Single-Polarization All-fiber DFB Laser with Keyed Axis Output

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Abstract: A single-polarized fiber DFB laser with keyed axis output is demonstrated from a D-shaped fibre configuration. The laser shows an output power of 3.8dBm and strong axis alignment when spliced to a polarization maintaining fiber.

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1. Introduction

Enhanced system complexity has led to a demand for increased transparency to minimise overall losses when passing through many nodes. In achieving this goal all-fibre devices will play an increasingly important role and hence significant efforts have been directed towards developing these components. Fiber distributed feedback (DFB) lasers have attracted much attention in recent years because they exhibit near ideal characteristics for application as both telecommunications sources for dense wavelength division multiplexed (DWDM) systems [1-3] and in sensing systems [4], this from the point of view of their inherent fiber compatibility supporting enhanced systems transparency, relative ease of fabrication, near perfect performance in terms of ultra-low relative intensity noise (RIN) and high signal-to-noise ratio (SNR). Furthermore, powers greater than 13dBm with single frequency, single polarization and single sided outputs have been demonstrated strongly favouring these devices for alignment to for example external modulators [5].

Different techniques have been proposed to generate single polarization operation action of these lasers ranging from mechanical deformations [6] to subtle effects such a polarization dependant phase-shifts [7] and UV-light induced differential gratings strength [5]. However, none of the above techniques have been demonstrated in fibers where the axis of operation can be readily identified making easy alignment to external polarization-sensitive components difficult.

In this paper we demonstrate for the first time a single-polarization fiber DFB-laser with a keyed output. The laser is written into a D-shaped fiber and the axis of operation is shown to be aligned substantially parallel to the flat face of this fiber. We show ~3.8dBm output power from the laser and demonstrate the keyed properties of the device through a deliberate alignment and 90° misalignment of the laser to the axis of a polarization maintaining (PM)-isolator.

2. Device description and experiment

The configuration of the D-shaped fiber and the writing details of the grating are shown in Fig. 1. The basic properties of the fiber are the same as discussed elsewhere [8], i.e. high concentration Er:Yb in a phospho-silicate glass host and a photosensitive annular B/Ge ring to the core. A diameter ratio D1:D2 of 100 μm:125 μm is employed with the flat-faced side being introduced at the preform-level rather than at the fiber-level.

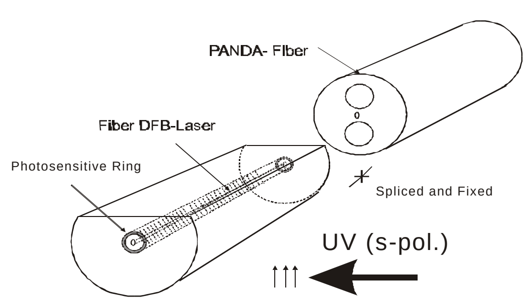

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Figure 1. Orientation of the D-shaped fiber relative to the PANDA-Fiber and the writing method of the DFB grating

Using a grating coupling coefficient of ê~200m^{-1}, a 5cm long centre ð-phase-shifted DFB laser is written into the fiber using our continuous grating writing technique and CW UV-light at 244nm. The polarization of the writing-beam is rotated to be orthogonal to the fiber axis (s-pol.) to generate a differential grating strength oriented relative to the key of the fiber [5] (see Fig. 1).

The laser is operated in a both a counter-pumping and co-pumped configuration using up to 70mW of light at 975.6nm. At the pump input side the laser is spliced to a standard non-PM fibre and a polarization controller and at the opposite side the laser is spliced to a PANDA-fibre with the fast axis aligned parallel to the flat face of the D-shaped fibre (Fig. 1). Due to a slight mismatch between the wave-guide properties of the D-shaped fibre and the PANDA fibre and the standard fibre and the D-shaped fibre, we estimate ~1.2dB splice-loss at either point, furthermore we estimate that the angular accuracy with which the two fibres are spliced together is ±10º. This uncertainty mainly arises from the manual visual positioning of these fibres relative to each other. Manual alignment is necessary because the splicing of the D-shaped fibre and the PANDA fibre is not supported by our particular PM-splicer.

When testing the keyed axis properties of the laser the PANDA-tail spliced onto the D-shaped fibre is spliced to a PM-isolator with a PANDA input-fibre. This splicing step is supported by standard PM splicers and can be performed with very high angular accuracy. The PM-isolator used here has an isolation of ~38dB and a polarization extension of 25dB between the slow and fast axis respectively. Furthermore, it is isolating in the fast-axis and exhibits an insertion-loss of ~ 0.5dB for the slow-axis.

3. Results and discussion.

Because the laser is centre π-phase shifted, it will operate with near identical powers out of either end. We confirm this by measuring the output from the laser in the counter-propagating configuration as depicted in Fig. 2. From this end ~3.3dBm is measured in a single-polarization confirmed using both a polarization analyser and a lightwave analyser by measuring whether any beat-signal is present. The measured polarization characteristics are a degree of polarization (DOP) of 100% confirmed by the fact that no beat-signal was detectable either. The laser has threshold of 7mW and the operational wavelength of the laser is 1548nm.

