# Fibre Array Packaging and Pigtailing of an Integrated InP-InGaAsp Two-State Multiwavelength Laser Chip

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*A mechanical sub-assembly is presented enabling fine positioning and fixation of a lensed 4-fibre array to an integrated two-state AWG-based multiwavelength laser chip. The device operates as an all optical memory element used in optical packet switching and signal processing. The alignment accuracy between fibre array and chip is in the sub-micron range and possible in 4 degrees of freedom. The design minimizes post-weld-shifts and enables re-positioning of the fibre array after the first fixation step. The mechanical sub-assembly is mounted in a package with a clamp method to reduce internal stress in the sub-assembly. The chip temperature is varied from 10 ºC to 30 ºC and stable coupling efficiency is measured.*

## Introduction

As a result of advanced integration technologies based on indium phosphide (InP), optical components can be integrated into multi-functional devices, which require multiple fibre connections [1]. A previous concept for coupling lensed fibre arrays to InP-based photonic optical chips in the sub-micrometer range by using metal deformation is presented in [2]. In this paper, the design presented in [2] has been modified and improved with respect to thermal stability and longitudinal alignment accuracy between the fibre tips and the photonic optical chip.

## Design

The sub-assembly is shown in figure 1. At the top is presented schematically the improved inner adjustable actuator part, on which the 4-fibre array (1) has been fixed. The actuator part is mounted using three elastic pins (2) and a tuning frame (3) inside the “U-shaped” component (6) of the sub-assembly shown at the bottom of figure 1. The optical chip (4) is precisely aligned and mounted on an universal chip mounting platform in the $\theta_y$ direction, parallel to the fibre tips by using two external actuators (not shown). The fibre array (1) can be aligned in 4 degrees of freedom (DOF), namely x, y, z and $\theta_z$. The 4 degrees of freedom are controlled by the three elastic pins (2) combined with a parallelogram (5). The three elastic pins define the x, y and $\theta_z$ positions and the parallelogram defines the z position. After aligning the fibre array (1) to the chip facet (4) in the z-direction, the fibre array can be aligned to the desired in- and output waveguides of the optical chip by using temporary connected piezo-electric actuators (not shown). Permanent fixation of the fibre array is achieved by laser welding the inner actuator part (5) to the tuning frame (3) lining up simultaneously positions 5a and 5b to positions 3a and 3b. This tuning frame is mounted to the “U-shaped” component (6) of the sub-assembly. Re-adjusting of the fibre array as a result of displacement of the inner actuator part due to post-weld-shifts (PWS) is possible, after the temporary piezo-electric actuators are disconnected, by deformation of the tuning frame at positions (3c)

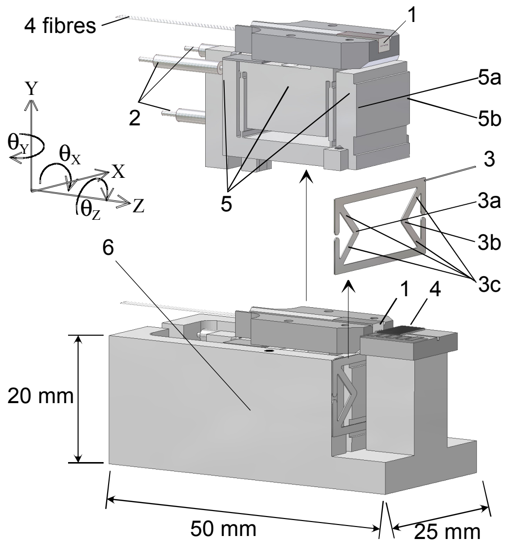



Fig. 1 Schematic presentation of fibre to optical chip sub-assembly. Top: inner adjustable actuator part which is mounted in the "U-shaped" component (bottom) using three elastic pins (2) and after aligning with external piezo-electric actuators (not shown) permanently fixed with the tuning frame (3).

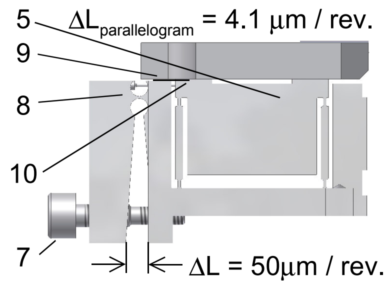



Fig. 2 Schematic presentation of the working principle of the longitudinal z adjustment with long travel (0.5 mm) and high accuracy (± 0.1 μm).

