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Micro-optics and Bragg Gratings for DWDM Source Array

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Abstract

A collective process is presented to achieve a four channels fibres ribbon with long working distance micro-optics ($46 \pm 0.7 \mu\text{m}$) and UV-induced Bragg Gratings. Four different external cavity single-longitudinal mode sources are obtained with this fibres ribbon in front of a Fabry Perot Laser Diode (FP/LD) at a wavelength around 1300 nm with Side Mode Supression Ratio of $44.35 \pm 1.85 \text{ dB}$, 3dB bandwidth of $76 \pm 1.7 \text{ pm}$ (13.7 GHz) and Relative Intensity Noise around $-138.6 \pm 2.8 \text{ dB/Hz}$. This is promising for assembling multichannel multiwavelengths emitters for Dense Wavelength Division Multiplexing (DWDM) networks.

Keywords: External cavity laser diode; Microlens array, Bragg grating

1. Introduction

The use of UV-written Bragg reflector in telecommunication SingleMode Fibre (SMF) to obtain single-longitudinal mode external cavity LD has already been demonstrated [1] [2] [3] [4]. These kinds of sources require highly efficient coupling and low parasitic reflections on LD and fibre [1]. Elsewhere the interest of collective and passive assembling of LD array and SMF ribbons to reduce the cost and size of emitters at the central office has been shown [5]. We have reported recently highly efficient and long working distance collective micro-optics suitable for those multichannel modules [6]. In this letter, we propose to investigate the association of both UV-writing and micro-optics fabrication technologies on fibre ribbon to achieve a multiwavelengths multichannel external cavity laser diode source (Figure 1) for DWDM applications. These micro-optics are a compromise between the coupling loss inside the cavity and tolerance to misalignment for collective assembling [6].

This device is expected to be less sensitive to temperature than Distributed Bragg Reflector laser diode due to the lower temperature dependence of the Bragg grating in silica, 15 pm.K^{-1} , compared with 100 pm.K^{-1} for DBR laser diode.

Fig. 1 Laser Diode array and SMF ribbon with micro-optics and Bragg gratings.

2. Fabrication process

Bragg reflectors centred on appropriate wavelengths ($\lambda_1=1280$, $\lambda_2=1282.46$, $\lambda_3=1284.76$, $\lambda_4=1286.81$ nm) were first UV-written within each of the standard ribbon including four 250 μm spaced SMF. The UV exposure was achieved using a transverse holographic arrangement (Lloyd mirror) [7] involving a frequency doubled Argon ion laser (Sabre Fred, from Coherent), operating at $\lambda_p=244$ nm. 100 mW output powers were used for this experiment.

Prior to the irradiation, the fibre ribbon was loaded with hydrogen for 20 days at room temperature at a pressure of 150 atmospheres, in order to increase the writing efficiency. The Bragg grating wavelength λ_B is fixed by the angle α between the laser beam and the mirror and defined by the relation : $\lambda_B = \frac{n_{\text{eff}}(\lambda) \cdot \lambda_p}{\sin \alpha}$, where $n_{\text{eff}}(\lambda)$

is the fibre core effective index at λ . The gratings (50% reflectivity, 10 mm long) were written successively by moving the cylindrical lens by means of a micro-translation stage (see the set-up, Figure 2).

Fig. 2 Bragg gratings writing process.

Secondly micro-optics called GRADISSIMO were made at the end of this fibre ribbon. They are based upon a GRADed Index section, which acts as a graded index (GRIN) lens, aligned and maintained with a coreless Silica section at the appropriate distance from the Single Mode fibre (Fig.1). The fabrication process which has

been described elsewhere [6] [8] [9] is briefly sketched in Figure 3. It consists in splicing graded index and silica fibre ribbons with an arc-discharge fibre ribbon splicer. Then the coreless silica ribbon is cleaved to obtain a length L_s of silica.

These silica sections are spliced in ribbon to the SMF ribbon. Finally the GRIN ribbon is cleaved to obtain GRIN sections of the desired length L_g .

The process is collective as only ribbons of GRIN, silica and SingleMode Fibres are cleaved and spliced.

