Design of λ/4 Phase Shifted DFB Fibre Raman Laser

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The feasibility of building a distributed feedback fibre Raman laser based on a long uniform fibre Bragg grating was suggested by Perlin et al. [1]. However, such a laser requires good grating uniformity along a very long length, e.g. 1m, and has not been investigated experimentally. In this study, we demonstrated an improved design of a DFB fibre Raman laser with an optimised λ/4 phase-shifted grating structure, which enables highly efficient laser operation at low threshold with a relatively short cavity length.

We modelled the laser's time-dependent behaviour using the standard nonlinear coupled mode equations [1]. The grating length was 20cm, so that good grating uniformity is achievable in fabrication [2]. In order to reduce lasing threshold, a large value of the coupling constant (κ=60m^{-1}) and a small value of the effective mode area (A_{eff} = 2μm^2) were used in the model. These values are achievable using gratings written in microstructured fibres [3]. The λ/4 phase shift was applied by smooth transition of the grating constant κ along a short length of the grating, dz, centred at the phase shifted position, z_{ps}, again corresponding to a realistic grating.

Assuming Raman pumping from one side of the grating, we were able to numerically investigate the laser dynamics under CW pumping condition. With the λ/4 phase shifted structure inside the grating, the model showed a clear threshold above which single-mode steady-state lasing occurred. Increasing the pump intensity still further resulted in nonlinear instability (self-pulsation and chaos) as expected. We next examined the effect of changing the position and width (dz) of the phase shift. For an abrupt transition (dz=0), the laser had a maximum output power when phase shift position was slightly displaced from the cavity centre (z_{ps}/L=0.59). Increasing the width of the transition region then increased the slope efficiency from 50% to 72% and decreased the threshold as seen in Fig. 1. In comparison, a grating with the same parameters but without the phase shift had a threshold of >20W and was not stable at any pumping power levels.

Contrary to Perlin's prediction [1] that flat cavity field distribution is the only field configuration for lasing in a nonlinear DFB laser, this laser exhibited a non-uniform cavity power distribution in steady state (Fig. 2), which is typical for a λ/4 phase shifted DFB laser. As dz/L increased from 0 to 0.16, cavity power distribution was flattened with about 20% drop of peak intensity at the phase shifted position.

In summary, we demonstrated a λ/4 phase shifted DFB fibre Raman laser with optimised design has low threshold and high efficiency. The values of the parameters used in modelling are achievable in today's mature fabrication technology.

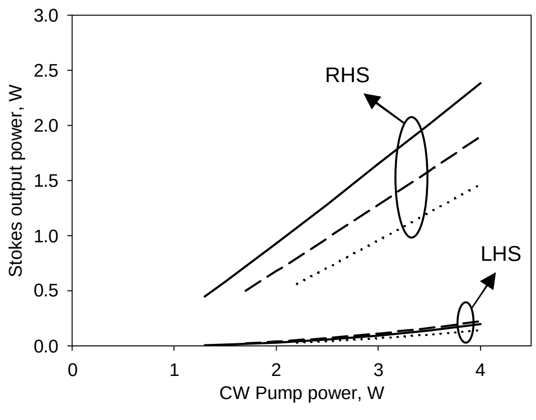

Fig. 1 Stokes output power versus CW pump power, z_{ps}/L=0.59. Solid line: dz/L=0.16. Dashed line: dz/L = 0.08, Dotted line: dz/L = 0.

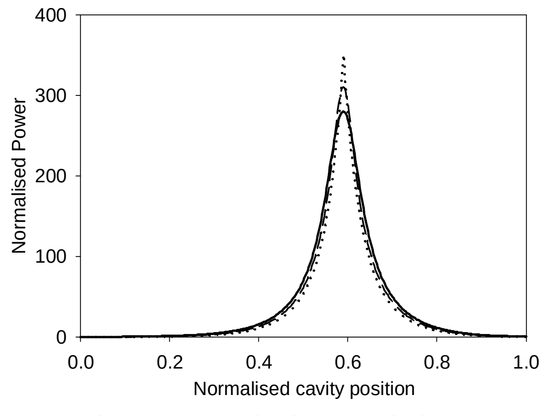

Fig. 2 Stokes wave power distribution inside the cavity in steady state, z_{ps}/L=0.59. Solid line: dz/L=0.16. Dashed line: dz/L = 0.08, Dotted line: dz/L = 0. Cavity power is normalised over input pump power (3W).

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[3] M. C. P. Huy, G. Laffont, V. Dewynter, P. Ferdinand, P. Roy, J. L. Auguste, D. Pagnoux, W. Blanc and B. Dussardier, "Three-hole microstructured optical fiber for efficient fiber Bragg grating refractometer", Opt. Lett., **32**, pp. 2390-2392 (2007)