High Performance Packaging Technique Used for Clamped Gain Semiconductor Optical Amplifier Array Modules Fabrication

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Abstract

In this paper, we present a high performance, versatile multifibre pigtailing technique adapted to tilted semiconductor optical amplifier arrays. Dynamic alignment of collectively processed tilted lensed ribbon fibre and YAG laser welding assembly are used for pigtailing of 4 clamped gain semiconductor optical amplifier array. The collective process makes this packaging technique attractive for array components. This paper describes the technology used and summarizes main results obtained on fabricated modules.

Introduction

Considering status of enabling technologies for deployment of new photonic networks using wavelength division multiplexing (WDM) technique, one must recognize that today very few components have been brought onto the market place. On the other hand, in the laboratory, advanced components such as Semiconductor Optical Amplifier arrays (SOA's), all optical wavelength converters, WDM array sources have been demonstrated and implemented in system experiments.

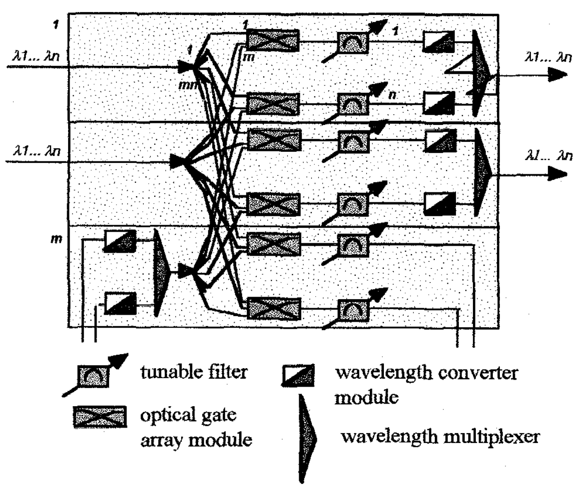


Figure 1: Architecture of a multiwavelength optical cross-connect node.[1]

Figure 1 shows an example of an optical cross-connect node. This type of architecture described in reference [1] uses wavelength converter modules and optical gate array modules. Optical gate arrays based on SOA's are designed for multiwavelength operation, to split and steer optical streams from one route to another. Requirements for this application include polarisation independence, a large input power dynamic range and therefore a large saturation output power, and a flat wavelength response with low gain ripple. Finally, for easier packaging and low coupling losses, large mode sizes are required. To meet these requirements, Clamped Gain Semiconductor Optical Amplifiers (CG-SOA's) have been designed and fabricated.

Development of suitable packaging technologies to achieve high performance compact and reliable array modules is a key point for the deployment of such nodes.

Description of clamped gain SOA array components

The schematic view of the DBR-based CG-SOA is shown in figure 2. The device consists of three sections : a central active section of 600 µm length and passive sections at the input and output with DBR gratings for wavelength selective feedback [3]. The active layer is based on a Separate Confinement Heterostructure (SCH) and consists of 0.2 µm thick tensile bulk active layer embedded between two quaternary layers (λ_g = 1.18 µm) 0.1 µm thick. The TE-TM gain matching is obtained for a tensile strain value of about 0.15 % [2] which remains below the critical limit for strain relaxation. The vertical layer stack includes a passive InGaAsP layer separated from the SCH by an 0.3 µm thick InP spacer layer. The active stripe is tapered over a length of 150 µm. The double core taper resulting from the tapered region combined with the underlying passive waveguide of 3µm width provides typical full beam divergences of 18°X18°. The overall device length is 1mm. The waveguides are 7° tilted from the cleaved facets and anti-reflection coated to achieve low reflectivities in the range of 10^{-5}. The amplifier spacing has been chosen to be compatible with 250 µm fibre spacing. The electrical isolation is ensured by proton implantation.

