

HIGH PERFORMANCE SEMICONDUCTOR ARRAY MODULE USING TILTED RIBBON LENSED FIBRE AND DYNAMICAL ALIGNMENT

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Abstract

A highly reliable, versatile multifibre pigtailling technique adapted to tilted semiconductor arrays is demonstrated for the first time on 4-SOA array. Coupling losses of 3.6 dB per facet and 17 dB fibre to fibre gain are measured.

Introduction

The deployment of new photonic networks using wavelength division multiplexing technique will give an important rôle to optical switching. In this context, the use of semiconductor optical amplifiers as optical gates are of great interest due to their fast switching and signal amplification capabilities. To increase the size of switching nodes it is of major importance to achieve high performance compact and reliable SOA array modules. High performance semiconductor optical amplifier (SOA) arrays at 1.55 μm have already been reported [1]. Self-aligned flip-chip packaging of these tilted SOA arrays on Silicon motherboard [2] has also been demonstrated with good characteristics and penalty free 2.5 Gb/s photonic switching has been obtained [3]. However, the use of polished fibres limits the coupling losses to ~ 7 dB per facet which prevents from achieving low noise factor which is essential at high bit rate. YAG laser welding has been also used to realise 6-laser diode array modules with cleaved fibre ribbon [4] which induced large coupling losses ~ 10 dB. However, pigtailling issue of tilted arrays with lensed fibres which provide much lower coupling losses has not yet been addressed.

In this paper, we present for the first time to our knowledge a high performance, versatile multifibre pigtailling technique adapted to tilted semiconductor arrays. Dynamic alignment of collectively processed tilted lensed fibre and YAG laser welding assembly lead to coupling losses as low as 3.6 dB per facet on the 4 SOAs. The collective process makes this packaging technique cost effective compared to discrete modules. Moreover, YAG laser welding assembly has already proved excellent stability[4], [6].

Tilted microlensed fibre fabrication

Hemispherical lenses are formed at fibre ends to improve optical coupling efficiency between the single mode 4-fibre ribbon and the SOA array. To accommodate for the tilt of the SOAs, the fibres must have their focal point in different planes. A collective process to fabricate such lensed fibres from ribbons of 4 fibres has been developed. Fibre ends are first etched simultaneously by using an HF solution. Tilt of the etched ribbon fibre (4 fibres) is obtained with a good accuracy by adjusting mechanically the angular position of the ribbon fibre in the HF solution [5]. Figure 1a shows the etched ribbon fibre after this step. "Tilt" angle is $22.7^\circ \pm 0.5^\circ$ and taper angle is around 8° . In a second step tapered fibres ends are melt using an electric arc discharger which produces a lens radius around 15 μm (figure 1b). Figure 2 shows lensed ribbon fibres in front of the amplifier array. Coupling efficiency, alignment tolerances and geometrical

accuracy have been measured on the optical bench. Typical coupling losses of 3 dB in front of semiconductor optical amplifiers have been obtained. High geometrical reproducibility has been measured on lenses radius ($15 \pm 0.5 \mu\text{m}$) and on pitch between the lenses ($250 \pm 0.5 \mu\text{m}$). Coupling tolerances for an excess loss of 0.5 dB are typically $1 \mu\text{m}$ in X, Y lateral axes and $5 \mu\text{m}$ in Z axis.

SOA array chip

The SOA array fabrication has been detailed in reference 1. Polarisation independent SOAs at $1.55 \mu\text{m}$ are obtained using nearly square bulk InGaAsP buried ridge structure. Low gain ripple is ensured by 7° tilted facets anti-reflection coated with $\text{TiO}_2/\text{SiO}_2$. Far field divergence achieved with $100 \mu\text{m}$ long active taper and $15 \mu\text{m}$ InP window facet are typically 20° and 25° in the directions respectively perpendicular and parallel to the junction. Internal gain close to 30 dB is achieved at 150 mA and fibre to fibre gain exceeding 25 dB have been obtained in discrete modules with these structures.

Module fabrication and results

Figure 3 shows the inner structure of the amplifier array module. The amplifier array is soldered junction down on an Aluminium Nitride heat sink which permits in addition to access both sides for pigtailling. Both single mode ribbon fibres are sandwiched and fixed between silicon V-grooves and flat glass plate. The heat sink and ribbon fibre submount are then placed on an INVAR block adapted for laser YAG welding.

The alignment between ribbon fibres and amplifier array is performed using a conventional dynamical alignment method. Optimisation is performed on first and last channels of the array. YAG laser welding is then used to fix in the optimum position [6]. The pigtailed SOA array is then placed in a "Butterfly" package as shown on figure 3. Overall dimensions of the module are : $47 \times 24 \times 15 \text{ mm}^3$. A peltier cooler, associated with a temperature sensor is used to stabilise the amplifier temperature.

Compared to single fibre, the use of fibre ribbon introduces excess loss $< 2 \text{ dB}$ before assembly. After YAG laser welding, additional excess losses (from - 1.2 to 0.7 dB) have been observed.

Average value of coupling losses on the 4 SOAs is respectively 6.4 and 3.6 dB for the first and second facets. Fibre to fibre gain of $17.3 \pm 3 \text{ dB}$ (figure 4) is achieved at 150 mA which is the highest ever reported on tilted SOA modules. Part of the gain variation already existed in the array chip. With this pigtailling technique, fibre to fibre gains exceeding 20 dB should therefore be obtained.