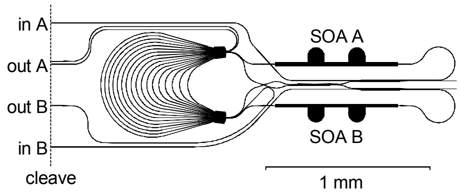
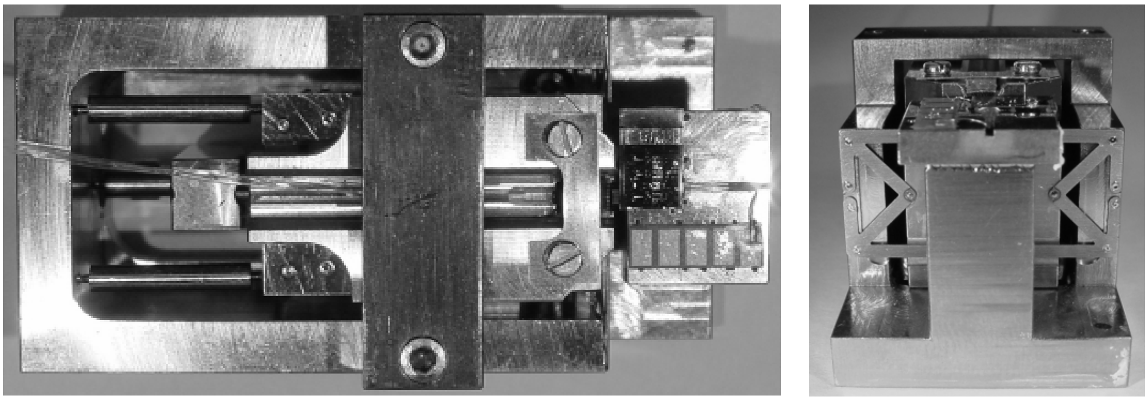



Fig. 3 Mask layout for two state multi-wavelength laser.



(a) (b)

Fig. 4 (a) Side view and (b) front view of the realised design for fibre-array Pigtailing.

using laser induced local heat. Detailed information concerning aligning the fibre array and describing the laser adjust process by means of the tuning frame can be read in ref. [2]. Figure 2 shows the side view of the z-alignment. The differential screw (7) is constructed of two different nominal diameters M2.5, with pitch of 0.40 mm and M2, with pitch of 0.45 mm respectively. One revolution of the screw results in difference ΔL of 50 μm. This movement is transferred to the parallelogram (5) with a transmission ratio of 12 : 1 by means of the lever construction (8), i.e. one revolution is a translation of the fibre array of 4.1 μm. The travel range of the actuator is 0.5 mm. The position of the parallelogram is permanently secured by welding a sheet at positions (9) and (10). To improve the thermal stability all components of the sub-assembly are fabricated in invar, benefiting from the low coefficient of thermal expansion (CTE) at room temperature ($1.3 \cdot 10^{-6}$ $K^{-1}$). The CTE increases with increasing temperature and at high temperatures its magnitude is almost equal to ordinary metals and alloys. Therefore this material has also been used for the tuning frame within this sub-assembly.

## Alignment, fixation and assembly procedure

The packaged chip is an InP/InGaAsP integrated two-state AWG-based multiwavelength laser, which functions as a one-bit optical memory [3]. Figure 3 shows the chip layout with 4 in-/output waveguides. After adjusting and fixing the fibre array in the optimal longitudinal z-position, the fibre array is actively aligned in the other 3 directions: x, y and θz. In table 1 this position is indicated with I, the initial optimal position, whereby the 2 fibres outside are optimally aligned to the (in A) and (in B) input waveguides of the chip. The received optical powers for all fibres are normalised to 100 %. In the next row II, the actuator part is welded to the tuning frame at positions 3a and 3b (see figure 1) simultaneously with equal laser energies of 5 J. Optical output signals and the absolute position of the fibre array are measured during the welding process. The shift of the fibre array as a result of the PWS is 0.3 μm and 0.1 μm in the x and y direction respectively. These small shifts lead to an optical power decrease of 5% for the in B port. The performance of the fibre array was measured before it was mounted and the maximum alignment error of the fibre height level (y direction) is ± 0.1 μm. The two inner fibres have a deviation difference of ± 0.6 μm in the fibre pitch of 250 μm (x direction). This causes more relative optical power decrease of the two inner (out A) and (out B) channels. The balanced laser energy and symmetry in the energy delivery focussing heads results in minimum PWS, therefore re-adjusting the fibre array using the tuning frames was not necessary to execute. Figure 4 shows the top view and right side view of the realised sub-assembly. The sub-assembly is mounted in a package (1) (see schematic presentation in figure 5) with a 16.6 W thermo-electric cooler (TEC) (2) on a three-point support (3), fixed unambiguously with a constant one-point loading using a thin beam of metal (4). The thin beam is mounted in the package under tension, acting as a spring, giving a constant one point loading force on the sub-assembly. By using this method the internal stress of the sub-assembly is minimised compared with traditional assembly procedure of the thermo-electric cooler by bolting and applying torque in small increments. Figure 6 shows a photograph of the realised device.

