Light-on-a-Chip Group

Electrooptical Engineering

ITMO UNIVERSITY

BGU

Mid-infrared supercontinuum covering the 1.413.3 μm molecular fingerprint region using ultra-high NA chalcogenide step-index fibre

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Outline

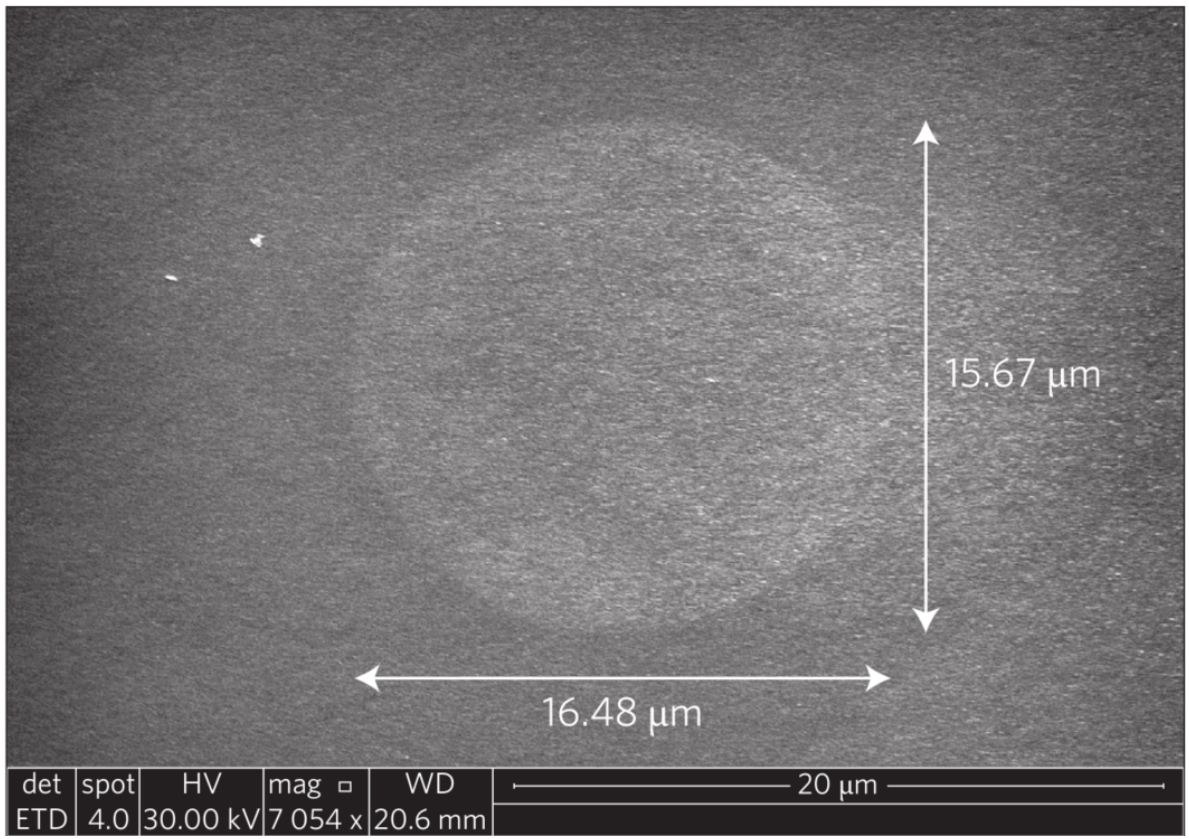
Scientific motivation and current situation

- The mid-infrared spectral region is of great technical and scientific interest because most molecules display fundamental vibrational absorptions in this region, leaving distinctive spectral fingerprints
- The use of silica fibres as the bandwidth-generating medium is limited by strong material absorption above 2.4 μm
- Current state-of-the art SCG fibre laser sources cover the 14.75 μm spectral region when based on fluoride or tellurite fibres
- Chalcogenide glasses have been shown to transmit light out to 25 μm, but the use of such materials in SCG has so far been limited by the lack of high peak power pump sources in the MIR

