Compact and Portable Multiline UV & Visible Raman Laser in Hydrogen-filled HC-PCF

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Abstract *We present a very compact multi-line Raman-laser with broad spectral coverage from near-IR through to the much sought after yellow, deep blue and UV. Each line of the laser exhibits high power density which is ideal for forensics and biomedical applications requiring narrow-linewidth and high-power at several discrete wavelengths.*

Introduction

The high efficiency of gas-laser interaction and low attenuation offered by hollow-core photonic crystal fibres (HC-PCF) has been exploited in many non-linear applications such as pulse shaping, quantum optics and Raman amplification[1]. Furthermore, when a gas-filled HC-PCF takes the form of a photonic microcell (PMC)[2,3], which consists of a gas-filled HC-PCF hermitically spliced to conventional all-solid optical fibers, it adds a highly compact and integrable value to this fiber, holding, thus the premise of the advent of a new breed of photonic materials.

A HC-PCF filled with an appropriate Raman active gas is particularly attractive as a compact Raman source that can offer both high conversion efficiency and spectral tunability. This has been illustrated in the recent generation of a multi-octave spanning optical frequency comb[4]. The comb was obtained through the use of large-pitch Kagome HC-PCF[5], and has opened excellent prospects for spectroscopic applications requiring discrete wavelengths. However, the bulky infrared laser-pump used in the work limits the usefulness when portability is a requirement. Among the fields which are in an acute need for portable multi-wavelength lasers we count those which require an on-ground diagnosis or data-collection such as environmental monitoring or forensic sciences. Here a compact, portable and a battery powered Raman laser is developed that provides discrete comb-lines throughout the UV and visible spectrum. The system consists of a compact high repetition rate microchip pump laser and a specially designed Kagome HC-PCF. The spectral coverage encompasses the sought after yellow, deep blue and UV wavelengths. The system is an excellent candidate for the above-mentioned applications. It is also an alternative to the conventional supercontinuum for applications where either a high spectral power-density, resolved spectral components or UV emission is needed. Finally, the observed self-coherence of the laser lines alludes to the possibility of temporal synthesis of such a comb.

Experimental Setup

Figure 1a shows photography of the components of the whole system. This consists of several-meter long HC-PCF PMC containing hydrogen gas at a pressure of10 bar. The PMC is pumped by a high repetition rate (7 kHz) 532 nm (doubled Nd:YAG) diode pumped solid-state microchip laser with an average output power of 25 mW (i.e. peak power of 6 kW). The pump laser can be hold on the palm of a hand (fig 1a). The whole system was then put into a small portable box (fig. 1b). Figure 1b also shows the output beam dispersed and displayed on the front of a box containing this novel laser.

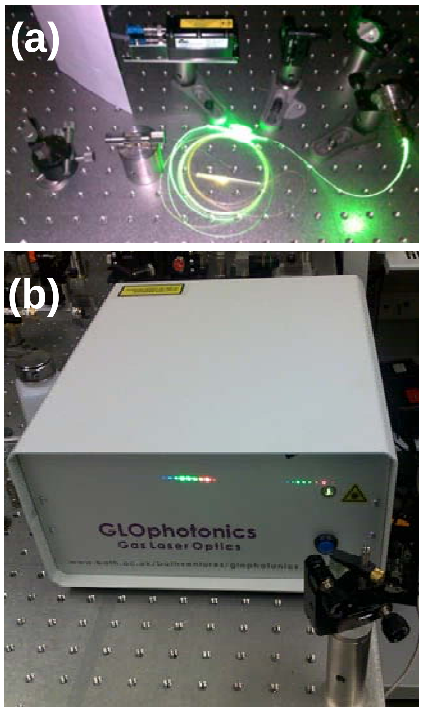

Fig. 1 (a) Photograph of experimental setup; (b) Photograph of a physical package containing the PMC based Raman laser. The laser output beam is dispersed and displayed on the front laser box.

The HC-PCF has a Kagome-lattice cladding which was designed so the high loss spectral region[2] coincides with the first vibrational Stokes wavelength. This diminishes the vibrational SRS generation (125 THz Raman shift) and therefore enhances the rotational Raman transition (~18 THz Raman shift). This enables the emission of several lines in the UV-Visible range as it is illustrated in fig. 1b.

