9 W average power, 150 kHz repetition rate diamond Raman laser at 1519 nm, pumped by a Yb fibre amplifier

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Commercially available pulsed fibre lasers at ~1.5 μm have many uses in imaging, defense, communications and light radar (LIDAR) [1]. For 3D scanning LIDAR, higher signal-to-noise ratio requires lasers with high average power and high pulse repetition rate (ideally several MHz) for faster scanning rate, whereas to improve distance resolution requires pulse durations <10 ns [2,3]. One limitation of the pulsed fibre lasers at ~1.5 μm is scaling to high average powers [4]. Raman frequency conversion of high average power fibre master oscillator power amplifier (MOPA) systems at ~1 μm is a potential alternative. The large Raman shift and Raman gain of diamond allows two-stage Raman conversion to ~1.5 μm for ~1 μm pumping [5]. Excellent thermal properties make diamond suitable for high average powers [6]. Much work has been done on conversion of 1.064 μm lasers to 1.485 μm using diamond [7]; however, the “eye-safety” requirements for LIDAR typically call for wavelengths above 1.5 μm, due to the order of magnitude higher Maximum Permissible Exposure limit [8]. Developing such a diamond Raman laser (DRL) was the major motivation for this research.

Experimentally a DRL at 1.519 μm was pumped by a maximum of 50W of power from an Yb fibre MOPA emitting polarized 15-ns pulses at 1.082 μm with 150 kHz repetition rate [9]. The MOPA’s linewidth of 0.18 nm was comparable to the diamond’s Raman linewidth. The pump beam was focused to 90 μm radius in a 4 mm long diamond crystal. The 15 mm long DRL cavity consisted of a plane input coupler and a 50 mm radius of curvature output coupler. The input coupler was highly reflective at 1.2 μm and 1.5 μm and highly transmissive at 1.08 μm. The output coupler had a transmittance of 70% at 1.52 μm and was highly reflective at 1.2 μm. The diamond was supplied by Element 6 (UK) Ltd. and had an absorption coefficient of <0.005 cm^{-1} at 1 μm and was oriented for propagation along the <110> axis. The pump was polarised along the <111> axis of the diamond and the mode sizes for 1st and 2nd Stokes were 90 and 100 μm respectively.

The maximum power achieved from the DRL at 1.52 μm (Fig. 1 (b)) was 9 W (Fig. 1 (a)) with a pulse duration of 7 ns (Fig. 1 (c)). The maximum conversion efficiency was 23% (Fig. 1 (a)). The slope efficiency was 29% before the plateau at 40W of pump power. The high-power roll-over may have been caused by the pump beam quality degradation, either in the MOPA or in an isolator that was used to block the back reflected pump emission. Funding: EP/P00041X/1, EPSRC EP/P001254/1. Research data: doi.org/10.15129/b17b6db6-7c52-46a3-b13a-f89b61e38c0c

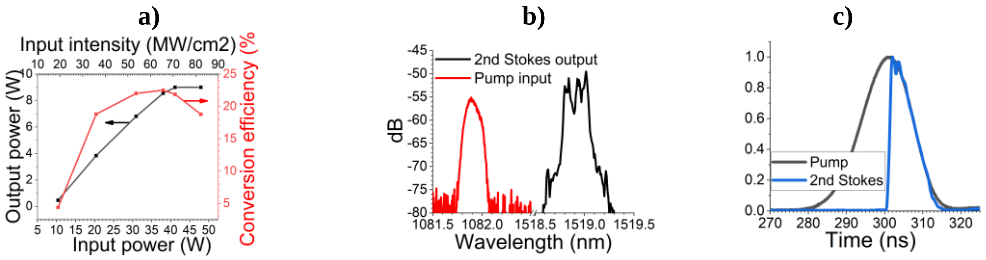

Fig. 1 Power transfer and energy conversion (**a)**), pump and output spectra (**b)**) and 2nd Stokes pulse (**c)**)

References

[1] G. P. Agrawal, *Nonlinear Fiber Optics*, 3rd. ed., (Academic Press, Boston, 2001)
[2] J.P. Dakin, RobertG.W. Brown, *Handbook of Optoelectronics (*CRC Press, 2010)
[3] E.P. Baltsavias, "Airborne laser scanning: basic relations and formulas," J. Photogramm. Remote Sens., **54**, pp. 199-214, (1999)
[4] M. N. Zervas and C. A. Codemard, "High Power Fiber Lasers: A Review," IEEE Journal of Selected Topics in Quantum Electronics, **20**, pp. 219-241, (2014)
[5] V. G. Savitski, S. Reilly, and A. J. Kemp, "Steady-State Raman Gain in Diamond as a Function of Pump Wavelength," IEEE J. Quantum Electron., **49**, pp. 218-223, (2013)
[6] J.-P. M. Feve, K. E. Shortoff, M. J. Bohn, and J. K. Brasseur, "High average power diamond Raman laser," Optics Express, **19**, pp. 913-922, (2011)
[7] Alexander Sabella, James A. Piper, and Richard P. Mildren, "Efficient conversion of a 1.064 μm Nd:YAG laser to the eye-safe region using a diamond Raman laser," Opt. Express **19**, 23554-23560 (2011)
[8] International Electrotechnical Comission, Safety of laser products – Part 1, 60825-1, (2001)
[9] Z. Huang, S. Pidishety, T. W. Hawkins, Y. Feng, Y. Feng, S. Zhu, L. Dong, and J. Nilsson, "Low-birefringence 120 W Yb fibr amplifier producing linearly polarized pulses with 69-GHz linewidth at 1083 nm," in *Laser Congress 2018 (ASSL)*, OSA Technical Digest (Optical Society of America, 2018)