Chalcogenide Glass Polarization Maintaining Photonic Crystal Fiber for Mid-Infrared Supercontinuum Generation

Amar N. Ghosh[1], Marcello Meneghetti[2], Christian R. Petersen[3], Ole bang[4], Laurent Brilland[3], Johan Troles[2], John M. Dudley[1], and Thibaut Sylvestre[1]

1. Institut FEMTO-ST, CNRS, Université Bourgogne Franche-Comté, Besançon, France
2. Glasses and Ceramics Group, ISCR UMR-CNRS 6226, University of Rennes 1, 35042 Rennes, France
3. SelenOptics, 263 Avenue du Gal Leclerc, Campus de Beaulieu, 35700 Rennes, France
4. DTU Fotonik, Dept. of Photonics Engineering, Technical University of Denmark, Ørsteds Plads 343, 2800 Kongens Lyngby, Denmark

Chalcogenide-glass-based optical fibers are excellent photonic platforms for nonlinear applications in the mid-IR region due to their wide transmission window, tunable dispersion and high optical nonlinearity. Furthermore, polarization-maintaining fiber minimizes polarization mode dispersion and eliminates polarization-dependent effects, thus enabling applications in interferometric techniques, gas sensing, integrated-optic devices and optical coherence tomography.

In this work, we demonstrate mid-IR supercontinuum (SC) generation in a highly birefringent polarization maintaining photonic crystal fiber (PM-PCF), for the first time to our knowledge. The PM-PCF was drawn from $As_{32}Se_{68}$ glass using casting method [2] featuring a transmission window from 2-10 µm and a high nonlinear refractive index up to 1.13×10^{-17} m^2/W. Microstructure optical fiber provides the opportunity of having strong birefringence by designing asymmetric arrangements of air holes. The PCF cross section consists of total 36 circular air holes distributed in 3 rings with 2 larger air holes adjacent to the core, as shows the scanning electron microscope (SEM) image in Fig. 1(a). The core diameter (i.e. distance between two big air holes) and the outer diameter of the PCF are 8.11 µm and 125 µm, respectively. The group velocity dispersion and group birefringence, shown in Fig. 1(b) and 1(c), respectively, were computed for the fundamental mode using numerical modelling from its SEM image. This fiber has a zero-dispersion wavelength around 4.5 µm and, at this wavelength, a large birefringence of 6.10^{-4} thus enabling strong polarization maintaining.

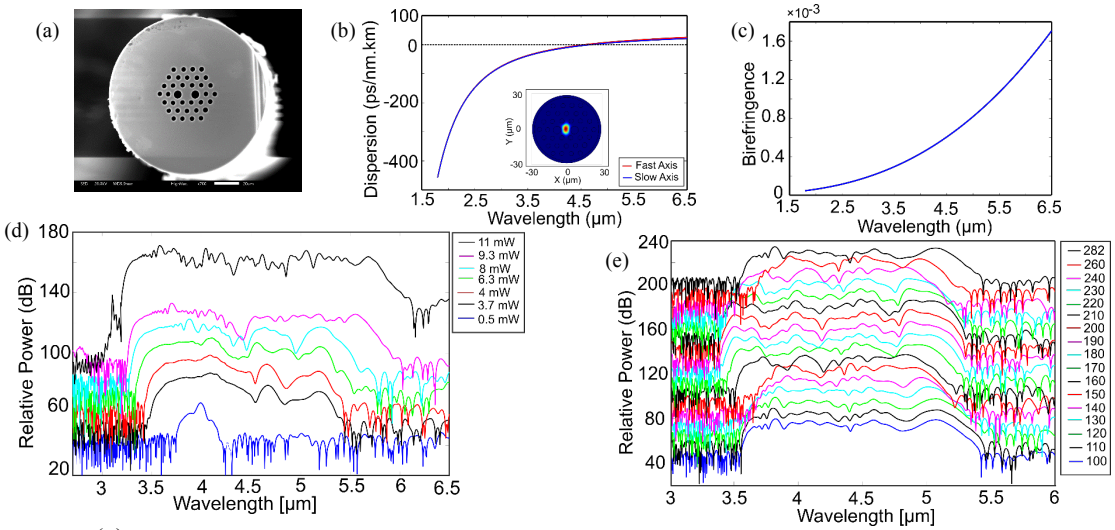

Fig. 1 (a) SEM image of the chalcogenide PM-PCF. (b) & (c) Group velocity dispersion and birefringence of the fiber. (d) SC spectra generated in the PM-PCF sample pumped at 4 µm with 250 fs laser pulses. (e) Dependency of SC spectra with incident angle of polarization for pumping at 4.53 µm.

A 25cm long PM-PCF was pumped with a 250 fs laser at 4 µm in the normal dispersion regime using the same experimental setup for MIR SC generation as in Ref.[3]. Figure 1(d) shows the generated SC spectra with different output power. For a pump power of 135 mW, we obtained a SC spectrum from 3.1 µm up to 6.02 µm with an average output power of 11 mW. The polarization dependency of the fiber is measured for a 4.53 µm pump at significantly low input power by changing the coupling angle through rotation of the fiber, which is shown in Fig. 1(e). These results demonstrate the potential of chalcogenide PM-PCF for polarized SC generation, and work is underway to optimize the spectral generation and polarization dependency further using detailed numerical modelling based on the calculated fiber guidance properties.

References

[1] A. B. Seddon, "A prospective for new mid-infrared medical endoscopy using chalcogenide glasses," Int. J. Appl. Glass Sci. **2** (3), 177–191 (2011).

[2] G. S. Athanasiou, J. Ernst, D. Furniss, T. M. Benson, J. Chauhan, J. Middleton, C. Parmenter, M. Fay, N. Neate, V. Shiryaev, M. F. Churbanov, and A. B. Seddon, "Toward mid-infrared, subdiffraction, spectral-mapping of human cells and tissue: SNIM (Scanning near-field infrared microscopy) tip fabrication," J. Lightwave Technol. **34**(4), 1212–1219 (2016).
[3] Q. Coulombier, L. Brilland, P. Houizot, T. Chartier, T. N. N'Guyen, F. Smektala, G. Renversez, A. Monteville, D. Méchin, T. Pain, H. Orain, J-C. Sangleboeuf, and J. Trolès, "Casting method for producing low-loss chalcogenide microstructured optical fibers", Opt. Express **18** (9), 9107 (2010).
[4] C. R. Petersen, R. D. Engelsholm, C. Markos, L. Brilland, C. Caillaud, J. Troles, and O. bang, " Increased mid-infrared supercontinuum bandwidth and average power by tapering large-mode-area chalcogenide photonic crystal fibers," Opt. Express. **25** (13)**,** 15336 (2007).

35 word abstract: Polarization-maintaining Mid-IR supercontinuum generation from 3.1 μm up to 6.02 μm is experimentally demonstrated in an $As_{32}Se_{68}$ glass highly-birefringent photonic crystal fiber pumped by an optical parametric generation source for OCT applications.