The first step in confirming the keyed out of the laser is taken through splicing the PANDA-fibre connected to the PM-isolator to the PANDA-fibre connected to the D-shaped fibre DFB-laser together aligning the fast and slow axis' of these fibres (parallel stress-applying parts (SAP)). The output measured through the PM-isolator in this case was found to be -6.4dBm. Then this splice is broken and the two PANDA fibres are deliberately spliced with an angle of 90º between the SAP. In this case the output through the PM-isolator is found to be 3.4 dBm. To confirm that the laser was still operating as expected the output from the opposite end (counter-propagating) measured a continued power output of ~3.3dBm in a single-polarization. From this simple test we conclude that the DFB-fibre laser indeed is operating in an axis parallel to the flat faced of the D-shaped fibre.

We believe that the reason for the only ~10dB extension of the throughput of the PM isolator arise from the uncertainty in the alignment of the D-shaped fibre to its connecting PANDA-fibre and *not* because the fibre is lasing in two polarization with a 10:1 power ratio. Operation in two modes would have been observed in the opposite direction as well if that had been the case. We believe the output power extinction from PM fiber between the two different axes could be further improved by a better alignment of the D-shaped fiber to the connecting PANDA fiber.

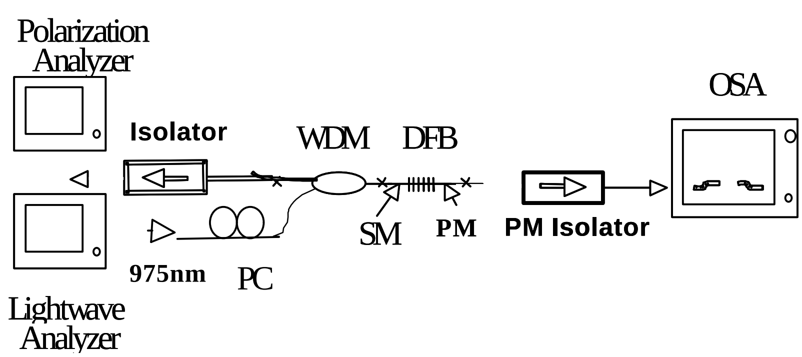

Figure 2. Pumping scheme and experimental setup (PC: Polarization Controller)

The output power from standard 1.55μm isolator and that from PM isolator under both aligned and 90º misaligned operations are plotted in Fig.3.

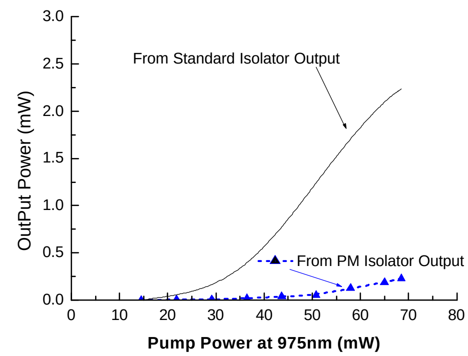

Figure 3a) Output power from the standard isolator and PM isolator (WDM loss: 0.3dB , standard isolator loss: 0.7dB PM isolator: 0.52 dB)

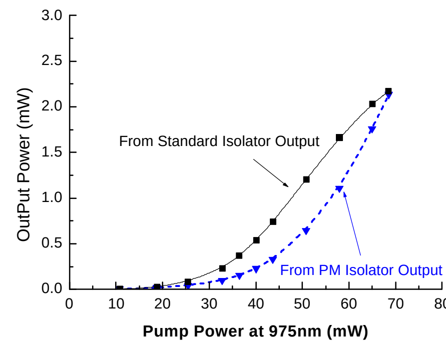

Figure3 b). Output power from the standard isolator and PM isolator (WDM Loss: 0.3dB, standard isolator Loss: 0.7dB) ,PM isolator PM axis linked to DFB rotated by 90 º

Through the standard isolator and measured in the counter-propagating configuration the fiber laser has a relative intensity noise (RIN) of –166.34 dB/Hz at 10 GHz and a line-width less than 40 kHz (limited by the 25 μs time delay of the self-homodyne set-up).

To check the pump-power polarization dependence of the laser, a polarization controller is inserted before the WDM (Fig. 2), we found a worst-case output power dependence of about 1.5 dB with a rotation of the polarization, but noticed that the degree of polarization of the laser output remained very stable whilst the polarization of the pump was changed. This output dependence with the pump-power polarization state is believed to be due to a slight geometrical birefringence in the fibre and hence a slightly different modal overlap for the pump with the gain medium. Another reason for the power variation could be a slight polarization dependence of the gain of the Er/Yb fiber.

3. Conclusion

We have demonstrated a single polarized all-fiber DFB laser written into a D-shaped fibre that provides a laser-source with a keyed axis output. We believe that such a source will simplify the connection to external polarization sensitive components such as for example intensity modulators and that it will make all-fibre DFB lasers even more attractive and a good alternative to conventional semiconductor DFB-lasers.

4. References

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