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Towards full mid-infrared supercontinuum generation with tapered chalcogenide-glass rods

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Abstract. We experimentally demonstrate that simple tapered Ge-Se-Te glass rods with femtosecond pumping enables efficient multi-octave mid-infrared supercontinuum generation, from 1.7 to 16 µm, while keeping an excellent spatial beam profile.

Supercontinuum (SC) generation has been studied extensively in various optical fibers. During the last 15 years, the interest has significantly shifted toward the mid-infrared (mid-IR) spectral region where molecules display fundamental vibration absorptions [1-2]. Among soft glasses, chalcogenides exhibit suitable transparency that makes them the unique candidate for fiber-based SC sources spanning the entire mid-IR (2-20 µm). However, the ability to handle high-quality glasses and fiber drawing to fabricate engineered low-loss fibers for SC generation beyond 10-12 µm is very challenging [3]. Here we propose an alternative approach to facilitate future developments of fiber SC sources reaching the 15-20 µm waveband, by simply post-processing of a chalcogenide rod-type fiber (i.e., a single-index fiber). We then demonstrate its efficiency by reporting on mid-IR SC generation spanning from 1.7 to 16 µm with femtosecond pulse pumping of a 5-cm-long tapered Ge-Se-Te rod.

As a well-known post-processing technology, tapering fibers enables the simultaneous management of light confinement and dispersion. In addition, tapering is an easier technical task compared with step-index, double-clad or microstructured fiber fabrication, in particular for chalcogenide glasses [4]. This also provides other beneficial impacts such as a higher coupling efficiency from laser beam to fiber, and it can have reduced effect on the optical loss. From $Ge_{20}Se_{70}Te_{10}$ glass rods synthetized by the melt quenching method, we have drawn low-loss single-index fibers (i.e., rods) with 180-µm outer diameter (see bottom of Fig.1a and corresponding losses depicted in Fig. 1b). Such thin rods are subsequently tapered by means of a computer-controlled filament fusion splicer to form biconical tapers. Different parameters (waist diameter, tapering length, etc.) were investigated to fabricate high-quality tapered rods with waist diameter ranging from 15 to 50 µm and tapering length below 5 cm.

The efficiency of tapered nonlinear rods for mid-IR SC generation was assessed by using the experimental setup shown in Fig. 1a. We made use of 170-fs mid-IR pulses with 4-µJ available energy (1-kHz repetition rate) around 6.3 µm to pump our distinct untapered and tapered Ge-Se-Te rods (with same 5-cm-long segment). Laser pulses are coupled into rods by means of a 20-mm-focal Ge lens and the output SC is collected through a mid-IR hollow-core fiber with high transmission over 2-16 µm and then launched into a monochromator coupled to our MCT detector operating up to 22 µm. Moreover, we also characterized the spatial distribution of output SC by near-field imaging the rod end-face onto a mid-IR camera. As a result, we were able to confirm the higher efficiency of tapered rods for SC generation when compared with untapered one, thanks to better light confinement and a more suitable zero-dispersion wavelength in the waist region (see Fig. 1b-1d). As an example, we here show in Fig. 1d one of the broadest SC spectrum spanning from 1.7 to 16 µm obtained in a tapered rod with 25-µm waist diameter. Corresponding SC energy was measured to be 0.16 µJ, only twice less than its untapered counterpart showing mid-IR extension limited to 12 µm (see Fig. 1c). Finally, we will show how this first SC demonstration in tapered rods might trigger new opportunities for chalcogenides into the mid-IR domain and beyond.

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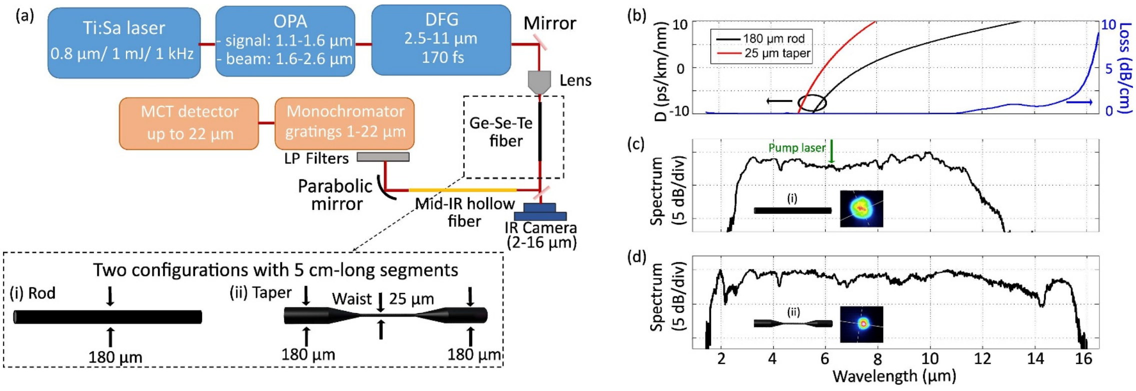

Fig. 1. (a) Experimental setup for mid-IR SC generation. (b) Left axis: Calculated dispersion of fundamental guided mode for 180- and 25-µm Ge-Se-Te rods. Right axis: Ge-Se-Te glass loss. (c-d) Measured output SC spectra for 5-cm-long segments of untapered and tapered rods. Insets show the near-field image of SC light at the rod end-face.

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