Main goal and achievements

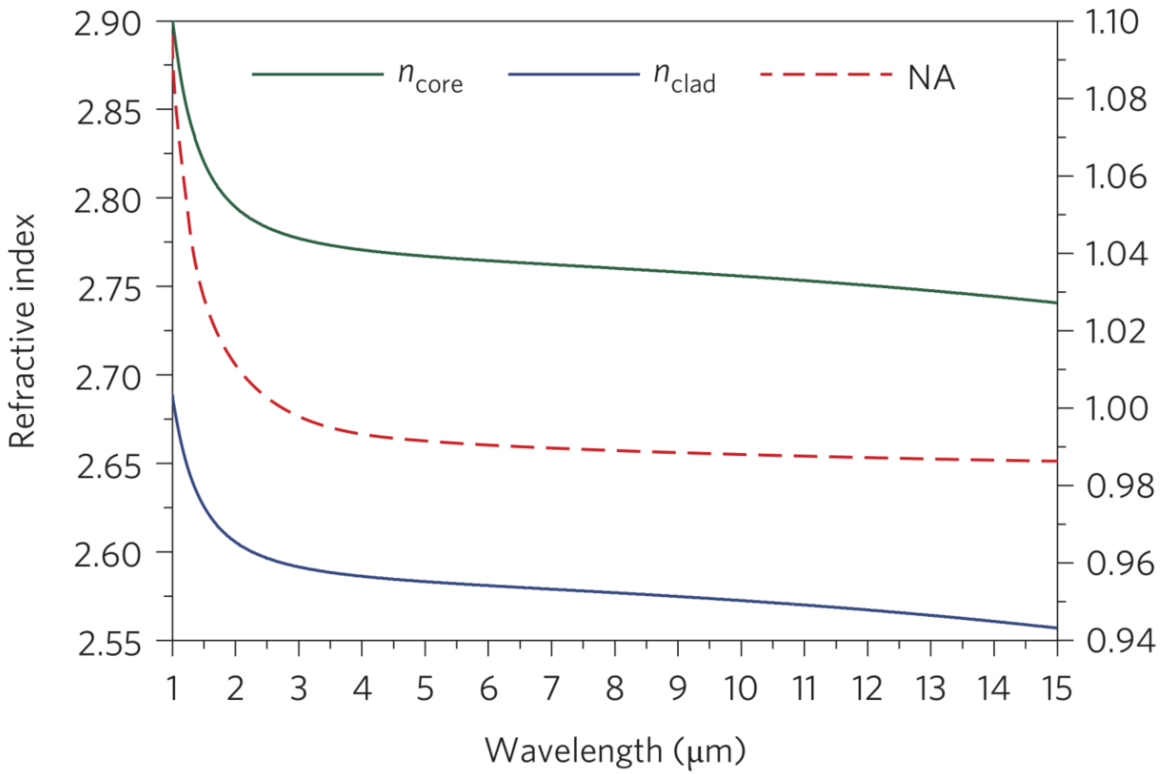
- Authors demonstrated MIR SCG in chalcogenide-glass SIFs, which have been specifically designed for both ultra-high NA and thermal compatibility of the core and cladding glasses.
- The SIF has a slightly elliptical $\approx 16 - \mu m$-diameter $As_{40}Se_{60}$ core surrounded by a $Ge_{10}As_{23.4}Se_{66.6}$ cladding.
- Because of the large core and NA, the fibre is effectively multi-moded; both the fundamental mode (FM) and the three most significant higher-order modes (HOMs) have been modelled.

