Multiple wavelength all-fibre DFB lasers

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Abstract - All-fibre DFB lasers operating CW at 1.55μm on simultaneous multiple wavelength channels at room temperature are shown. The demonstrated lasers have channel separations of 25, 50 and 100GHz with identical output powers of 1mW.

Indexing Terms - Bragg gratings, fibre DFB lasers, WDM sources

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Introduction

All-fibre distributed-feedback (DFB) lasers [1] exhibit many attractive features and being based on and around a fibre Bragg grating they exhibit the robustness in performance offered by these, together with inherent fibre compatibility. They can readily be manufactured to operate in both a single longitudinal and single polarisation mode and strong single-sided output has also been demonstrated by offsetting the phase-shift from the centre position [2]. As the technology of fibre Bragg grating fabrication and manipulation has reached a level where the formation of complex refractive index profiles are possible [3,4], the step towards all-fibre systems is approaching at rapid pace. Multiple wavelength laser configurations have been demonstrated [5] and their applications to, for example accurate frequency referencing in wavelength division multiplexed (WDM) systems has been proposed. However, some of the previous demonstrations have suffered from the necessity to reduce the homogeneous line width of the gain medium to allow stable, multiple wavelength operation.

In this paper we demonstrate multiple wavelength Moiré DFB fibre lasers operating CW at room temperature on two wavelength channels separated by 25, 50 and 100GHz respectively. The complex grating structure has been written in a single step with any post-processing. The output power from each wavelength channel is ~0dBm for ~60mW pump power @ 980nm.

Laser design and experiment

The DFB gratings are written using a multiple exposure technique based on a grating plane by plane basis illumination with interferometric control that allows for very complex structures to be formed [3,4]. The Moiré structure is generated using apodisation, achieved by dephasing subsequent exposures with respect to each other on the fly, and hence is formed in just one writing procedure. The alternating regions of positive and "negative" refractive index change are obtained by inserting a discrete π-phaseshift after each half period of the sinusoid (Fig. 1). In order to obtain the preferential output from the lasers, the phase-shift is offset by 6% from the centre position [2]. At this phase-shift position no π-phase-shift is inserted (Fig. 1) thereby effectively shifting the two halves of the laser by π. The wavelength separation between the channels is determined by the period P of the modulation and is given by [3]

$$\Delta\lambda_{sep} = \frac{\lambda_B^{\,2}}{2\cdot n_{ave}\cdot P} \qquad \textbf{(1)}$$

where λ_B is the average Bragg wavelength in the structure and n_{ave} is the average refractive index. The DFB fibre lasers are written using ~100mW of CW UV-light at 244nm from a frequency doubled Ar-ion laser, and the total coupling coefficient, κ, in the gratings is estimated to be 350m^{-1}, yielding an effective coupling coefficient in either channel of ~175m^{-1}. The lasers are written using UV-light polarised orthogonal (s-pol.) to the axis of the fibre. This has been demonstrated as a technique to generate a differential grating strength [6] and subsequent single polarisation mode operation of the lasers [2]. The fibre used in the experiment is comprised of a photosensitive boron/germanium ring around a phosphorus Er/Yb-doped core [7]. To enhance the photosensitivity even further the fibre is deuterium loaded at 70°C and 60atm. for 7 days. The fibre has strong pump absorption of ~250dB/m at 980nm, and an absorption of ~35dB/m at 1535nm, up to ~60mW at 980nm is used to pump the lasers. The lasers are all 5cm long and the total writing time for each of the devices is just 20min.

Results and discussion

Fig. 2 shows the lasing characteristics of the two wavelength channels in each of the 3 lasers. The wavelength channels are separated by 100GHz, 50GHz and 25GHz (P=1mm, 2mm and 4mm respectively, see (1)). The output power vs. pump power shows slope efficiencies of ~10% for each of the two wavelength channels in each of the 3 configurations. Furthermore it shows that near identical channel output powers of ~0dBm are obtained for the maximum pump power of ~60mW @ 980nm for each of the wavelength channels in the lasers. The power in each of the channels is stable to within 0.1dBm and the wavelengths to ~0.1pm (12.5MHz) measured with a wavemeter (0.1pm res.).

Due to the homogeneous broadening mechanisms and the related homogeneous line width of the erbium in the silica-phosphorus glass host, one would expect that the laser would only lase in the mode that reaches threshold first, because this mode then would clamp the gain for all other modes within the homogeneous line width. However we believe this is avoided in this multichannel fibre DFB structure because of the strong hole burning provided by each of the wavelength channels. It is confirmed that the two wavelength channels operate in single but orthogonal polarisation modes, by strain-tuning a strong (R>99.99%) apodised Bragg grating across the output of the lasers to block one channel at a time and monitoring the polarisation state on a polarisation analyser. The feedback provided by the grating is blocked by an isolator after the laser.

