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Highly Efficient Collective Coupling Between Laser Diode Array and Lensed Fibre Ribbon.

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Abstract A new concept is proposed for lensed fibres fabricated according to a collective and low cost process. This process is based on cleaving and splicing of optical fibre ribbons and is suitable for the coupling of laser diode arrays and fibre ribbons.

1. Introduction

The introduction of optical communications into the access network involves reducing the cost of optical components. Regarding transceiver modules in the central office, a way to lower packaging cost, could be to apply the collective and passive alignment process (without activating the laser array during alignment). For this the reason the characteristics of optics should be compatible with the packaging tolerances and allow to achieve an effective coupling [1]. The main features [2,3] of this coupling arrangement are high efficiency coupling, relaxed alignment tolerances, long working distance, small packaging volume and low cost fabrication process.

2. Principle and fabrication

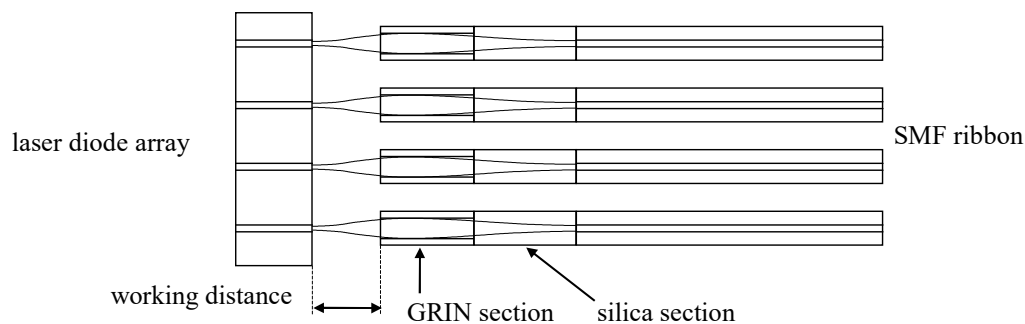


Fig. 1. Schematic representation of optical coupling arrangement between the LD array and SMF ribbon.

In the present paper, a new concept [4] proposed for a lensed fibre ribbon, requires a simple collective fabrication process. As shown in Fig. 1., this optics consists of a graded index (GRIN) fibre section which acts as a GRIN lens [5]. This latter is maintained at the proper distance to the single-mode fibre (SMF) by a coreless silica fibre section. The micro-optics are made with standard ribbons composed of four 250 μm spaced fibres. We used the G652 single-mode fibre and 85/125/250-Alcatel graded index fibre.

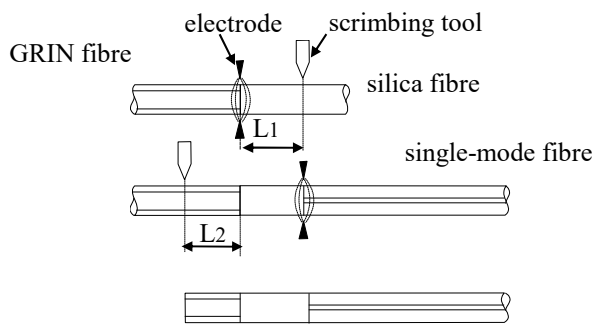


Fig. 2. Schematic illustration of the micro-optics fabrication process.

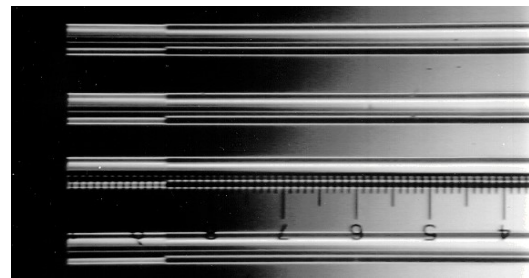


Fig. 3. Photograph of the micro-optics ribbon.

The fabrication process is illustrated in Fig. 2. Using an arc-discharge fibre splicer, the GRIN ribbon is first spliced to the silica ribbon. The silica ribbon is then cut at a distance L_1 from the silica/GRIN splicing. The GRIN and silica ribbon are spliced to the SMF ribbon. Finally the GRIN part of ribbon is cut at a distance L_2 from the silica/GRIN splicing. The two splicing losses are below 0.1 dB. Fig. 3 shows a view of the micro-optics ribbon. The reproducibility of the lengths is about 2 μm for each section of ribbon. The external fibre diameter of 125 μm is maintained along the lensed fibres. Note that this collective micro-optics ribbon only requires a collective fibre splicer and cleaver.