Fiber image



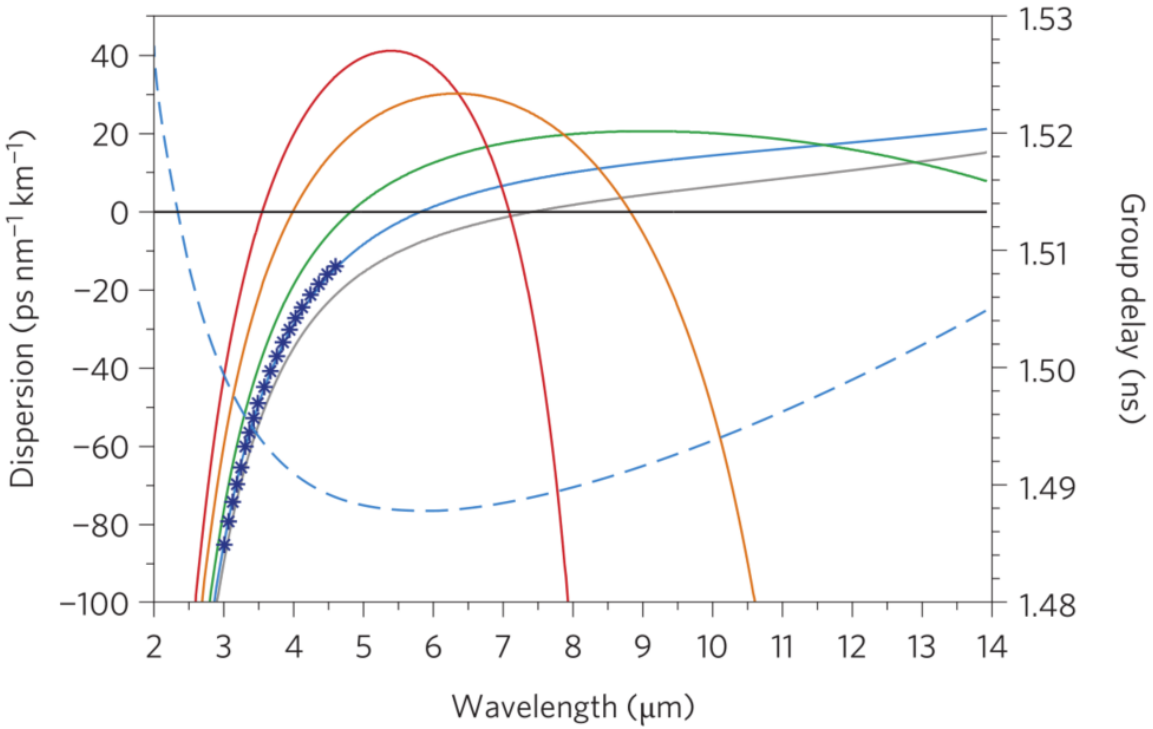
Scanning electron microscope image of the fibre core. Vertical and horizontal scale bars for the core are 15.67 μm and 16.48 μm, respectively.

Chalcogenide fibre parameters



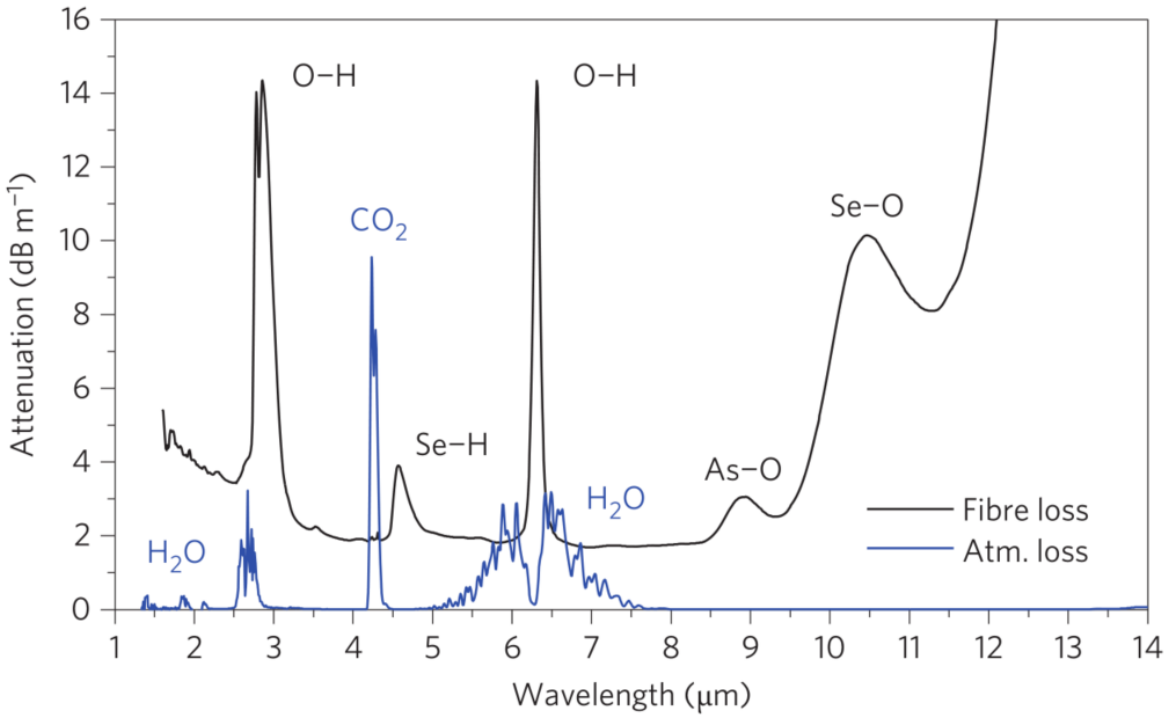
Measured refractive indices of the fibre core and cladding glasses, and the calculated NA.