Results

The output spectrum observed with only 20 mW of average coupled-power is shown in figs. 2a & 2b. The spectrum spans over 450 THz and contains 23 lines in the hitherto poorly covered UV-Visible range. In addition to 9 rotational Raman sidebands of the initial pump, the spectrum counts one vibrational Stokes and two vibrational anti-Stokes. Each of these vibrational lines gives rise to a number of rotational sidebands, resulting in a spectrum comb-like extending from 712 nm in the near infra-red, to 353 nm in the UV. Figure 1b also exhibits the fraction of the 10 mW output power contained in each spectral line. This illustrates the efficiency of the process whereby 60% of the optical power is converted from the pump line to the rest of the spectrum. Given the linewidth of each line being under a GHz level, the spectral peak-power density is in excess of 100 mW/GHz for all the generated lines. This is larger than what is available in conventional supercontinua by more than four orders of magnitude even when a much more powerful pump lasers are used[6]. Furthermore, the spectrum exhibits emission at wavelengths that are highly sought after such as yellow lines for biomedical applications or deep blue and UV lines for DNA sequencing to mention a few. Significantly higher quantum conversion and power density can be achieved by moderately increasing the pump power. Such an unprecedented efficiency is due to the strong light confinement in the HC-PCF and the transiency of the amplification regime of the Raman scattering[2]. Finally, the generated spectral comb can be Tailored or extended by a judicious design of the fibre or a choice of the pump laser.

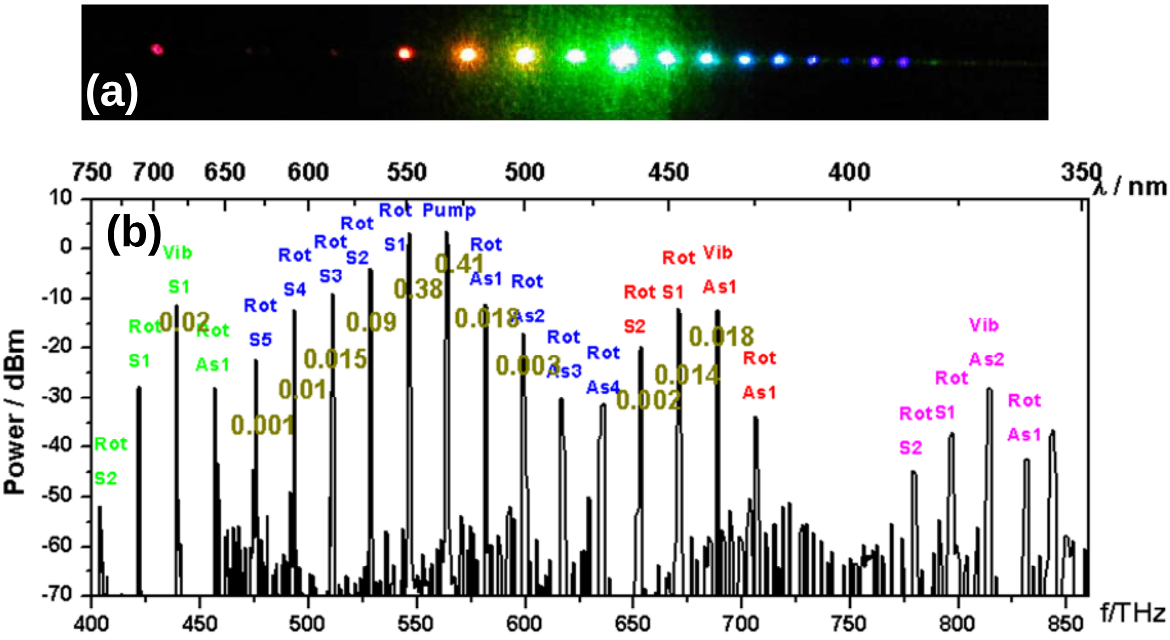

Fig. 2 (a) Dispersed output spectrum recorded on a CCD camera; (b) Output spectrum measured using an optical spectrum analyzer.

Conclusions

In conclusion, we developed a highly compact multi-line laser based on Raman scattering in a PMC. The laser exhibits a comb-like spectrum spanning from the UV to the NIR. Each line shows a narrow linewidth and a high power density. The system can be further reduced in size by the use a fibre-pigtailed laser, removing the need for coupling optics by splicing directly to the microcell, resulting in an extremely compact all-fibre multi-line Raman laser. This Raman laser has applications in areas such as forensics and drug recognition using fluorescence, where relatively high power density is required at a number of discrete wavelengths. Furthermore, the preliminary results on coherence of the spectral components show that the present laser source could be used for temporal synthesis.

References

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