Novel Applications of fibre tapers

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ABSTRACT

In this talk we will discuss new applications for fibre tapers ranging from femtosecond pulse manipulation to optical clock generation in micro-coil resonators. Fundamental to these interactions is the enhanced nonlinearity arising from the smaller cores making compact optical devices possible.

Keywords: Microstructured optical fibre, taper, parabolic pulse

Introduction

Tapering an optical fibre is an important method for post-processing that can radically change its optical properties leading to a wide range of devices. In this paper we consider some of our recent work looking at different types of fibre tapers and how they can be used. This work is split into two areas, the first considers the tapering of micro-structured optical fibres for the manipulation of femtosecond optical pulses, while the second area is concerned with nonlinear optics in optical micro-coil resonators.

Optical Pulse Control

In nonlinear optics it is well known that a spatially varying dispersion is equivalent to gain or loss in the Nonlinear Schroedinger Equation (NLSE)[1]. This allows the control of optical pulses through effects such as soliton compression solely by varying the dispersion of the fibre along its length. In the past this has been achieved by tapering the fibre while drawing it resulting in kilometre lengths of dispersion varying fibre suitable for the manipulation of picosecond pulses. However as the length scale over which the dispersion needs to be varied is the dispersion length this method is impractical for femtosecond pulses. Hence we have developed a novel fibre taper rig capable of making metre length tapers with an arbitrary taper profile as shown in Fig. 1.

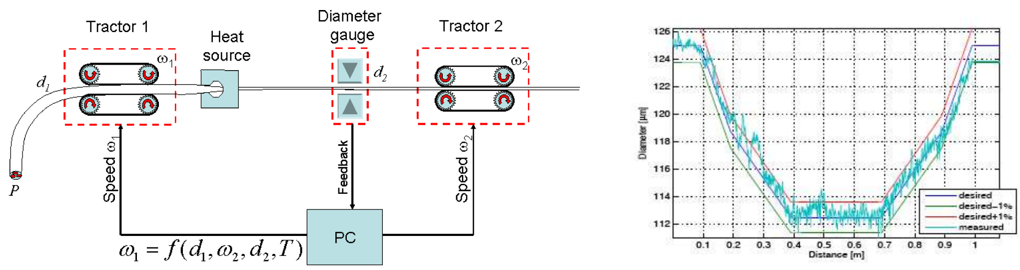

Figure 1. (a) Schematic of the improved fibre taper rig, and (b) a typical example of the taper profiles that can be made using it.

We have studied the possibilities of using microstructured optical fibres (MOFs) for pulse control due to their attractive dispersive and nonlinear properties. In particular using small core MOFs the effective nonlinearity can be a factor ten larger than standard fibres while the dispersion can be easily varied between ± 100 ps/nm/km at $1.55\,\mu$m by varying the outer diameter by less than 10%. We have targeted three main areas of improvement, the first is parabolic pulse generation[2], the second is enhanced super-continuum generation and the last is optical pulse compression[3]. In all cases we have shown that by using tapered fibres it is possible to significantly improve the output pulse quality compared to using untapered fibres. Importantly these results are obtained using pulse powers that can be achieved using commercially available femtosecond optical pulse sources and thus

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such tapers have important applications in being able to dramatically and easily alter the pulse characteristics of commercial sources. We have also shown that tapering MOFs can alter the Brillouin threshold making it significantly higher than in a standard fibre. Lastly we have optimised the dispersion profile of the fibre tapers using a genetic algorithm which results in significantly better output pulses than has been previously found.

Optical Microcoil Resonators

The second application of optical tapers that we wish to discuss are optical microcoil resonators[4]. These consist of a tapered optical fibre coiled in a helical manner on top of itself as shown in Fig. 2. Light propagating in such a coil is similar to the game of snakes and ladders where the coupling of light from one turn to the other takes the role of the snake and/or ladder. In the linear regime such coils can trap light indefinitely and so act as high Q resonators. Such resonators have some particularly attractive features such as the ease of coupling light into and out of the resonators and also that they naturally create an internal cavity through which material can flow allowing them to be used as sensors[5]. However here we are primarily concerned with the nonlinear aspects of such coils.

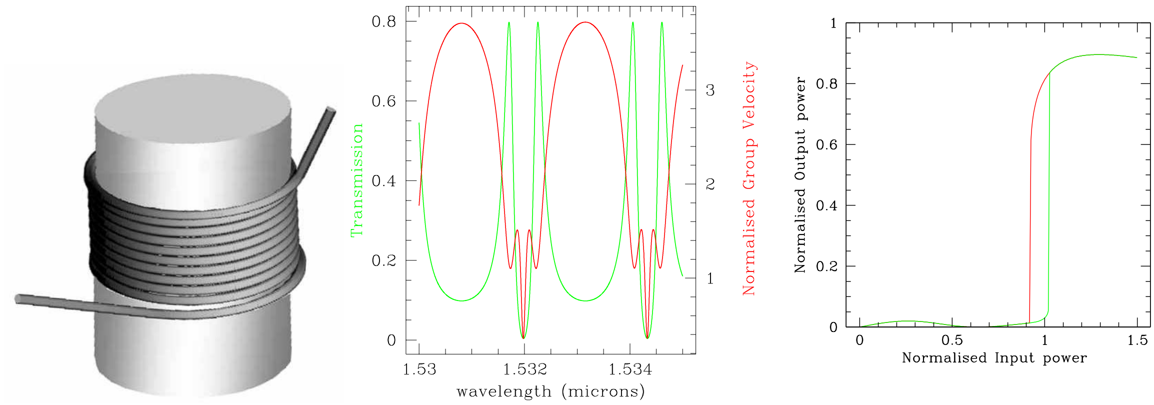

Figure 2. (a) Schematic of a micro-coil resonator. (b) Linear transmission and group velocity of a resonator and (c) the corresponding nonlinear behaviour of such a resonator.

In the nonlinear regime we have shown that such coils are bistable over a range of input powers and wavelengths[6] while additionally such coils can be used in optical communications for optical re-shaping, noise reduction or optical memory[7]. More recently we have looked at the time response of such coils and found that in some parameter regimes the CW solution is unstable and leads to self-pulsating. Such a solution could be used as a high speed optical clock signal since the repetition rate of the pulses is given by the round trip time of the cavity which is of the order of 10s of picoseconds. In other regimes the micro-coils become unstable and the output is chaotic.

Conclusions

We have shown that optical fibre tapers can play an increasingly important role in many areas of optics from pulse control and manipulation to supercontinuum generation and even all-optical switching. The key to this is the ability to precisely control the diameter of the taper along its length and to make metre length fibre tapers.

References

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