Conclusion

A high performance, versatile multifibre pigtailling technique adapted to tilted semiconductor arrays has been demonstrated for the first time on 4-SOA array. Dynamic alignment of collectively processed tilted lensed fibre and YAG laser welding assembly lead to coupling losses as low as 3.6 dB per facet on a 4-SOA array. Fibre to fibre gain of $17.3 \pm 3 \text{ dB}$ are achieved at 150 mA. As the noise factor is directly related to the coupling loss, such a technique is essential to produce SOA arrays suitable for high speed operation. In addition, this process can be applied to any tilted semiconductor array. Moreover, YAG laser welding assembly has already proved excellent stability which makes this technique very attractive for high performance array modules.

References

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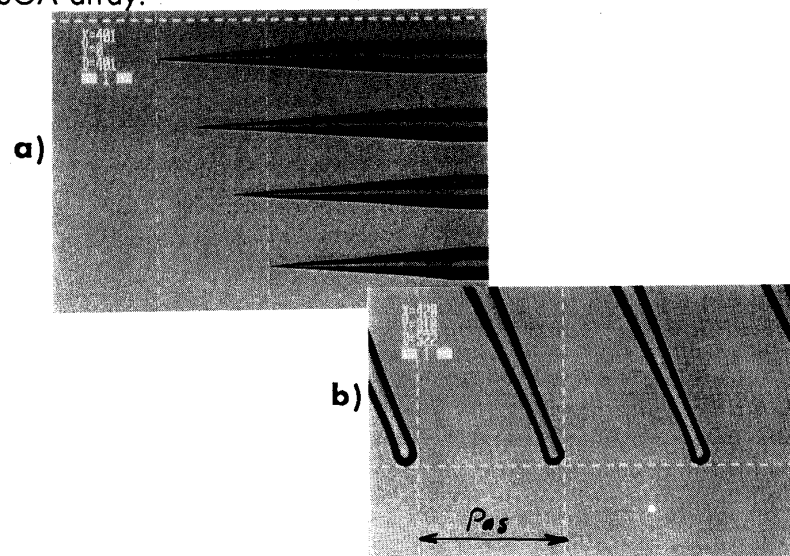


Figure 1 : Photograph of the tapered fibre ribbon after chemical etching (a) and after lens formation in electric arc (b).

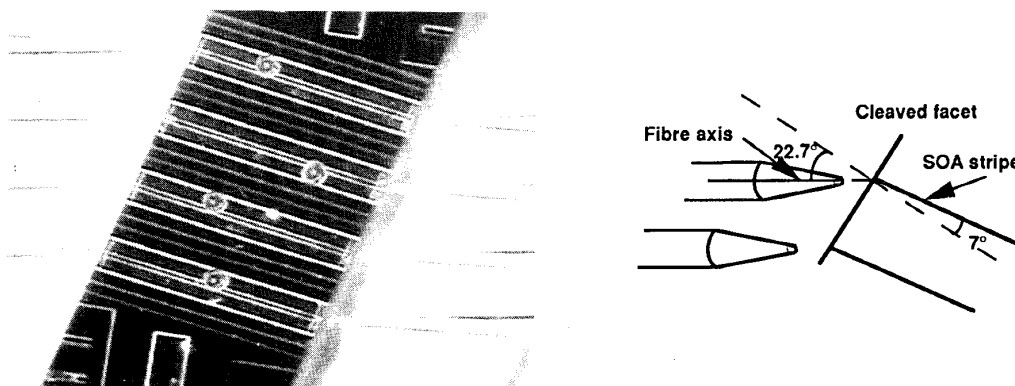


Figure 2 : Photograph of the 4-SOA array with the lensed tilted fibre ribbon and scheme of fibre/SOA positioning..

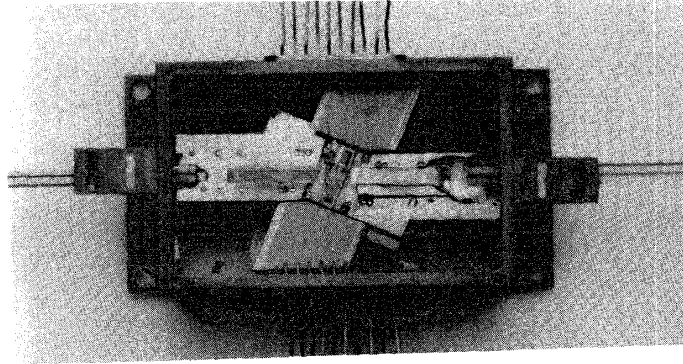


Figure 3 : Inner view of the semiconductor optical amplifier array module assembled with YAG laser welding.

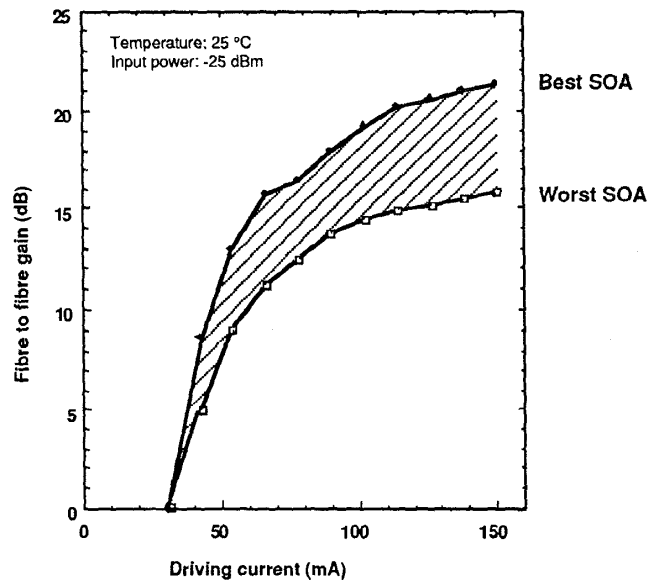


Figure 4 : Fibre to fibre gain measured at 1.55 μm on the 4-SOA array module. Part of the gain difference comes from the SOAs themselves.