. Introduction

Tapered silica/air-clad fibers are promising photonic devices with many attractive features and a wide range of possible applications. Supercontinuum generation is one of the most important examples [1-4]. Numerous applications of the SC include: optical coherence tomography, sensor techniques spectroscopy, dispersion measurements, and telecom applications such as WDM sources and clock recovery, WDM-TDM/OCDM conversion and others [1-5]. Previously, SC generation has been successfully demonstrated by using tapered fibers and photonic crystal fibers (PCF). Though PCF seems to be a favorite in many respects, tapered fibers also have many attractive practical characteristics.

In this paper we present a dual-core tapered fibre (DCTF) specially fabricated for generation of SC with polarization control. The dual-core tapered design of highly nonlinear fiber allows simple fabrication procedure leading to low cost of such device. Compact design is advantageous for packaging. SMF-compatible input and output ports provide high splicing efficiency. Dual core configuration makes possible effective polarization control of generated SC and delivers richer and more flexible design possibilities compared to conventional cylindrical tapered fibers.

## 2. Experimental setup

Dual-core tapered fiber has been manufactured by drawing a pair of stripped SMFs. During the draw process the cross-section profile of the fiber can be changed from a figure-of-eight shape to quasi-elliptic. A formed fused dual-core waveguide has two input ports and two output ports, which makes possible its application as a coupler. It is smoothly tapered to the input and output ports that retain a structure of original SMFs.

The experimental setup shown in Fig. 1 comprises a Ti:Sapphire femtosecond laser source followed by the double-prism pair to provide optimal pre-chirping for SC generation in the DCTF [3,4]. The SC generation takes place in a uniform section in the middle of DCTF because it has the smallest effective area across the device. This waveguide also has a controllable dispersion provided by the anti-symmetric dipole mode as described below.

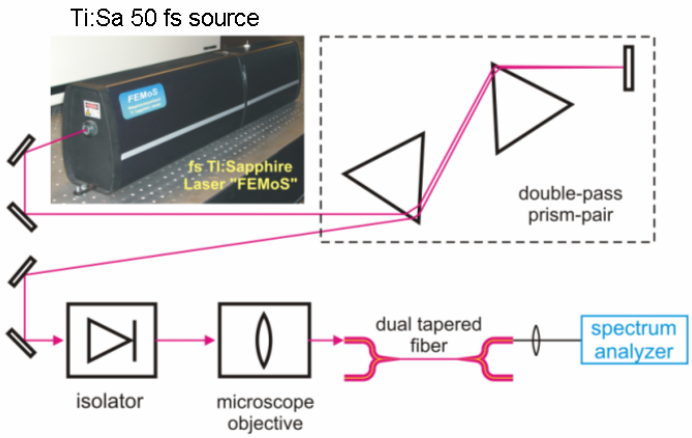


*Fig.1. Experimental setup.*

## 3. Numerical optimization of DCTF design

The properties of the generated SC, as well as its occurrence, are extremely sensitive to the interplay between nonlinearity and dispersion [5, 6]. In a DCTF a new geometry and a new degree of freedom (the core separation) are introduced that can be used to design fibers with optimal characteristics. A dual-core fiber is essentially multi-mode because of high contrast between the glass core and air cladding. However it is possible to design a dual core configuration so that only one mode is efficiently excited. A dual-core fibre configuration is characterized by the core diameter *b* and distance between the core centers *a* or aspect ratio *b/a*. Several lowest modes for each configuration have been computed using full-vectorial Maxwell mode solver. Fig. 2 shows examples of the first eight lower order mode profiles.

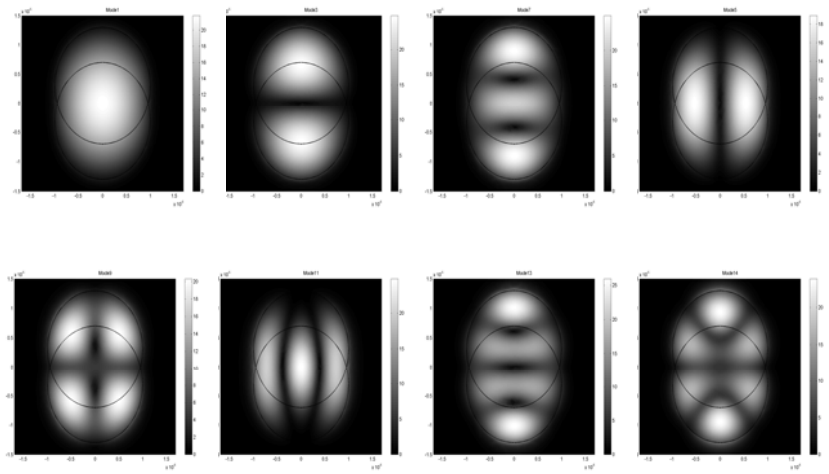

*Fig. 2. Mode gallery in dual core silica/air clad fiber.*

It is seen that it is possible to tune the geometry so that the light coming into one of the input ports can be efficiently coupled to only one of these modes. In the considered configuration a launched laser beam excites asymmetric dipole mode.