3. Optical Coupling Characteristics

The micro-optic ribbon is held in a silicon fibre-carrier fitted with four 250 μm spaced v-grooves. The LD used in experiments had an operating wavelength of 1.3 μm . Light emitting half angles (and radius mode) defined by the far-field 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. Fig. 4. shows the lensed ribbon coupled with the LD array. In order to measure the homogeneity of the micro-optic (Fig. 5.), the coupling efficiency of each fibre of the ribbon is measured at the optimum position in front of the same LD. The coupling efficiency defined as $10\log(P_{\text{coupled}}/P_{\text{emitted LD}})$ is -4.54 ± 0.04 dB for a working distance of $48 \pm 0.8 \mu\text{m}$.

Theoretical coupling loss either by beam propagation method, or by propagation of gaussian beam [6] is -4.5 dB (not detailed in this paper).

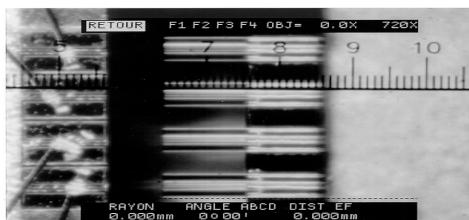


Fig. 4. Photograph of four-channel LD array chip coupled with a micro-optic ribbon.

Laser Diode	Coupling Loss dB	Working Distance μm
fibre 1	-4.5	48.7
fibre 2	-4.58	48.2
fibre 3	-4.55	47.6
fibre 4	-4.54	47.2

Fig. 5. Optical coupling efficiency of each fibre of the ribbon measured at the optimum position in front of the same LD.

The measurements of the coupling loss as a function of axial and lateral displacements are shown in Fig. 6. The optical coupling of the micro optic is compared with a butt coupling of SMF. Loss increments due to displacements in the x and y directions are roughly the same, that is why only one curve is plotted. The optical alignment tolerance is $\pm 9 \mu\text{m}$ for the axial

direction for 1 dB loss. The micro-optics is better than SMF in the range between +20 μm and -40 μm for axial displacement. The lateral tolerance is $\pm 1 \mu\text{m}$ for 1 dB loss. For this displacement the micro-optic is better than SMF in the $\pm 2.4 \mu\text{m}$ range.

Since no anti-reflecting coating was applied, the -26 dB Fresnel reflection of the air/GRIN interface was measured using an optical coherent domain reflectometer. The two other splicing interface reflections were as low as -80 dB. Nevertheless the oscillation amplitude of the coupling loss along z axis was less than $\pm 0.2 \text{ dB}$ due to the rather long working distance.

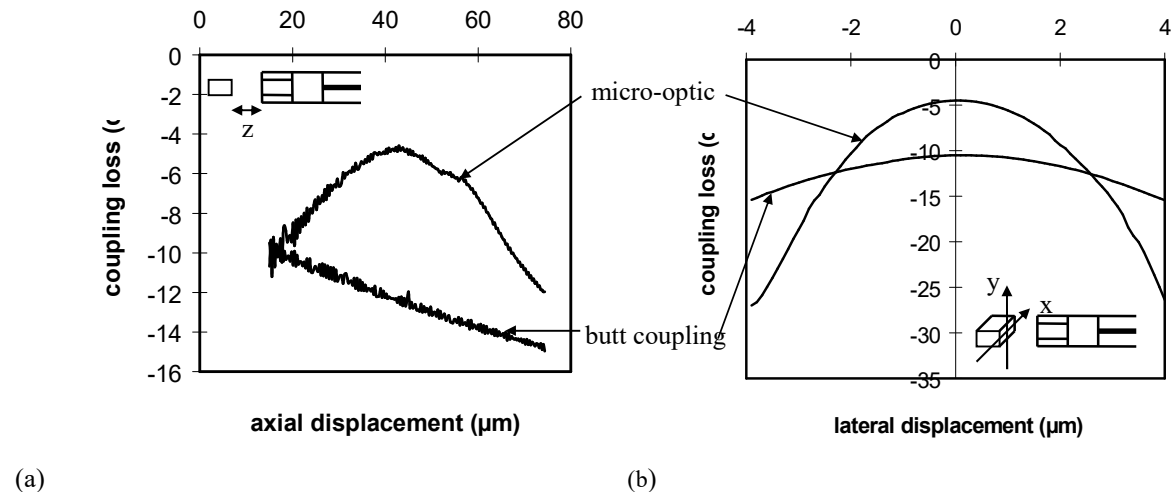


Fig. 6. Coupling-loss characteristics as a function of axial displacement (a) and lateral displacement (b).

4. Conclusion

Our arrangement provides several attractive features with respect to conventional coupling techniques. The lensed fibre ribbon is fabricated using a collective and simple process which allows reproducibility and mass-production. Long working distances, relatively high coupling efficiency and large positioning tolerances have been obtained. The new concept is promising for production of multichannel optoelectronic modules.

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