We are currently working towards the demonstration of lasers operating in parallel polarisation modes on more that 2 channels using our sampled grating technology [3]. Obviously the maximum number of wavelengths that can be made to lase using this technique is determined by the maximum gain available in the length of the fibre used for the DFB structure.

One advantage of these structures is that the wavelength/frequency matching of several channels is simplified as they are effectively dictated by and locked together via the superstructure. Such effective frequency locking is a parameter that is of great importance in sensor systems where for example beat frequencies are measured. In WDM systems precise channel allocation is desirable to minimise the potential crosstalk that can occur between adjacent channels. Furthermore temperature stabilisation and packaging are simplified because the powers of the wavelength channels are effectively contained within the same length of fibre.

Conclusion

We have successfully shown an all-fibre DFB laser configuration allowing stable CW operation on two closely spaced wavelength channels at room temperature. Near identical output powers of the two channels of ~1mW are demonstrated with channel separations of 25GHz, 50GHz and 100GHz making the lasers attractive for WDM systems and well-suited for sensor purposes.

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Fig. 1 Refractive index profile and phase-shift positions in the multiple wavelength DFB fibre laser.

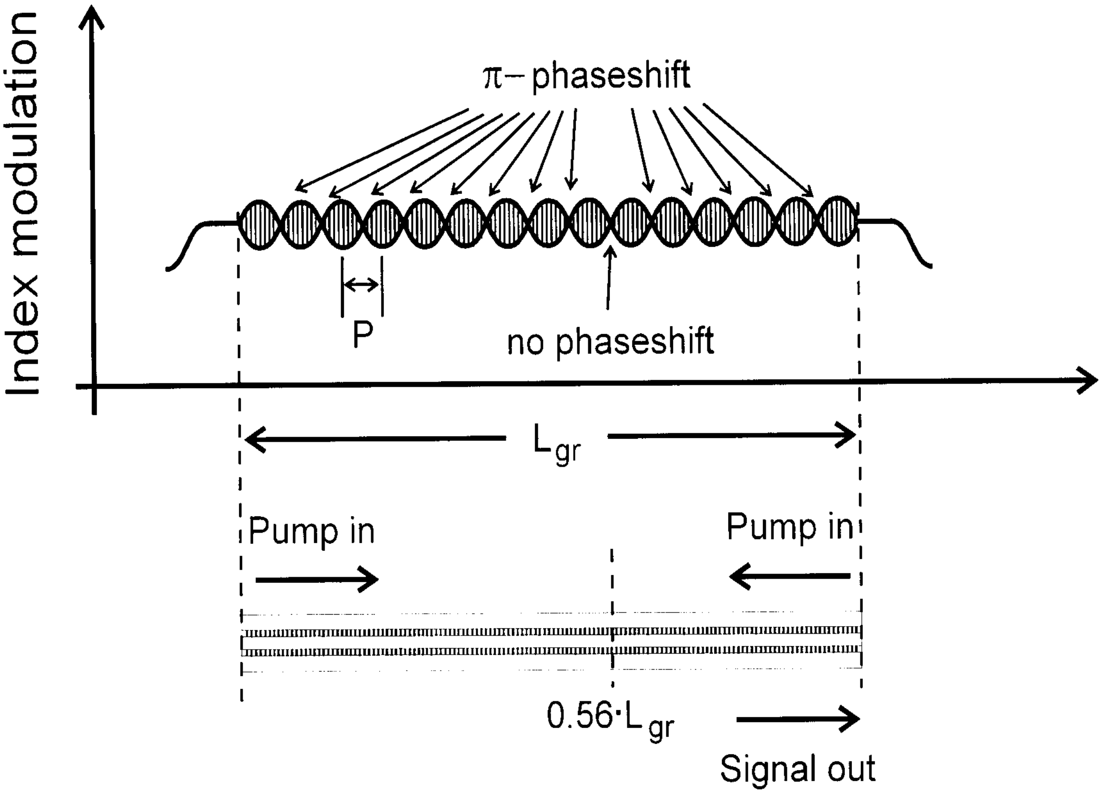

Fig. 2 Lasing spectra for the a) 100GHz, b) 50GHz and c) 25GHz channel separation multiple wavelength DFB fibre lasers.