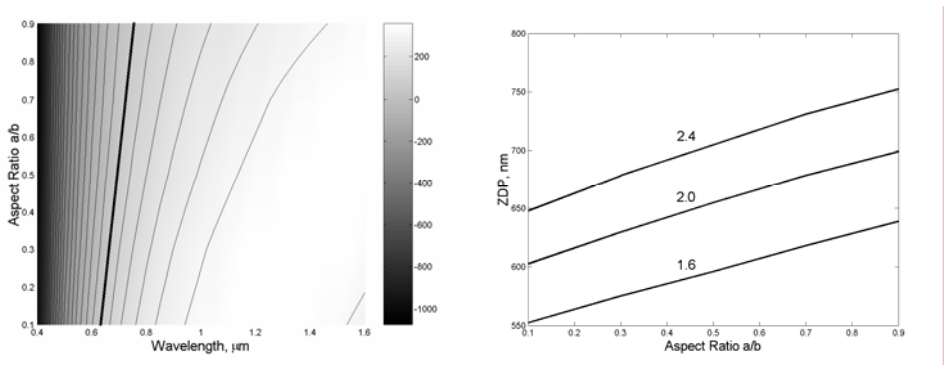


*Fig. 3. Dispersion of the dipole asnti-symmetric mode.*
*Left:Contour plot of dispersion of silica/air clad fiber for different aspect ratios (b=2 m).*
*Bold line - zero dispersion point.*
*Right: Zero dispersion point versus aspect ratio b/a for different core diameters (labelled)*

Dispersion of the dual-core fibre has also been investigated numerically. Figures 3 and 4 show dispersion of the dipole anti-symmetric mode. An important feature of the dual core design is a possibility to tune a zero dispersion point (ZDP) (shown by the bold line in Fig. 3) by variation of waveguide parameters. Several general properties can be observed. Smaller core diameter and larger distance between the cores correspond to higher dispersion. Another distinctive property is a noticeable shift of zero dispersion wavelength with variations of the core diameter.

## 4. Experimental results

The scheme of the experiment on SC generation is shown in Fig. 1. It has been observed that SC is initiated at the certain point in dual-core fiber. Typically, this point is at 2 cm after the input taper to get the widest output spectrum and is controlled by the initial pre-chirp. Another important observation is that the two output beams

have the same peak power. It implicitly confirms the generation of the dipole single mode inside the dual core waist section of this device, because the equal partition of power between two output ports doesn't depend on the waist length. Both output light beams have practically Gaussian profile and are polarized along the major axes.

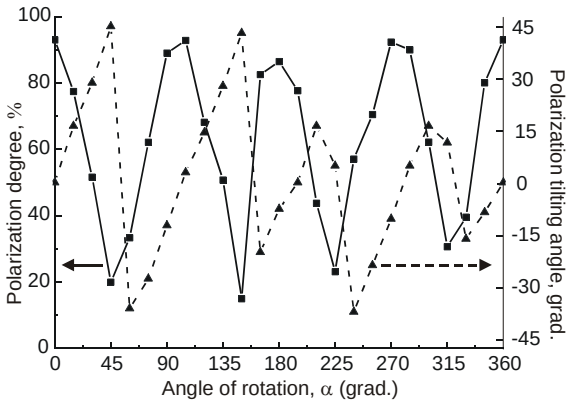


*Fig 5. Polarization properties of generated SC*

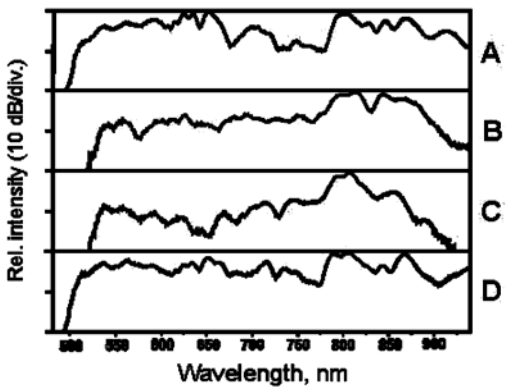


*Fig 6. Super-continuum spectra for different degrees of polarisation:*

*A: $\delta$ =93% ($\alpha$=0$^o$), B: $\delta$ =68% ($\alpha$ =120$^o$), C: $\delta$=23% ($\alpha$ =225$^o$), D: $\delta$=93% ($\alpha$ =270$^o$)*

Polarization properties of the generated SC are illustrated in Fig. 5. Solid curve shows the degree of polarization of SC (%) versus the angle α between input polarization plane and major axis of dual core waveguide. The degree of polarization $\delta$ is determined from the results of measurement of maximal ($I_{max}$) and minimal ($I_{min}$) SC intensities passing through the rotating polarizer (Glan prism) by the formula: $\delta(\%)=100\times(I_{max}-I_{min})/(I_{max}+I_{min})$. The dashed curve shows the SC polarization tilting angle versus $\alpha$. Figure 6 shows the spectrum of generated SC**.**It is seen that the output spectra of polarized SC cover over 400 nm at the –20 dB level.

## 5. Conclusion

A new design of tapered dual-core fiber has been developed. It can be potentially used as a hybrid 3-in-1 device comprising: taper, coupler, and polarized SC generator. Comprehensive numerical modeling of the silica/air clad dual-core fiber modes has been applied to optimize waveguide geometry. The generation of the polarized SC with a degree of polarization of 97 % has been demonstrated.

## 6. References


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