Picosecond Fiber MOPA Pumped Supercontinuum Source With 39 W Output Power

Kang Kang Chen[1,*], Shaif-ul Alam[1], Jonathan H. V. Price[1], John R. Hayes[1], Dejiao Lin[1], Andrew Malinowski[1], C. Codemard[1], Debashri Ghosh[2], Mrinmay Pal[2], Shyamal K. Bhadra[2] and David J. Richardson[1]

[1]*Optoelectronics Research Centre, University of Southampton, Highfield, Southampton, SO17 1BJ, United Kingdom*
[2]*Fibre Optics Laboratory, Central Glass & Ceramic Research Institute Kolkata, CSIR, India*
kkc@orc.soton.ac.uk

Abstract: We report picosecond fiber MOPA pumped supercontinuum source with 39W output, spanning at least 0.4-1.75µm with high and relatively uniform spectral power density of ~31.7mW/nm corresponding to peak power density of ~12.5W/nm in 20ps pulse.

OCIS codes: (060.2320) Fiber Optics Amplifiers and Oscillators; (060.4370) Nonlinear optics, fibers.

1. Introduction

Photonic crystal fibers (PCF) with high non-linearities and tailored dispersion profiles have been widely used for supercontinuum generation [1, 2]. Recently, Travers et. al. [3] demonstrated a supercontinuum source pumped by a 400 W CW laser at 1.07 µm with either 50 W average output power in the region of 1.05-2.2 µm or 28 W covering 0.6 – 1.9 µm spectral region with power densities varying between 2 mW/nm in the visible and ~30 mW/nm in the infrared. Here we present a picosecond fiber MOPA pumped supercontinuum source with high optical-to-optical conversion efficiency of ~68%, covering from 0.4-1.75 µm with an output power as high as 39 W at an incident pump power of 57 W with relatively uniform spectral power density over 30 mW/nm.

2. Experiment and results

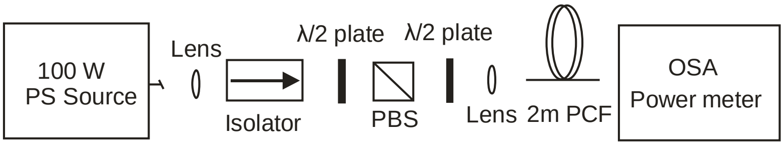

Fig. 1. Schematic diagram of the setup.

Figure 1 shows the schematic of the experimental setup. The pump laser used in here has been described previously [4]. A 21 ps duration, 0.15 nm linewidth gain switched semiconductor diode at 1060 nm was used for the seed. The fiber MOPA produced 0.85 µJ pulses with up to 100 W of linearly polarized average power at selected repetition rates from 28 MHz to 919 MHz through the use of an electro-optic modulator pulse-picker. The output beam has a stable M^2 of ≤1.1 due to the use of a tapered splice into the final stage amplifier. The polarization extinction ratio (PER) was better than 19 dB after the MOPA but the optical elements used inside the bulk isolator degraded the PER to a certain extent. A half wave plate and a polarization beam splitter were used to eliminate the light coupled into the other polarization axis inside the isolator. The total insertion loss in isolator, half wave plate and PBS was about 30%. Another half wave plate just in front of the coupling lens enabled alignment of the polarization axis of the beam to the birefringence axis of the PCF.

Measured dispersion values and the extrapolated dispersion profile of the PCF fiber are shown in Fig. 2 along with an end facet view. Pitch (Λ) of the air holes was measured to be 5.29 µm with d/Λ ~ 0.956 while the diameter of the fiber core was 4.37 µm. The zero dispersion wavelength lies around 1040 nm as shown in Fig. 2. Therefore the ps pump source lies in the anomalous dispersion region providing maximum spectral broadening due to the interplay between nonlinear effects including SPM, FWM, SRS, XPM and soliton fission. A short piece of PCF fiber (~2 m) was adequate to generate continuum as detailed below. Figure 3 shows the average output power of the supercontinuum source as a function of the incident pump power. The highest power continuum of 39 W was achieved at 114.8 MHz with > 80% launch efficiency and 87% pump depletion. The insets in Fig.3 show the far field pattern of the output beam and the prism separated white light demonstrating the blue enhanced visible spectra. The roll off in output power is due to the beam quality degradation inside the bulk isolator with increasing MOPA output power and thermal effect at the coupling end of the PCF. Power scaling is possible by resolving thermal problem in the isolator. Figure 4 shows the spectral evolution at an incident power level of 0.15 W, 11 W and 57 W. The system produced a spectrum covering at least 400 nm to 1750 nm (measurements limited by range of our OSA

(ANDO AQ6315)) with spectral flatness better than 10 dB. It is to be noted here that the maximum broadening was achieved when the polarization of the coupled beam was aligned to one of the birefringence axes of the PCF. Figure 5 shows the temporal profiles of the optical pulses corresponding to low power pump transmission, filtered with a 1.2 nm bandwidth AOTF at 1186.6 nm and 1317.6 nm, as well as that of the broadband spectra measured using a 20 ps resolution InGaAs photodiode and sampling scope. The shoulder to the rear of the pulse was verified to be due to light on the other birefringence axis of the PC. Note that the extended tail was confirmed to be an electrical measurement artifact through impulse response measurement using clean 200 fs pulses.

