Raman-DFB fibre laser enabled FWM in passive optical fibres

Jindan Shi *, Peter Horak, Shaif-ul Alam and Morten Ibsen
Optoelectronics Research Centre, University of Southampton, Southampton, SO17 1BJ, U.K.
jxs@orc.soton.ac.uk

Wideband wavelength conversion utilizing four-wave mixing (FWM) in optical fibres has received significant attention in the area of fibre communications and networking, due to the natural low-loss compatibility with the conventional optical transmission systems [ref]. Within a 30cm long centre π phase-shifted distributed-feedback (DFB) grating, formed in a commercially available germano-silica optical fibre (PS980, from Fibercore Ltd.), we recently experimentally demonstrated up to ~167nm wavelength conversion with a conversion efficiency up to -25dB [1, 2]. The concept of the FWM in that work was the following; firstly, a ~2W single-mode, single polarization Yb-doped fibre laser at 1064nm was used to pump a Raman DFB (R-DFB) grating to generate a narrowband signal at ~1117nm (the Bragg wavelength of the DFB) [3]. This lasing signal with a power of ~80mW subsequently acted as the pump for the FWM process allowing for the wavelength conversion of a low-power probe signal (~10mW) extending from 1040.8nm to 1207.8nm. Evidently, the phase-matching condition must be fulfilled to facilitate the FWM process. Although the wavelength region for the demonstrated FWM process lies entirely within the normal dispersion regime of the fibre, we believe that both the dispersion from the grating itself and the high intensity of the circulating lasing signal within the grating contributed strongly to modify the overall dispersion within the structure, thus enabling the phase-matching for such an efficient and wide-range FWM process.

In this work, we investigate this hypothesis theoretically, and compare the numerical results with the experimentally observed data. The numerical model is based on the parameters used for the R-DFB grating in the experimental demonstration, i.e., using a centre π phase-shifted Bragg grating of a length of 30cm and coupling-coefficient of 37 m^{-1}, formed in the PS980 fibre (NA~0.12; MFD~6.2μm @ 1100nm). The FWM pump wave, i.e., the R-DFB lasing signal, exhibits a nonlinear intensity distribution profile symmetric around the phase-shift in the DFB cavity, as seen in Fig. 1(a). Both the intrinsic fibre dispersion and the grating dispersion are taken into account in the simulations as discussed above. The FWM phase-mismatch factor (δk) is therefore composed of two parts: (1) the group-velocity dispersion (GVD) profile of the bare fibre, and (2) the DFB grating structure, δk_{FBG}. The evolution of the amplitude of the pump, probe and conjugate waves are obtained by numerically solving the coupled amplitude equations with a Runge-Kutta algorithm. The simulations show that the FWM conversion-efficiency enabled by the R-DFB fibre laser is more than 10^6 times higher than that obtainable from the same length of pristine fibre. Additionally, the 20dB wavelength conversion bandwidth is also found to be around 10 times wider.

Fig. 1(b) shows the calculated FWM conversion efficiency against the frequency detuning (the frequency separation between the probe and the pump wavelength) for varying δk_{FBG}. For the sake of comparison, the experimental data is also included in Fig. 1(b). The experimental data follow a similar trend to that of the simulated data. Furthermore, with the inclusion of the effects of the FBG induced dispersion, the peak FWM conversion efficiency is seen to shift to a larger frequency detuning, and the detuning frequency range is also seen to increase. We will present further simulation data at the meeting.

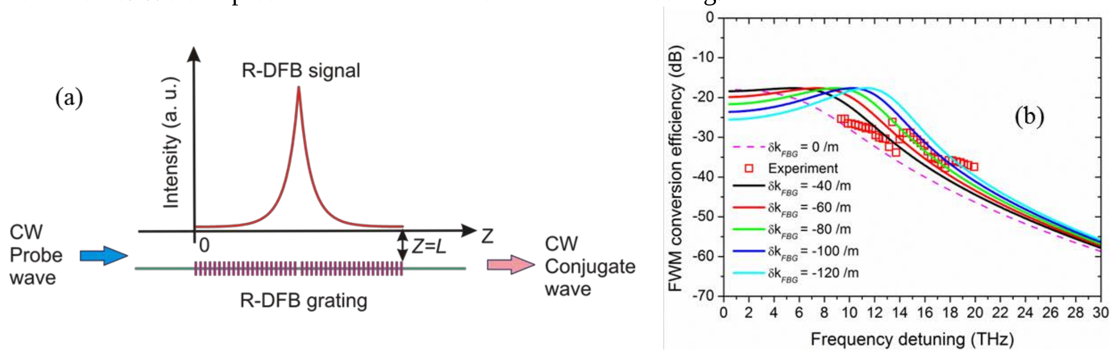

Fig. 1 (a) Schematic diagram of the spatial model setup for analysing the FWM in the R-DFB fibre laser; (b) Experimental and theoretical FWM conversion efficiency against frequency detuning in 30cm long centre π phase-shifted R-DFB fibre laser.

References:

[1]. J. Shi, S.-u. Alam, and M. Ibsen. '*Ultra-Broadband Wavelength Conversion Based on Four-Wave Mixing in a Raman DFB Fiber Laser*'. in proceedings to *OFC'2013*, paper JW2A.23, 2013.

[2]. J. Shi, S.-u. Alam, and M. Ibsen, '*Ultrawide-range four-wave mixing in Raman distributed-feedback fiber lasers*', Optics Lett., **38** (6), pp. 944-946, 2013

[3]. J. Shi, S.-u. Alam, and M. Ibsen, '*Sub-watt threshold, kilohertz-linewidth Raman distributed-feedback fiber laser*', Optics Lett., **37** (9), pp. 1544-1546, 2012.