



## **Soliton self-compression in air filled Kagome HCPCF**

Martin Maurel, Foued Amrani, Benoît Debord, Frédéric Gérôme, Fetah Benabid

### **► To cite this version:**

Martin Maurel, Foued Amrani, Benoît Debord, Frédéric Gérôme, Fetah Benabid. Soliton self-compression in air filled Kagome HCPCF. Conference on Laser and Electro-Optics /Europe (CLEO/Europe-EQEC 2019), Jun 2019, Jun 2019, Munich, Germany. Paper CD-1.3. <hal-02330720>

**HAL Id: hal-02330720**

**<https://hal.science/hal-02330720v1>**

Submitted on 23 Nov 2020

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



HAL Authorization

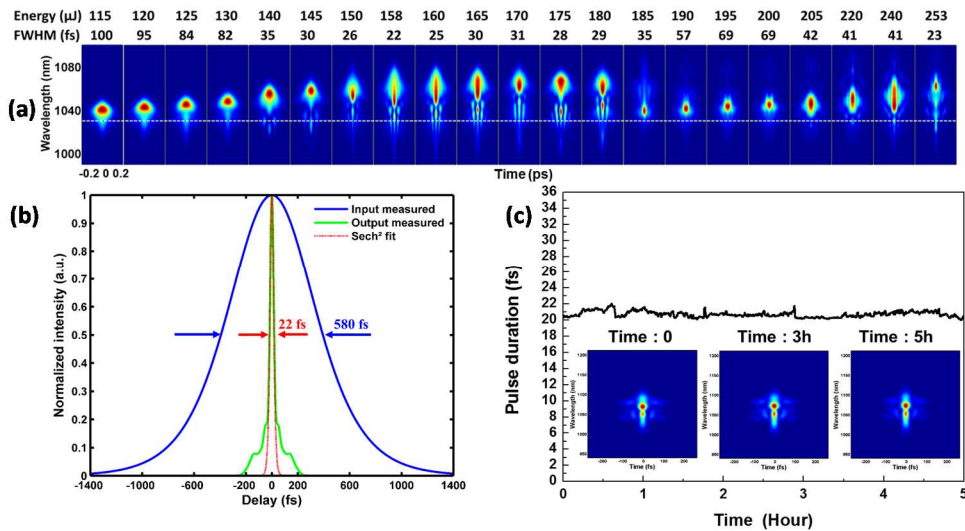
# Soliton self-compression in air filled Kagome HCPCF

Martin Maurel<sup>1,2</sup>, Foued Amrani<sup>1</sup>, Benoît Debord<sup>1,2</sup>, Frédéric Gérôme<sup>1,2</sup>, Fetah Benabid<sup>1,2</sup>

1. GPPMM group, Xlim laboratory, CNRS- Université de Limoges, France. 2. GLOphotonics, 123 avenue Albert Thomas Limoges, France

Hollow-core photonic crystal fibre (HCPCF) proved to be a powerful platform for optical pulse compression. Several results, reported in the last few years, show both exceptional compression performances over a large energy dynamic range and varied experimental conditions [1][2][3], and new physical dynamics [4]. Among the reported performances, we list those achieved with Inhibited-Coupling guiding HCPCF (IC-HCPCF), and where soliton self-compression down to the single or a few cycle regime were achieved with a  $\sim 1.8 \mu\text{m}$  wavelength and 80 fs duration input-pulse [1], and with a 790 nm wavelength and 24 fs duration input-pulse [2]. Conversely, the low values and spectral profile of the IC-HCPCF dispersion, combined with its fine control through a judicious choice of a filling gas, enabled the observation of several nonlinear optical regimes as varied as modulation instability, self-phase modulation, supercontinuum generation, or plasma-induced soliton blue-shift and fission. Remarkably, in the latter regime, experimental and theoretical results show that soliton-plasma interaction and its high sensitivity to the input laser and IC-HCPCF parameters are overarching several novel solitonic phenomena[4]–[6] such as strong soliton self-compression, blue and red frequency-shift and fission. Here, we report on experimental observations of soliton self-compression and temporal-spectral propagation dynamics of 100 microJoule-scale ultra-short pulse (USP). The frequency-resolved optical gating (FROG) results show the compression of 580 fs to a highly stable 22 fs pulse in a single stage, and the observation of an original sequence between soliton red and blue frequency-shift for input pulse energy range of 100-250  $\mu\text{J}$ .

The experimental set-up consists of a few meter long Kagome IC-HCPCF exposed to atmospheric air and excited with USP laser. The latter is a 580 fs duration Yb-based laser with a maximum energy of 1 mJ, a central wavelength of 1030 nm and the repetition rate of 1 kHz. The fibre has an inner core diameter of 57  $\mu\text{m}$ , a loss of 30 dB/km and group velocity dispersion (GVD) of  $\beta_2 = -300 \text{ fs}^2/\text{m}$  at the laser wavelength. Fig 1(a) shows the FROG evolution of the output from a 4 m long fibre with the input energy, from 115  $\mu\text{J}$  to 255  $\mu\text{J}$ . Within this range, the results show a 100 fs wide soliton self-compressed and red-shifted pulse at 115  $\mu\text{J}$  to further frequency red-shift with increasing energy, to reach a 22 fs pulse at 158  $\mu\text{J}$  (*i.e.* Intensity  $\sim 10 \times 10^{14} \text{ W}/\text{cm}^2$ , and comparable with the air ionisation). For the energy range 157-180  $\mu\text{J}$ , the FROG shows a more structured spectrogram corresponding to soliton fission, and moderate temporal broadening. At 185-190  $\mu\text{J}$  range, a sudden strong blue-shift and temporal broadening takes place, after which the pulse triggers another red-shift and then compression sequence to reach a duration of 23 fs at 253  $\mu\text{J}$ . We associate this novel dynamics to the interplay between an onset of photo-ionisation, which induces plasma and soliton blue-shift, with soliton formation and Raman red-shift [4]. Despite the high sensitivity of this phenomenon, the compressed pulse is highly stable. Figs. 1(b) and 1(c) summarises this observation at an input energy of 158  $\mu\text{J}$ . The autocorrelation traces (Fig.1(b)) show a compressed and close to sech<sup>2</sup>-shaped (red dashed curve) pulse of 22 fs (Green curve), which 26 narrower than the input pulse (blue curve). The pulse-width from 2 m long fibre was monitored over 5 hours (Fig. 1(c)), and was found to be 21 fs with standard deviation of only of 0.3 fs.



**Fig. 1** (a) Spectral and temporal evolution of the output pulse with energy, (b) Autocorrelation traces of the compressed and input pulses at 158  $\mu\text{J}$  input energy, (c) Pulse-width evolution with time over 5 hours of continuous running.

[1] T. Balciunas *et al.*, *Nat. Commun.*, vol. 6, (2015).

[2] K. F. Mak *et al.*, *Opt. Lett.*, 38(18), 3592–(2013).

[3] B. Debord *et al.*, *Opt. Express*, 22(9), 10735–10746 (2014).

[4] M. F. Saleh *et al.*, *Phys. Rev. Lett.*, 107(20), 203902 (2011).

[5] P. Hölzer *et al.*, *Phys. Rev. Lett.*, vol. 107(20), 203901 (2011).

[6] B. Debord *et al.*, in *Optics InfoBase Conference Papers*, 2014.