Chalcogenide fibre parameters



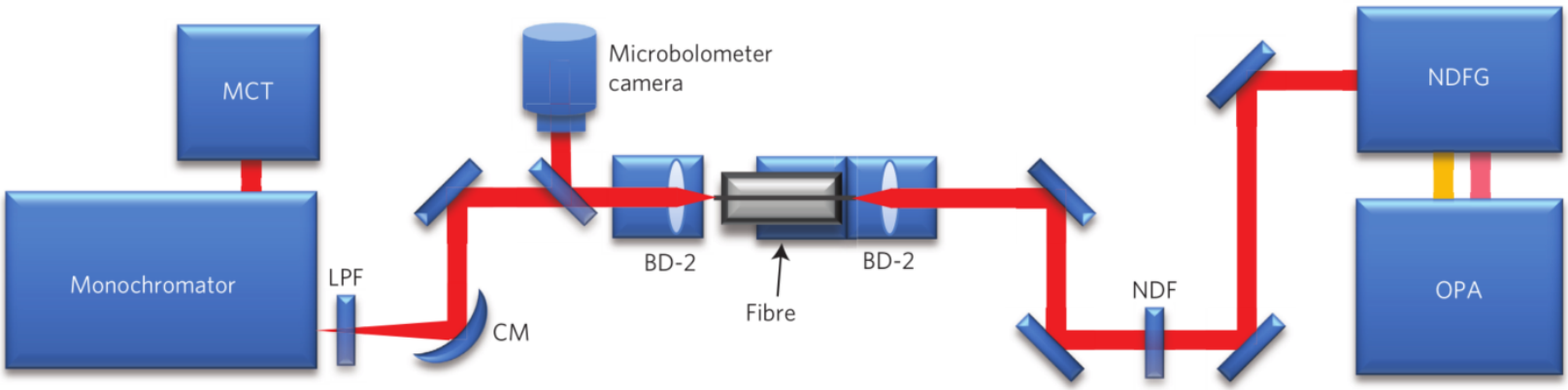
Calculated dispersion profiles (solid lines) of the core material (grey) and the four dominant guided modes of the fibre, LP01 (blue), LP11 (green), LP02 (orange) and LP12 (red), together with the measured dispersion (symbols) and calculated group delay (dashed line) of LP01.

