Four-wave mixing process induced by a self-phase modulated pulse in a hollow core capillary

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Abstract: In this work, we investigate the modal four waves mixing (FWM) process in an argon filled capillary appearing from the spectral broadening of a pump pulse injected in the fundamental mode. The edge of the spectrum at the low wavelength part seeds the FWM process to generate an high order mode in the near infrared.

1. Introduction

Nonlinear pulse propagation in multimode optical fibers have recently regained interest this last years for their additional degree of freedom enabling the manipulation of the temporal and spatial features [1,2]. Particularly, multimode properties of fibers allow the enhancement of nonlinear converter spectral band by using for example a Four Wave-Mixing (FWM) with modal phase matching [3]. In the case of a gas filled Hollow-Core Capillary (HCC) pumped by an ultra-short pulse, several investigations focus their attention on the nonlinear interaction of the modes through the self-focusing [4] or ionization processes [5]. In this work, we investigate the phase-matched modal FWM processes self-seeded by the spectral broadening of a pump pulse injected in the fundamental mode.

2. Experiment

In the experimental set-up, we used a 30 cm long HCC with a 150 µm core diameter pumped by an ultra-short pulse delivered by a 1 kHz Ti:Sa laser source (800 nm, 120 fs). The output energy is 170 µJ. The HCC is placed inside a chamber with two 5-mm-thick windows and filled it with Argon at a pressure of ~2 bar. At the output chamber, the pulse is split by a dichroic mirror to separate the visible and infrared parts. The filtered beams are detected by specific spectrometers simultaneously and the beam profiles are recorded by a camera. From the pump beam profile (Fig. 2.a), we consider that only the fundamental mode is injected in the capillary. Fig. 2.a also shows the spectrum at the HCC output. The pulse propagates in the normal dispersion regime and the spectrum broadens mostly due to self-phase modulation (SPM) up to ~700 and 900 nm.

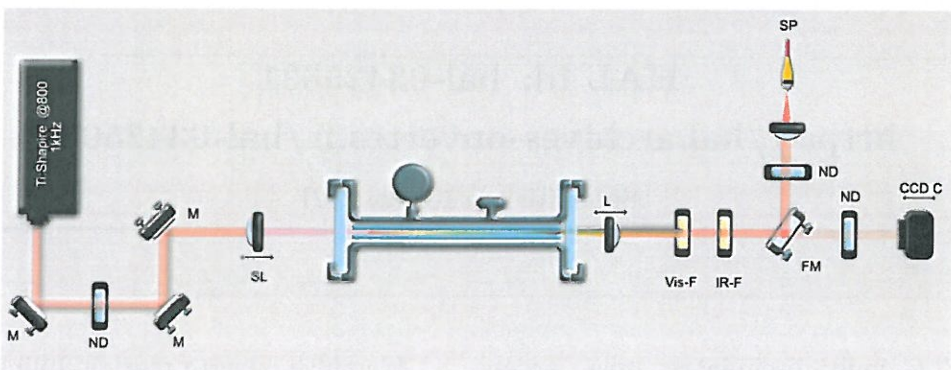

Figure 1. Experimental set up. SL Plano Convex lens; BS, beam splitter; ND absorptive neutral density filter; Vis-F, long-pass filter in visible region; IR-F, long-pass filter in infrared region; SP, Spectrometer; FM, Flip Mirror; M, Mirror. CCD C, Camera, L positive lens.

3. Results and discussion

During the propagation, the pump pulse undergoes a symmetrical spectral broadening. At the HCC output, the high wavelength part (>1000 nm) of the spectrum is selected with a long-pass filter. By removing the central part of the pump, the edge of the spectrum is detected up to 1150 nm (Figure 2.b). According to the beam profile, this part actually propagates on a high order mode (HE_{21}) and appears from a FWM process seeded by a signal lying in the low wavelength side of the spectrum. Indeed, Figure 2.c shows the coherence length as the function of the wavelength and the pressure when the generated infrared profile can be the HE_{11}, HE_{21} or HE_{12} mode. In this case, the pump and signal propagate in the fundamental modes.

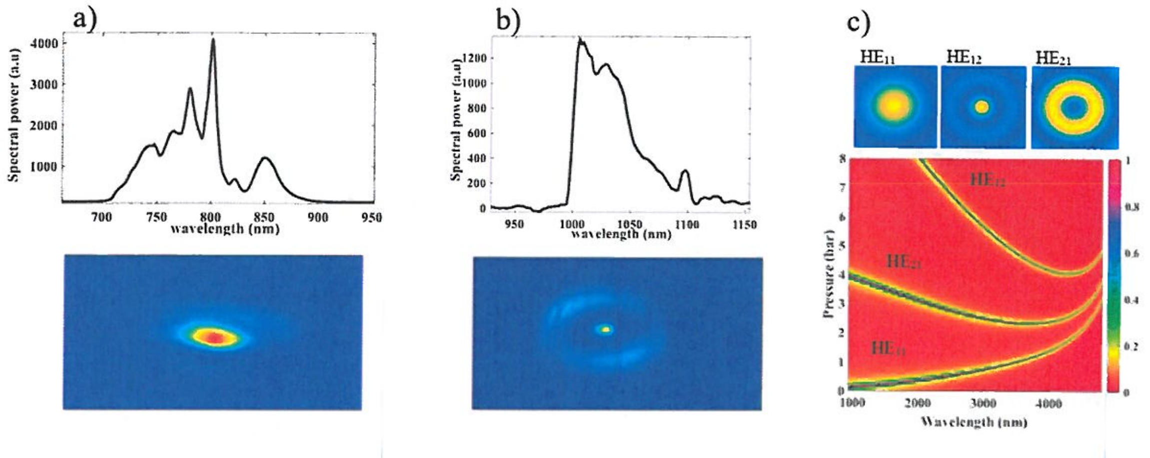

Figure 2. a) Spectrum and beam profile at the HCC output. b) Spectrum and beam profile when the high-wavelength part is filtered. c). Calculated coherence length when the signal and pump (at 800 nm) profile are in the fundamental modes and the infrared is in the HE11, HE12 or HE21 mode.

4. Conclusion

In this work, we investigate the modal FWM in an argon filled capillary apperaring simultaneously with SPM. This self-seeding effect is a very promising method to extend the spectral tunability with various modal phase-matching from a pump pulse in the fundamental mode.

5. Acknowledgement

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