Visible supercontinuum generation in a low DGD graded index multimode fiber

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Abstract: We demonstrate over two octaves supercontinuum generation in a graded index multimode fiber using a picosecond microchip laser at 1064 nm. Enhanced visible supercontinuum is obtained in a tunable fashion based on initial launching conditions.

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1. Introduction

Supercontinuum (SC) generation is nowadays finding extensive applications in biomedical optics, optical metrology, spectroscopy, and microscopy, to mention just a few [1,2]. In this regard, extensive investigations have been carried out to develop compact, efficient and robust fiber-based SC sources. Thus far, most of the SC studies have been performed almost exclusively in single mode (or few mode) fiber structures. This field experienced rapid growth with the advent of photonic crystal fibers (PCF) that allowed for the first time an unprecedented control over dispersion and nonlinear characteristics [1-5]. On the other hand, extending SC generation into the visible part of the spectrum has always been a subject of considerable investigation. This aspect becomes particularly challenging especially if high spectral densities with high uniformity are required using readily available pump sources. Quite recently there has been a resurgence of interest in multimode optical fiber systems, both in the linear and nonlinear domain [6,7]. In general, multimode fibers can handle high power levels and can enable a multitude of nonlinear interactions between their many supported modes that would have been otherwise impossible in single mode structures.

In this work, we report visible SC generation using a low differential modal group delay (DGD) telecommunication multimode graded index fiber with a core diameter of 50 μm, pumped in the normal dispersion regime. A compact picosecond amplified microchip laser at 1064nm with pulse energies ~95 μJ and maximum peak power of ~240 kW was used to generate a broad SC extending from 414 nm to 1750 nm.

2. Experimental Results

A schematic of the experimental setup is shown in Fig. 1(a). Pulsed light from a Q-switched microchip laser at 1064 nm (400 ps, 95 μJ and 500 Hz) was coupled into the aforementioned 50 μm core graded index fiber using a 50 mm focal length lens. The power coupled into the fiber was controlled using a polarizing beam splitter cube (PBS) and a half wave plate (HWP). The initial launching conditions into the MMF were adjusted by using a 3D translational stage. The output spectrum was then measured using an OSA (ANDO AQ 6315E) ranging from 350 nm to 1750 nm.

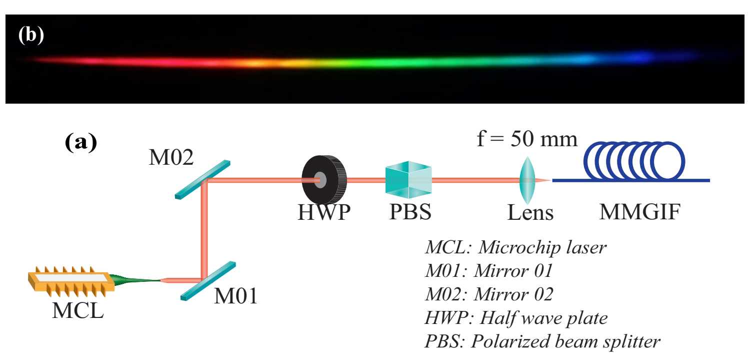

Fig. 1. (a) Schematic of the experimental setup. A Q-switched microchip laser at 1064 nm is coupled to a sample of MMF using a 50 mm focal length lens. (b) Typically obtained disperse spectrum from a 25 m MMF.

A typical dispersed spectrum in the visible, generated in a 25 m long fiber, for a pump peak power of ~210 kW is displayed in Fig. 1 (b). The entire SC spectrum generated is this fiber under these same conditions is depicted in Fig. 2(a). One can observe that the input pulsed light produces a dramatic spectral broadening on both sides of the pump wavelength extending from ~ 414 nm to 1750 nm. We note that our measurements were restricted at longer wavelengths due to the OSA's spectral response. Fig. 2(a) clearly demonstrates that in this fiber SC generation spectrally unfolds in a rather uniform fashion between 600 nm and 1750 nm as long as the fiber length exceeds 20 m. At this point the exact origin of the peaks observed in the visible spectrum is still an open question given that the system is pumped in the normal dispersion region. We attribute their formation to the complex interplay between cascaded parametric FWM and Raman processes in this heavily multimoded environment.

In order to better understand the evolution of SC generation in our graded index MMF, we have performed a series of measurements for various power levels and shorter fiber spans while keeping the input launching conditions the same. Figures 2 (b-c) show two typical spectra for two different input powers corresponding to peak powers of ~ 33 kW and 210 kW, respectively. The fiber length used for this experiment was 11 m. As it is clear from Fig. 2(b), at lower input powers (~33 kW) two distinct peaks can be observed around the pump, located at 1016.4 nm and 1114.4 nm. These features significantly broaden as the pump power is further increased as shown in Fig. 2(c).

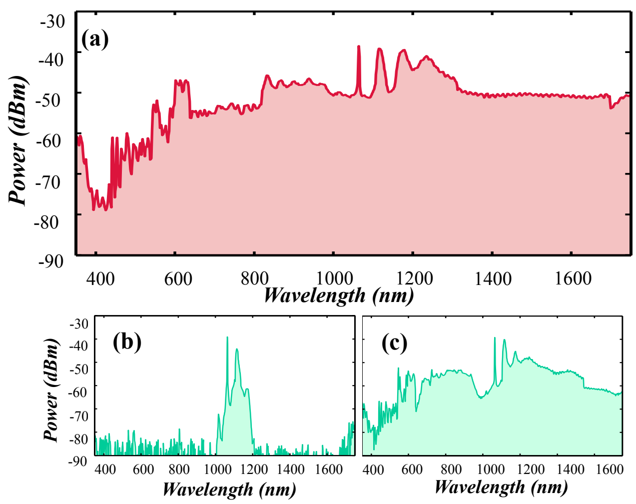

Fig. 2. (a) SC spectrum generated in a 25 m long MMF for input peak power ~210 kW. SC evolution in 11 m MMF with increasing pump power (b) 33 kW and (c) 210 kW.

3. Summary

We demonstrated uniform SC generation in the visible using a low DGD multimode optical fiber when pumped in the normal dispersion regime at 1064nm. The generated SC exhibited a high brightness and its spectrum convers the band between 414 nm to 1750 nm. Of interest would be to further study the effect of launching conditions (modal content) and refractive index profiles on the evolution of SC generation in such heavily multimoded fibers.

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