Chalcogenide fibre parameters



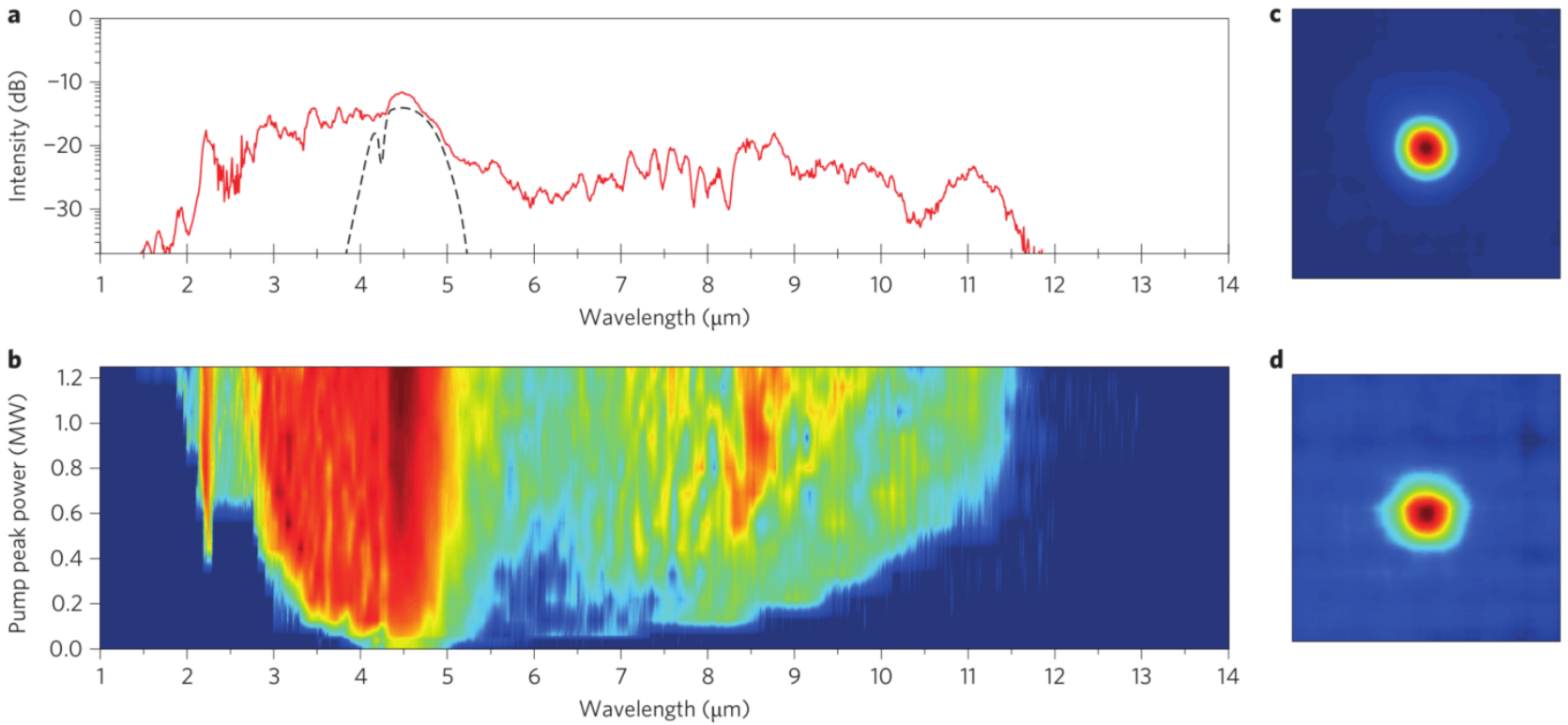
Loss measurements performed using a Fourier transform infrared spectrometer, where the fibre measurement was performed using an intermediate fabrication step fibre with a core diameter of $\approx 288\ \mu m$ and the atmospheric loss was measured in a 250 mm compartment.

Generating and measuring MIR SC.