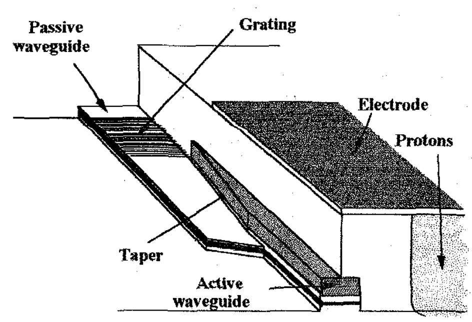


Figure 2 : Schematic view of DBR- based CG-SOA

nitride heat sink and tested on an optical bench. Main parameters (taken at 200mA injected current) and typical characteristics of these arrays as mentioned in ref [3] are:

- fibre to fibre gain Gff > 10 dB
- polarisation dependence < 1 dB
- gain ripple <0.5 dB

Comparison of multifibre coupling solutions

The design guidelines for choice of coupling system between SOA array and fibres are as follows:

- multifibre coupling (four inputs / four outputs)
- low coupling losses /low optical feedback
- adaptation to tilted component
- module compactness

Comparison of multifibre coupling solutions has been carried out. Lensed fibres and ribbon lensed fibres of different structures (spherical /aspherical lensed fibres) using various techniques (drawing, polishing, chemical etching) have been realised. Evaluation on optical bench using following parameters have been made : coupling losses (C.L.), lens-fibre distance (Z), alignment tolerances (ΔX, ΔZ), geometrical precision. Table 1 shows main results of experiments.

Use of aspherical fibres realised by drawing [4] leads to good performance (low coupling losses, high distance between lens and amplifier). However geometrical reproducibility is not compatible with ribbon lensed fibre fabrication.

Commercially available lensed fibres with a conical shape (tip radius $\cong$ 12 µm) have been tested. Coupling losses are similar to aspherical lensed fibres realised by drawing. Tip radius reproducibility is not sufficient for ribbon lensed fibre fabrication.

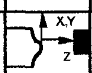
Lensed fibre type		C.L (dB)	Typical tolerances (10%) ΔX (µm) Z (µm) / ΔZ (µm)	Geometrical precision
FME (drawing)	 X,Y Z	-2	0.9 30/6	Poor
Conical (Polishing)		-2,4	1 <15/6	Not sufficient ΔRadius: +/-1 µm
Conical (Chemical etching)		-3	1.2 20/8 (Tip radius : 15 µm)	Good : ΔRadius: +/-0.5µm *(ΔLength: <+/-2µm)* *ΔPitch: +/-0.5µm*

Table 1: Comparison of ribbon lensed fibre techniques

Lensed ribbon fibre fabrication

A new technique using chemically etched lensed ribbon fibres has been developed and evaluated [5]. 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 SOA's, the fibres must have their focal point in different planes (figure

ribbons of 4 fibres has been developed. Fibre ends are first etched simultaneously by using an HF-based 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-based solution. Figure 3a shows the etched ribbon fibre after this step. "Tilt" angle is 22.7° ± 0.5° and taper angle is around 8°. In a second step tapered fibre ends are melt using an electric arc discharger which produces a lens radius around 15 µm (figure 3b). Displacement speed and arc current discharge are the main parameters for tip radius value and reproducibility. Figure 4 shows lensed ribbon fibres in front of the SOA's. Coupling tolerances between lensed ribbon fibres and amplifiers for an excess coupling loss of 0.5 dB (10%) are typically (6-8)µm in the light propagation axis and 1.2 ±0.2 µm in both directions into the plane perpendicular to this axis.