## Thermal stability characterization of package

The stability between the fibre tips and chip facet is determined by measuring the average spontaneous emission power of all four ports (in A, out A, in B, out B) by supplying current to both SOA's (10 mA). The chip temperature is varied from 10 ºC to 30 ºC by controlling the TEC. We measured only the increase of spontaneous emission power as a function of decreasing chip temperature of both SOA's with the same linear slope for all four ports. (see figure 7). This implies that the coupling is stable for the measured temperature range. The chip temperature is set at 25 ºC and the SOA's A and B are biased at 182 mA and 205 mA respectively to make the device operate symmetrically. In figure 8 are given the two stable device states of the output signal measured at the out A port of the device. The difference in optical output is related to the optical chip operation [3]. The coupling efficiency of the lensed fibres with lens radii of 15 μm is 4.5 dB for the fibre outside and 5.5 dB for the two inner fibres, which have a fibre pitch offset of 0.6 μm, due to the quality of the fibre array. The optimum coupling

| | Dx [μm] | Dy [μm] | in A [%] | in B [%] | out A [%] | out B [%] |
|---|---|---|---|---|---|---|
| I | 0 | 0 | 100 | 100 | 100 | 100 |
| II | - 0.3 | -0.1 | 100 | 95 | 87 | 86 |

Table 1. Displacements in x and y direction and accompanying normalised optical power in % at initial position (I) and after welding the fibre array (II).

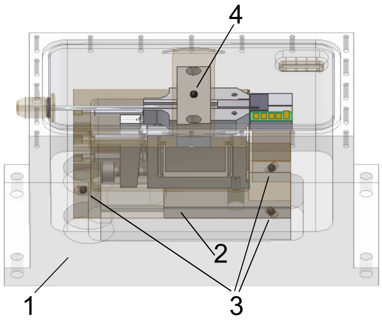



Fig. 5 Schematic presentation of three-point support, one-point loading fixation method of the sub-assembly in the package.

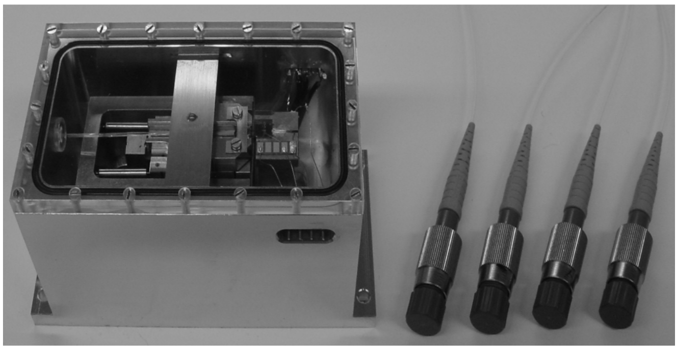


Fig. 6 Photograph of realised device. Dimensions 7.7 cm (l) x 4.5 cm (b) x 4.2 cm (h).

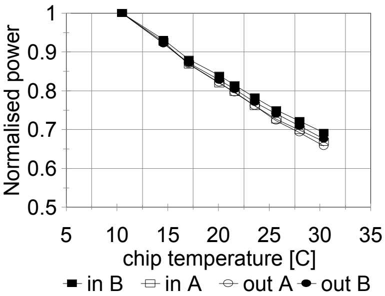



Fig. 7 Measured normilised spontaneous emission power as function of chip temperature.

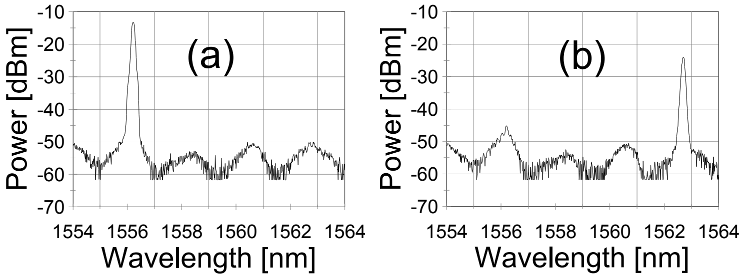



Fig. 8 Spectra measured at output (out A) of the packaged chip for both states (a) laser A is dominant, (b) laser B is dominant.

loss is 4.5 dB, given the fibre, which is tapered to an angle of 75º in combination with a lens radius of 15 μm and the geometrical dimensions of the waveguide (0.6 μm x 2 μm).

## Conclusions

An improved design is realised to align and fix a fibre array in 4 DOF's to a two-state multi wavelength laser chip. The design is improved concerning alignment accuracy in linear longitudinal z-direction and thermal stability between the fibre tips and chip facet. The optimum position of the fibre array is laser welded at a well-balanced and symmetrical laser set-up, resulting in minimum and neglect able PWS of 0.1 μm – 0.3 μm. The sub-assembly shows excellent thermal stability for the measured temperature range of 10 ºC to 30 ºC.

## References

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[2] J.H.C. van Zantvoort et al, in IEEE, JSTQE. vol 8, no. 6, 2002, pp. 1331-1340.

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