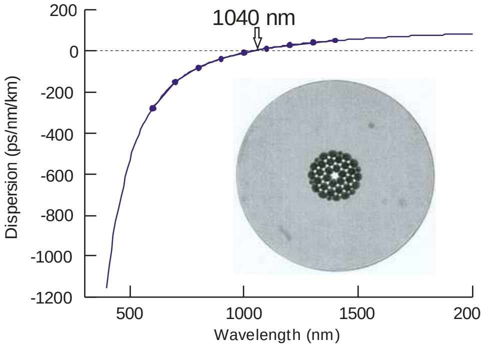

Fig. 2. Measured dispersion data (blue dots), extraploted dispersion curve (solid line) and the corresponding fiber structure

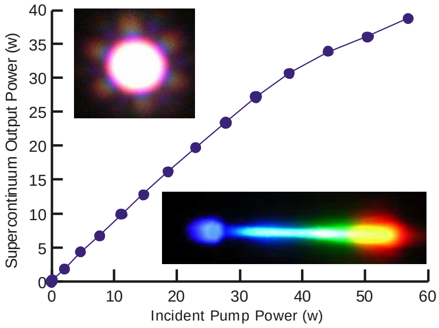

Fig. 3. Supercontinuum output power vs incident power. Inset show the far field pattern of the output beam and prism separated white light

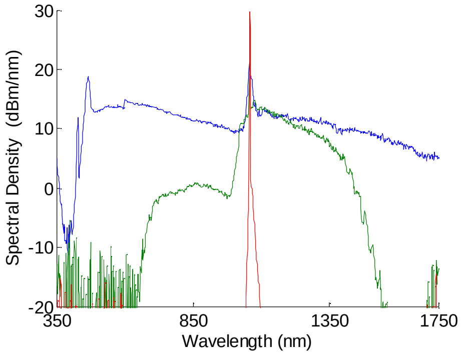

Fig 4. Supercontinua evolution in a 2m long PCF at 0.15 W, 11 W and 57 W of incident pump power

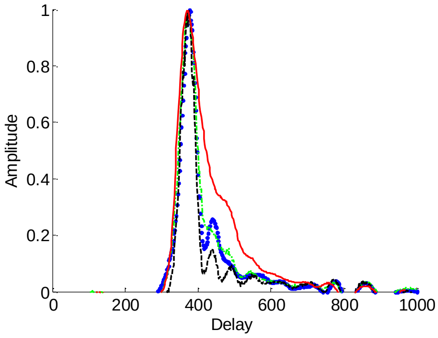

Fig 5. Pulse shape of transmitted low power pump (blue dotted line), filtered at 1186.6 nm (green dash dotted line), filtered at 1317.6 nm (black dashed line) and broadband (red solid line).

3. Conclusions

We have successfully demonstrated a picosecond fiber MOPA pumped high power supercontinuum source covering at least 0.4-1.75 µm spectral. Average output powers as high as 39 W with > 80% launch efficiency and 87% pump depletion were achieved with an overall conversion efficiency of 68%. A power density of up to 31.7 mW/nm with good uniformity across the full spectral range was obtained.

4. Acknowledgement

This work was supported in part by the Technology Strategy Board project (LAMPS) & UK and India cooperation project (UKIERI). The PCF was fabricated at Central Glass & Ceramic Research Institute Kolkata, CSIR, India under CSIR Network Project-NWP026 & DST. Mr. M. Alharbi assisted with the characterisation of the fiber.

5. References

[1] J.K. Ranka, R.S. Windeler and A.J. Stentz, “Visible continuum generation in air-silica microstructure optical fibers with anomalous dispersion at 800 nm”, Opt. Lett., 2000. 25(1): p. 25-27.

[2] J.M. Stone and J.C. Knight, “Visibly "white" light generation in uniform photonic crystal fiber using a microchip laser”, Opt. Express, 2008. 16(4): p. 2670-2675.

[3] J.C. Travers, A. B. Rulkov, B. A. Cumberland, S. V. Popov, J. R. Taylor, “Visible supercontinuum generation in photonic crystal fibers with a 400W continuous wave fiber laser”, Opt. Express, 2008. 16(19): p. 14435-14447.

[4] K. K. Chen, S.-U. Alam., J. R. Hayes, D. Lin, A. Malinowski and D. J. Richardson, “100W Single Mode Single Polarization Picosecond Ytterbium Doped Fibre MOPA Frequency Doubled to 530 nm”, CLEO Pacific Rim, 2009, Paper TuF4-4, Shanghai, China.