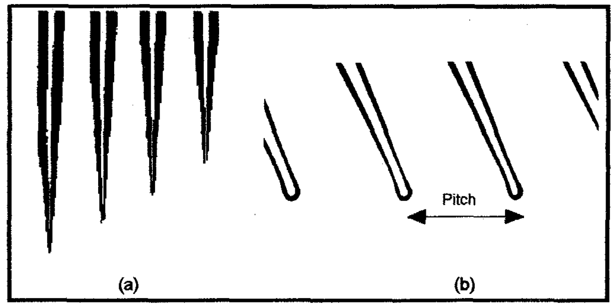


Figure 3: Photograph of tilted tapered fibre ribbon after chemical etching (a); after lens formation in electric arc (b)

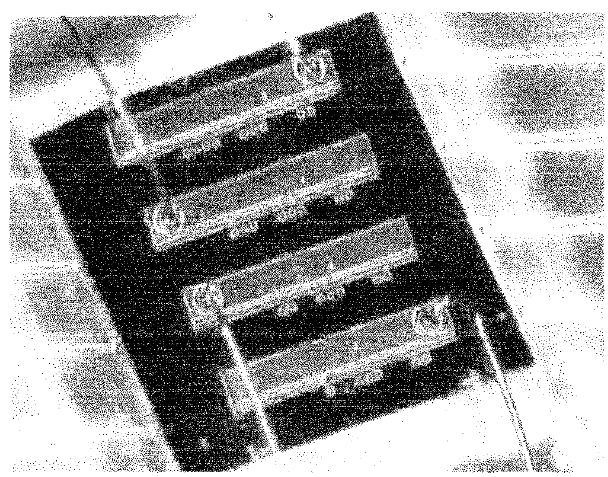


Figure 4 : Photograph of the 4-SOA array with the lensed tilted fibre ribbons.

Modules fabrication

Key issues for multifibre pigtailing technologies are coupling losses and alignment tolerances. Thanks to far field characteristics of components (18°x18° typical FHWM beam divergence) and to reproducibility of collectively processed lensed fibre ribbon (15 ± 0.5 µm lens tip radius and 250 ± 0.5 µm"pitch"), reproducible coupling losses of typically 3 dB per facet have been achieved. The alignment between fibre ribbons and amplifiers is performed using a conventional dynamical alignment method. YAG laser welding assembly is then used to fix in the optimum position. The pigtailed CG-SOA array is placed in a "butterfly" package. Overall dimension of the module are : 47x24x15 mm^3. A Peltier cooler associated with a temperature sensor is used to stabilize the CG-SOA's temperature. Figure 5 shows the optical gate array module on its electronic card as implemented in the crossconnect node of the OPEN project [6].

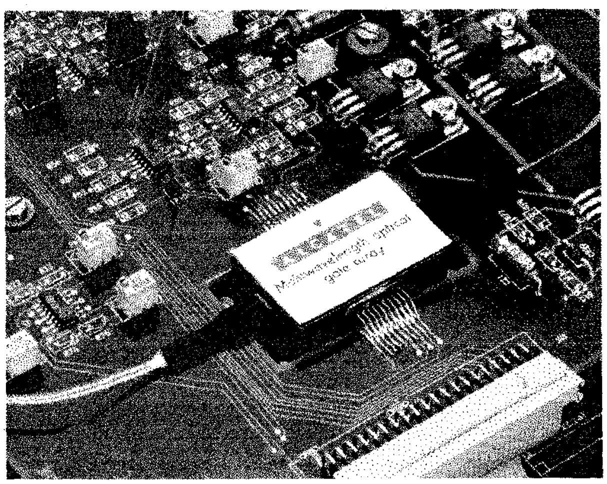


Figure 5 : Optical gate array module on its electronic card

Results

Five optical gate array modules have been fabricated and tested. Figure 6 shows gain characteristics versus driving current obtained on a typical optical gate array module . Fibre to fibre gain increases with the driving current up to the lasing threshold of 50mA where gain is clamped. The