Fig. 3 Micro-optics collective fabrication process.

The 125 μm outer diameter is maintained all along the fibres and the pitch between fibres of the ribbon remains 250 μm . So these ribbons with micro-optics and Bragg reflectors are suitable for hybridisation in V or U grooves on silicon motherboards.

The return loss of this micro-optics without any Anti-Reflection (AR) coating, >25 dB, is higher than the return loss of a cleaved SMF (14.7 dB). This relative high return loss associated with a long working distance (around 50 μm) are very interesting features to achieve an external cavity source.

3. Experiments and results

Each fibre of this non-coated ribbon is then successively aligned in front of a FP/LD operating near 1.3 μm , whose front facet is AR coated (10^{-4} parasitic reflection). So, the 18 mm long resonant cavity is composed of the non-coated LD back facet and the Bragg reflector (see Fig.1). Light emitting half angles (and radius mode) of LD, at $1/e^2$ of the maximum intensity, are 25°

($\omega=0.89 \mu\text{m}$) and 30° ($\omega=0.71 \mu\text{m}$) in the parallel and perpendicular directions against the epitaxial surface, respectively. The different characteristics measured are summarised in Table I.

	Working distance (μm)	Power (mW)	λ (nm)	SMSR (dB)	RIN (dB/Hz)	FWHM (pm)
Fibre 1	46,7	3,32	1279,97	44,1	-139,9	76
Fibre 2	45,4	3,24	1282,44	46,2	-141,7	73
Fibre 3	46,5	3,04	1284,84	45	-135,8	74
Fibre 4	46,6	3,08	1286,84	42,5	-137	74

Table I. Measured results for each fibre in front of the LD.

Due to micro-optics, the working distances between the LD and fibres are homogeneous ($46 \pm 0.7 \mu\text{m}$) and long enough to reduce drastically parasitic reflections on fibres compared with SMF butt coupling. The optical powers are also uniform around $3.18 \pm 0.14 \text{ mW}$ (4.5 dB loss compared with 10.5 dB for butt coupling) for a 60 mA LD bias current at 22°C . Notice that the same micro-optics in front of tapered LD leads to 1.07 dB loss.

We obtain a single-longitudinal mode emission in each fibre (Figure 4), with a wavelength spacing between two neighbouring channels around 2.3 nm (421.1 GHz) from 1280 to 1286.81 nm, a Side-Mode-Suppression Ratio (SMSR) of $44.35 \pm 1.85 \text{ dB}$, and a 3 dB bandwidth (FWHM) of $76 \pm 1.7 \text{ pm}$ (13.7 GHz). The Relative Intensity Noise (RIN) [10] is measured between -141.7 and -135.8 dB/Hz for the four fibres. As a comparison we have measured the RIN of a DFB laser diode around -155 dB/Hz. We could reduce the RIN of the external cavity LD by using a more selective Fibre Bragg Grating.

The measurement precisions are $\pm 2.5 \mu\text{m}$ for the working distance, $\pm 0.1 \text{ mW}$ for the power, $\pm 20 \text{ pm}$ for the wavelength, $\pm 0.5 \text{ dB}$ for the SMSR, $\pm 2 \text{ dB/Hz}$ for the RIN and $\pm 3 \text{ pm}$ for the bandwidth.

The experiment was made around 1300 nm because components were available in the laboratory at this wavelength but the same experiment could be reproduced at a wavelength of 1550 nm.

Fig.4 Spectrum in each channel (span 17 nm).

4. Conclusions

We have presented four single-longitudinal mode external cavity sources (SMSR= $44.35 \pm 1.85 \text{ dB}$, RIN around -140 dB/Hz), about 2.3 nm spaced wavelengths around 1284 nm and uniform optical powers ($3.18 \pm 0.14 \text{ mW}$), based on a four channels fibres ribbon. Both grating fabrication process and micro-optics arrangement are performed collectively on this fibre ribbon. This method can be applied successfully to hybridisation on silicon motherboards, which is promising to reduce the assembling cost of multiwavelengths sources for DWDM purposes [11].

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