Realisation of Single Polarisation State of Fibre Ring Laser by Utilising Intracavity 45˚ Tilted Fibre Bragg Grating

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Abstract: Single polarisation operation of fibre ring laser has been realised by employing an intracavity 45˚-tilted fibre Bragg gratings (45°-TFBGs). The degree of polarisation of 99.94% of the laser was demonstrated with good stability.

OCIS codes: (060.2340) Fiber optics components; (140.3510) Lasers, fiber

1. Introduction

Fibre lasers play important roles in optical communication and sensing applications, for which single mode and single polarisation state of the laser are more desirable. However, due to low-birefringence of standard and active fibres, the output of a fibre laser is in general unpolarised. To realise single polarisation operation for fibre lasers, several methods have been developed. One scheme involves integrating an integral polariser [1] and the other approach incorporates high-birefringence rare-earth doped fibre with two anisotropic fibre Bragg gratings [2]. Though these two methods can provide very high degree of single polarisation oscillation, the integral polarisers are difficult to fabricate and may induce high insertion loss to the laser cavity redeeming its efficiency. In this paper, we report a novel technique to realise single polarisation state of a fibre ring laser by employing an intracavity polariser based on a 45˚ tilted fibre Bragg grating (45°-TFBG) structure.

2. Polarisation Characteristics of 45˚-TFBGs

It has been reported that a unique polarisation discrimination property occurs when the Bragg grating structure is tilted at exact 45°, i.e. the grating will transmit only *p-polarisation* light in the fibre and completely outcouples *s-polarisation* from the side of the fibre [3]. This property makes 45°-TFBGs as an ideal in-fibre polariser to be integrated into fibre laser cavity. The 45˚-TFBGs used in our experiment were UV-inscribed in hydrogen loaded B/Ge fibres using scanning phase mask technique with a 244nm UV source from a CW frequency doubled Ar^+ ion laser. A phase mask with a period of 1800nm was rotated 33.7˚ with respect to the fibre axis to produce titled fringes of 45˚ in the fibre core and induce radiation response around 1550nm range [3]. Limited by the size of the phase mask, the maximal length of the 45˚-TFBG is only about 4mm. In order to obtain high polarisation extinction ratio, multiple short gratings were produced in tandem.

Two 45˚-TFBGs (T1 and T2) with lengths of 35mm and 50mm were characterised for their polarisation dependent loss (PDL) using two schemes illustrated in figure 1. In scheme 1 (figure 1a), light from a broadband source (BBS) was first polarised by a polariser before launched to the 45°-TFBG and the polarisation controller was also employed to change the polarisation state of the light in the grating. By changing the polarisation state, we can measure the maximum and minimum transmission spectra using an optical spectrum analyser (OSA). PDL spectrum was then obtained by subtracting the minimal transmission from the maximal transmission. As the light of different wavelengths from the BBS is polarised at different degrees, the measured PDL is an average effect over the measured wavelength range. Alternatively, we used a tuneable laser to replace the BBS in the second scheme which is shown in figure 1b.

Figure.1. Schematic of PDL measurement system employing (a) a broadband source and (b) a tunable laser.

Figure 2 (a) and (b) plot the PDL spectra measured with the BBS scheme for T1 and T2, respectively. As can be seen from the figure that the short grating T1 gives PDL ranging from 4dB to 6dB over 1500nm to 1600nm while for the longer grating T2 the PDL ranges from 20dB to 32dB. The ripples appeared in the spectra were caused by the residual reflection at the air-cladding boundary. Measurement results with method 2 are shown in figure 3. As the tunable laser was set at 1550nm, only the section between the two dotted vertical lines is the true value of the PDL at 1550nm and the features outside this region should be ignored. As shown in figure 3, the measured accurate PDL values for T1 and T2 at 1550nm are 5dB and 35dB.

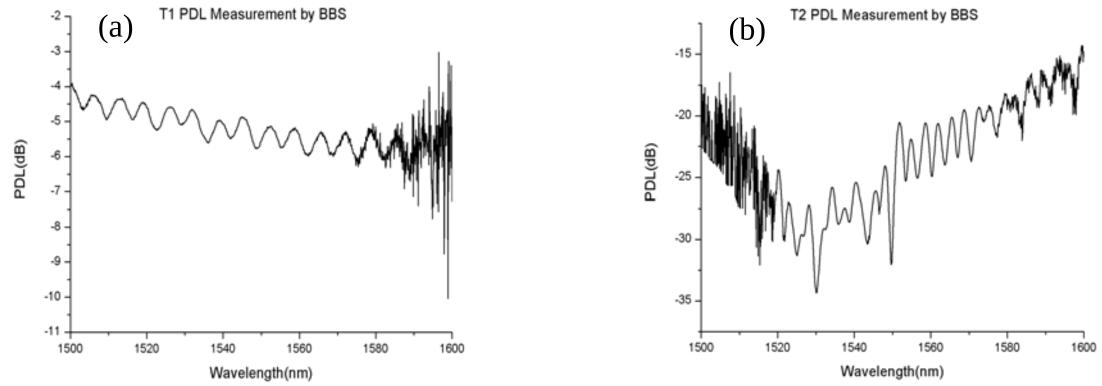

Figure.2. PDL spectra over 1500nm to 1600nm for (a) T1 and (b) T2 based on BBS scheme measurement

