Supercontinuum generation in a sapphire fiber and comparison with a compact PCF based light source

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Abstract: A single crystal sapphire fiber pumped with ultrashort laser pulses was used to generate supercontinuum light. Its emission was next compared with this of the PCF based source in terms of the applicability to Multiwavelength-CRD-Spectrography.

OCIS codes: (190.0190) Nonlinear optics; (320.6629) Supercontinuum generation

1. Introduction

Since its discovery by Robert R. Alfano and Stanley Shapiro in 1969 [1], the supercontinuum (SC) is still one of the hottest topics studied in optical and photonics science. Several applications have been proposed to this nonlinear optical phenomenon: Wavelength Multiplex Division (WMD) communication systems and networks [2,3], Optical Coherence Tomography (OCT) [4,5], atmospheric science [6-9], and most recently, for Cavity Enhanced Absorption Spectroscopy (CEAS) and Cavity Ring-Down Spectroscopy (CRDS) studies [10-13].

Specially, the SC generation in microstructure Photonic Crystal Fibers (PCFs) by ultrashort pulse propagation has become a subject of great interest worldwide due to the low pulse energies required to generate the SC yielding a coherent and high brightness white-light [14]. In microstructural fibers, when pump wavelength lies in a normal dispersion region, Self-Phase Modulation (SPM) initiates the continuum generation while in an anomalous dispersion region, the high-order solitons initiate its formation. The combination of Four-Wave Mixing (FWM) and Raman processes extends the spectral width of the generated spectrum [15]. Therefore, the SC can span more than two-optical octaves extending from the ultraviolet to the infrared spectral region. The use of single crystal sapphire fibers in turn, takes the advantage of its high laser damage threshold (melting temperature >2000^{o}C) and a good nonlinearity (comparable to the fused silica) to generate SC with high spectral energy density, besides presenting a low material dispersion over a wide wavelength range (0.8–4 μm) [16].

2. Experimental setup and results

In our experiment, a 5 cm long single crystal sapphire fiber with a diameter of 425 μm was used for SC generation. The Ti:Sapphire femtosecond laser (λ = 800 nm) delivered pulses with duration of 430 fs and 500 μJ of energy at 1 kHz repetition rate. The 6 mm diameter beam was focused using a positive lens (f = 800 mm) and the fiber was placed approximately 40 mm after the focus to ensure that its entire cross-section was illuminated (due to the natural divergence of the beam) and at the same time, to avoid any damage on the surface. According to the manufacturer, the fiber presents relatively large numerical aperture, corresponding to one cone with 47 degrees when immersed in air. Therefore, to collect the white light an aspheric lens (f = 25 mm) was used to collimate the SC beam and reduce possible spherical aberrations. Figure 1 depicts the description above.

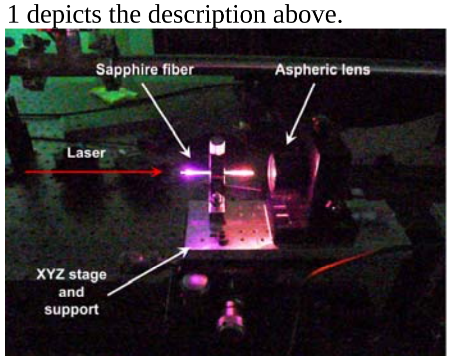

Fig. 1 Setup showing the SC generation using a sapphire fiber pumped with a femtosecond pulse.

One compact PCF based light source with 8 kHz repetition rate was next used for the comparison. This was a turnkey device consisting of 1 m long photonic crystal fiber and pumped by a passively Q-switched, microchip Nd:YAG laser. Both the fundamental (1064 nm) and second harmonic (532 nm) emission were used to pump the fiber delivering spectrally broad SC (400 – 1800 nm) and producing total average power > 15 mW. The respective spectra and the emission pattern of the SC generated in these two cases are shown in Fig. 2.

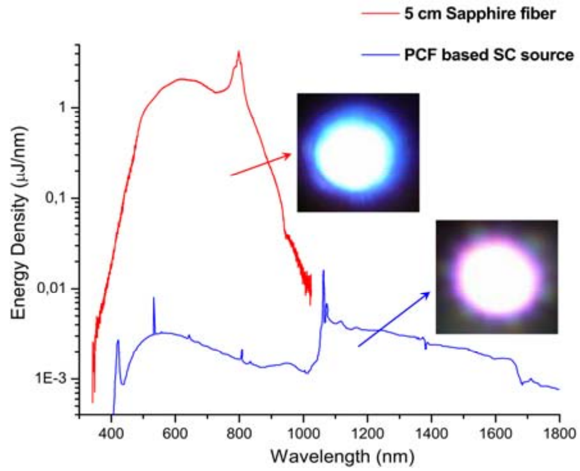

Fig. 2 Comparison between the SC spectra generated through the sapphire fiber setup (red curve) and by the PCF based source (blue curve). Also are shown the respective emission pattern.

As indicated in Fig. 2, the SC spectrum generated using the PCF based source is approximately 2.3 times broader than this one obtained with the sapphire fiber, which is restricted mainly in the visible region. However, the spectral energy density of the sapphire generated SC is at least 3 orders of magnitude higher than this of the PCF. It is still an applicable result, in particular if intense broadband spectrum in the visible region is required. For example, using the PCF source we have measured weak overtone absorption of molecular water (polyads 4ν and 4ν+ δ) and b-X transition of oxygen molecules between 610 nm and 730 nm using the Multiwavelength-CRD-Spectrography [17].

3. References

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