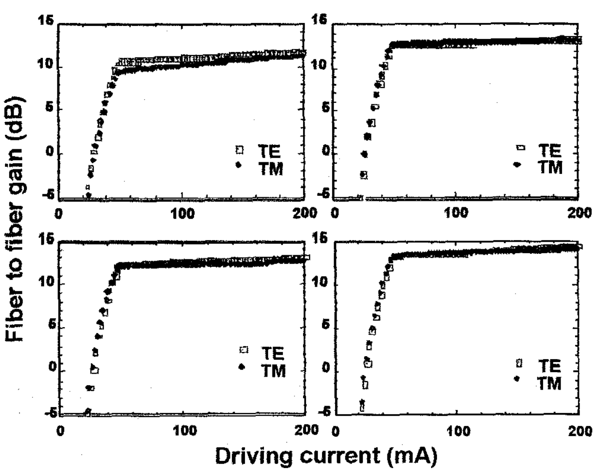


Figure 6 : Gain characteristics versus driving current of an optical gate array module.

average gain of the module is 13.2 dB with a uniformity of ± 1.25 dB which is close to the uniformity measured on the SOA array before pigtailing. The TE-TM gain polarization sensitivity remains below 0.5 dB. For driving current higher than 80mA the noise factor (Nsp/C1) is about 8 dB which is in agreement with the 3 dB measured coupling losses (C1). Negligible gain ripple has been measured over all modules. The output power saturation measured at 200 mA is >+10 dBm. Note that increasing again the driving current increases the output saturation power. The measured gain, output power saturation and noise factor are similar to those measured on single CG-SOA module [7]. The 1 dB optical bandwidth is about 30 nm which is compatible with system requirements [3].

Figure 7 shows the distribution of measured characteristics on 5 fabricated optical gate array modules (corresponding to 20 CG-SOA gates) : fibre to fibre clamped gain (measured at 200 mA and 1.55 μm) has a total dispersion from 10 to 14.4 dB. Fibre to fibre gain homogeneity on the 4 gates of each module is within 2 dB. The mean TE-TM gain polarization sensitivity is 0.4 dB with a total dispersion from 0.1 to 0.9 dB. The output saturation power measured at 200 mA (overall gates) is over 10 dBm.

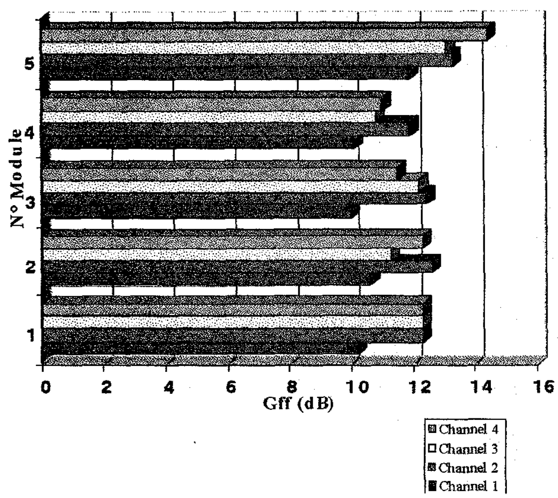


Figure 7 : Characteristics on 5 optical gate array modules

Storage tests have been realised on such assemblies. Applied storage temperature was successively 40, 50 and 60 °C during 168 h at each temperature. The coupling losses variations do not exceed 0.5 dB. Finally modules using this pigtailing technique have been submitted to normalised shock and vibration tests without any observable degradation :

- Shocks : 100g/6ms, 3 shocks by direction for 6 directions
- Vibrations : 10g during 2 hours by axis for 3 axes.

Conclusion

A high performance, versatile multifibre pigtailing technique adapted to tilted O/E component arrays has been used for 4 CG-SOAs' array module fabrication. On 5 modules fabricated, mean fibre to fibre clamped gain (measured at 200 mA and 1.55 µm) is 12.3 dB with a total dispersion from 10 to 14.4 dB. Fibre to fibre gain homogeneity on the 4 gates of each module is within 2 dB. Similar characteristics to those of individual modules have been observed. Preliminary storage tests vs temperature have shown a good stability of coupling losses. The new pigtailing method developed here is well suited for other O/E components used in photonic node architectures, like all optical wavelength converters , WDM array sources,...

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