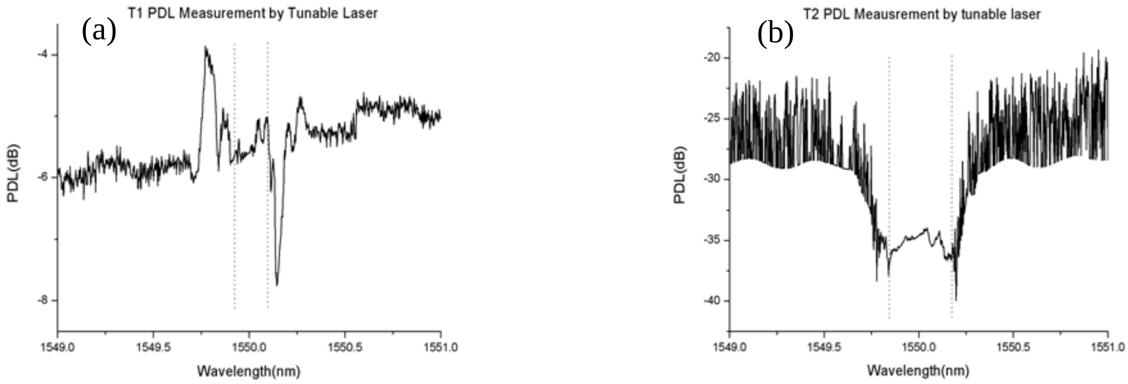

Figure.3. PDL spectra for (a) T1 and (b) T2 based on tunable laser measurement.

3. Degree of polarisation improvement of fibre ring laser

In order to evaluate the polarising function of 45˚-TFBGs, we constructed a fibre ring laser (as shown in fig. 4) employing 10m Er fibre, two optical isolators, one 980/1550nm WDM to pump the ring laser with a 980nm diode and a 10:90 coupler for laser output. A circulator connected to a 1550nm FBG was also incorporated in the cavity to provide single frequency oscillation at 1550nm.

The degree of polarisation (DOP) measurement of the output of the fibre laser is conducted by the setup shown in the dotted line box in figure 4 and DOP calculation is based on the following expression:

$$\text{Degree of Polarisation (DOP)} = \frac{P_{POL}}{P_{POL} + P_{UNPOL}} \times 100 \ \%$$

where P_{POL} and P_{UNPOL} stand for the power of polarised and un-polarised parts of the light. Therefore, 100% DOP represents a single polarisation output.

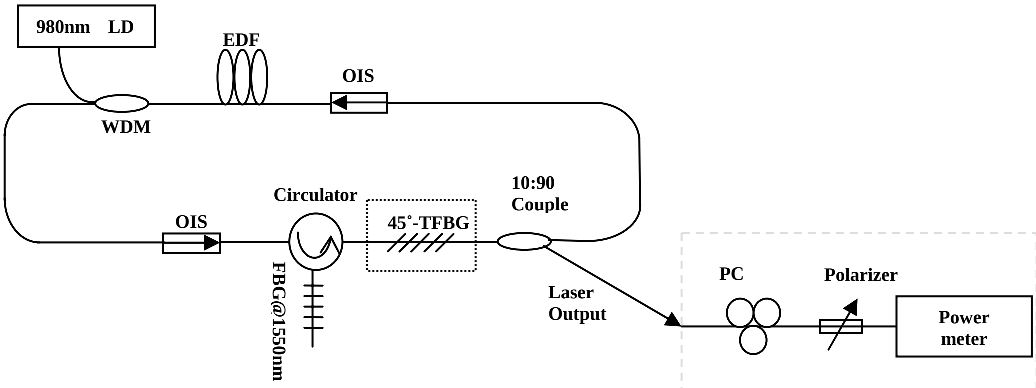

Figure.4. Schematic diagram of the fibre ring laser structure. The polarisation degree of the laser output is measured using the setup shown in dotted box.

Similar to the PDL measurement, adjusting polarisation controller can give the maximum (P_{POL}+½P_{UNPOL}) and minimum (½P_{UNPOL}) of the fibre ring laser. Without 45˚-TFBG in the laser cavity, the fibre ring laser produce the output with DOP only about 2dB, i.e. 22.48% in percentage term. This indicates that the laser output is almost unpolarised. When incorporating the 45˚-TFBG into the cavity, the laser output showed DOP of 27dB for T1 and 35dB for T2. They correspond to 99.6% and 99.94% in percentage term, which clearly show that the output of the laser is highly polarised and almost at single polarisation state. In comparison with 22.48% of the laser without intracavity 45˚-TFBG, this is a remarkable improvement and it is more interesting to note that by introducing a relative weak 45˚-TFBG (like T1) into the cavity, a high degree of polarisation state can be achieved.

We also examined the stability of polarisation state of the fibre ring laser with the intracavity grating T1. The laser was monitored over 5 hours and the DOP variation against the monitoring period is plotted in figure 5. It can be see that over 5 hours, the DOP value dropped by only ~2dB, which in percentage terms corresponds to the change from 99.78% to 99.65%: an insignificant reduction.

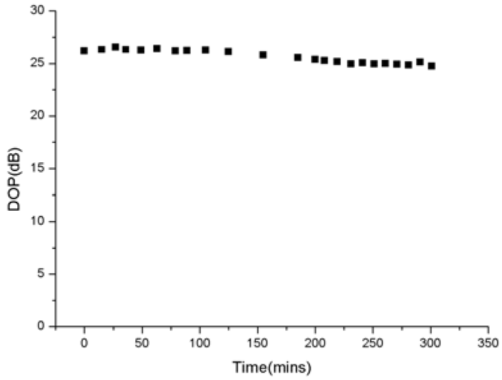

Figure.5. DOP long time stability experiment

4. Conclusions

We have demonstrated that the single polarisation state of a fibre ring laser can be achieved by employing an intracavity 45°-TFBG. Without the grating, the laser was random polarised indicated by its measured DOP of 36.9%. By inserting a 45°-TFBG of even modest PDL, the fibre became highly polarised achieved a DOP > 99%. It was also demonstrated that the single polarisation state of the laser was very stable over 5 hours monitoring period.

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5. Reference:

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