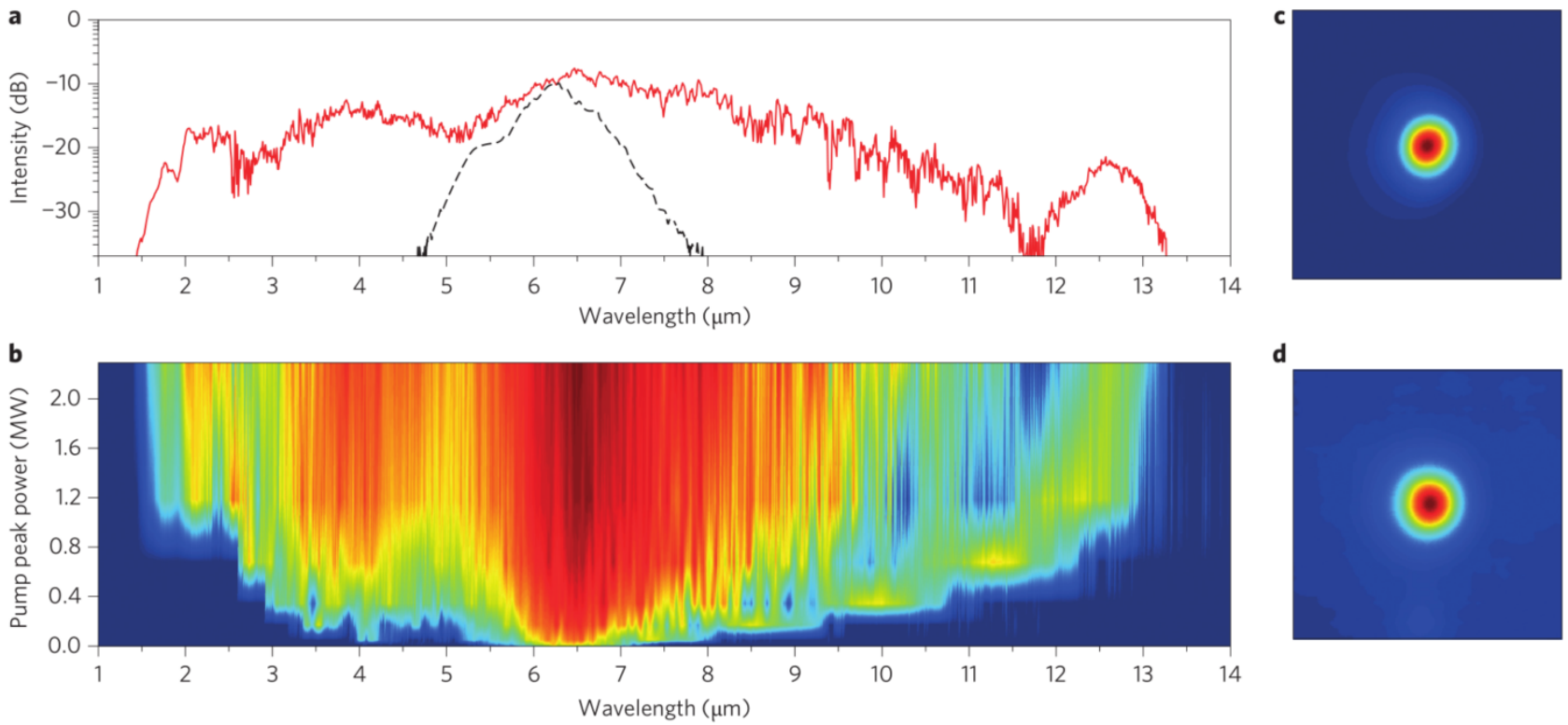
A noncollinear difference frequency generation (NDFG) unit pumped by an optical parametric amplifier (OPA) was used to produce the MIR pump. The output was free-space-coupled into the fibre and subsequently collimated by aspheric lenses. A concave mirror was placed before the monochromator to prevent beam clipping and compensate for chromatic aberrations. Proper coupling to the core was verified by near-field imaging using a micro-bolometer camera. BD-2, black-diamond-2 aspheric lenses; NDF, neutral density filter; CM, concave mirror; LPF, long-pass filter.

Experimental SCG results: 4.5 μm.



The pump centred at 4.5 μm. a) maximum power spectra b) Spectral evolution with increasing pump peak power c) Fibre output near-field beam profile for all WL d) for 7.3 μm

Experimental SCG results: 6.3 μm.



The pump centred at 6.3 μm. a) maximum power spectra b) Spectral evolution with increasing pump peak power: broad flat SC c) Fibre output near-field beam profile for all WL d) for 7.3 μm

Conclusions

- Despite a broad spectrum with wavelengths comparable to the core diameter, one can observe proper core guidance in the fibre, with the energy remaining confined to the core at all power levels.
- The maximum average output power was limited to $\approx 150\mu W$ due to the low 1 kHz pump repetition rate.
- The fibre-based supercontinuum source reported here represents a breakthrough in broadband MIR light sources, covering the transparent atmospheric windows of 3 - 5 μm and 8 - 13 μm (ref. 1), as well as the important part of the fingerprint region from 1.4 to 13.3 μm.
- Future applications: early cancer diagnosis, chemical sensing and food quality control.