Blue light generation in holey fibre using frequency doubled fibre pump source

R.E. Kennedy, S.V. Popov and J.R. Taylor

A report is presented on the efficient generation of 18 mW of 428 nm light by propagating frequency doubled 780 nm pulses from an all-fibre integrated picosecond pulse source with kW level peak power through a length of highly nonlinear holey fibre. The wavelength conversion process is attributed to resonant coupling between solitons and dispersive radiation.

Recently, 24% conversion efficiency from 800 nm radiation to 430 nm radiation was obtained by pumping a holey fibre (HF) with a zero dispersion wavelength of 700 nm with MW peak power, fs pulses from a Ti:sapphire laser [1]. Qualitatively similar results were obtained by configuring the laser to emit 1.3 ps pulses with ~1 kW peak power. The wavelength conversion technique has been considered numerically [2] and attributed to resonant coupling between solitons and dispersive radiation. This process has also been exploited through the use of short tapered holey fibres [3], allowing the generation of visible radiation at selectable wavelengths. From the point of view of applications of this wavelength conversion technique outside of the laboratory, it is important to consider more practical pump sources. In this Letter we demonstrate this technique using a frequency doubled kW level, ps fibre source.

The experimental setup is shown in Fig. 1. The ps all-fibre source is described in detail in [4] but a brief summary is given here. The system is an SPM-based compressor [5] with compression in aircore photonic bandgap fibre. ~40 ps pulses from a modulated external cavity semiconductor laser at a wavelength of 1.56 µm were amplified in an erbium-doped fibre amplifier to a peak power of 12.5 W and subsequently spectrally broadened by propagation through 3.5 km of dispersion shifted fibre (DSF). The pulses were then further amplified to a peak power of ~1.3 kW in a low nonlinearity EDFA (LN-EDFA) and finally compressed in 110 m of anomalously dispersive aircore photonic bandgap fibre. The fibre had a core diameter of 11 µm and a spectrally flat anomalous dispersion of 90 ps nm⁻¹ km⁻¹ over the wavelength range of operation. The output pulses had a FWHM duration of ~1 ps and a peak power of ~20 kW. The output spectrum had a bandwidth of ~5 nm, indicating a significant chirp. Note that this part of the system was completely fibre integrated, and did not require any bulk optical alignment, which is an important advantage in terms of low maintenance operation.

The pulses were then frequency doubled in a 3 mm crystal of periodically poled KTP. With the crystal temperature maintained at 174 °C, 418 mW of 783 nm radiation was generated, with an estimated internal efficiency of 41%. Note that recent advances in nonlinear crystal waveguide technology [6] may allow all-fibre integrated frequency doubling in the near future, although possibly with somewhat lower average powers.

The frequency doubled pulses were then launched into 3.3 m of HF. The fibre used had a core diameter of 2 µm, a zero dispersion wavelength of 660 nm, and an estimated anomalous dispersion of 150 ps nm⁻¹ km⁻¹ at 780 nm. With an average power of ~200 mW coupled into the core of the HF, an infrared continuum was apparent in the output spectrum, together with a strong blue component at 428 nm, as shown in Fig. 2, which is plotted on a linear scale. The 428 nm peak has a FWHM of 18 nm, and contains about 20% of the total output power. An average power of 90 mW was measured at the HF output. The average power could potentially be increased by using a lower duty factor and a higher output power from the LN-EDFA.

The spectral behaviour and the strong coupling of a distinct visible wavelength component to the soliton Raman component is indicative of the resonant coupling between solitons and dispersive radiation [7], as has also been described in [2]. However, the use of a fibre-based pump source, with the possibility of higher average power and full fibre integration, represents a more practical alternative to the Ti:sapphire laser and points to a wider application potential.

Conclusions: We have demonstrated 20% conversion efficiency to 428 nm by pumping a holey fibre with frequency doubled pulses from an all-fibre integrated ps duration, kW level fibre source. The wavelength conversion mechanism is understood in terms of coupling between solitons and dispersive radiation. The use of a fibre-based pump source provides advantages in terms of potential average power scalability and low maintenance operation.

Fig. 2 Spectrum at holey fibre output

The output spectrum had a bandwidth of 5 nm, indicating a significant chirp. Note that this part of the system was completely fibre integrated, and did not require any bulk optical alignment, which is an important advantage in terms of low maintenance operation.

References