Effective Fiber Pigtailing Procedure of a QD-SOA

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The integration of laser-support fiber adjustment is presented as an alternative effective pigtailing method for traditional trial and error efforts using laser hammering or mechanical bending approaches. The mechanical micro module, which allows for a well-controlled accurate step-by-step alignment sequence of the fiber, together with the fiber pigtail procedure of a quantum dot semi-conductor optical amplifier are described. During the assembly process, post-weld-shifts and post-release-shifts to the order of 5 – 10 μm are compensated in the final re-alignment procedure with sub-micrometer accuracy resulting in an optimal optical power coupling between the single-mode fibers and the amplifier. We measured stable coupling connections by driving a current of 1 A trough the device at a chip temperature of 10 °C.

Introduction

A mechanical micro module is designed in order to pigtail two fibers to a quantum dot semi-conductor optical amplifier (QD SOA) [1]. The effective alignment of the fibers is performed using laser-support fiber adjustment [2].

Design and pigtail sequence

The mechanical micro module consists of two fiber-subassemblies which are mounted at opposite sides to each other with the chip in the middle. The right hand fiber–subassembly is shown in figure 1 and is constructed of a fiber support (1) on which the lensed fiber (2) is fixed. This combination (1) and (2) is connected by two tuning frames (3) and (4) to the fiber-strain relief module (5). Tuning frame (3) adjusts the fiber tip in the lateral x-direction, parallel to the chip facet whereas a second tuning frame (4) controls the transversal position of the fiber tip in the y-direction. The position of the fiber support (1) is measured continuously in the linear δX and δY direction, using a non-contact displacement measuring system based on inductive technology. Because the position of the fiber support is measured at the opposite position of the fiber tip as shown in figure 1, the position of the fiber tip related to the waveguide is also visually measured using a calibrated microscope. The assembly procedure is shown in figure 2. First the chip (6) is soldered onto the chip carrier (7) and electrical connections are bonded. The chip carrier (7) is mounted onto a thermo-electric cooler (TEC) element in a package (not shown). Next, the fiber-subassembly is placed in the package and visually aligned into the optimum focus length position of the lensed fiber tip and lateral x-position by using a pneumatic alignment tool (8). The fiber-subassembly is welded to the chip carrier by two laser weld joints simultaneously. The two laser heads are positioned at symmetrical angles related to the fiber-subassembly and have well-balanced laser energies of 5 J. The weld sequence is (w1) and (w1'), (w2) and (w2'), (w3) and (w3'), and (w4) and (w4'), whereby the back weld joints are not visible in figure 2 (b). In the pre-assembled fiber-subassembly, tuning frame (4) is only welded to the fiber-strain relief module (5) at weld joints (w5) as shown in figure 1. Next, the fiber

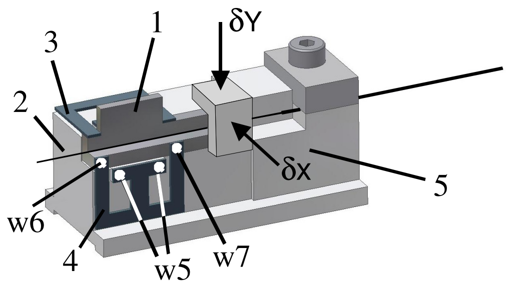


Fig. 1 Schematic presentation of the fiber-subassembly. The fiber tip (2) can be laser-adjusted in the x- and y-direction using both tuning frames (3) and (4).

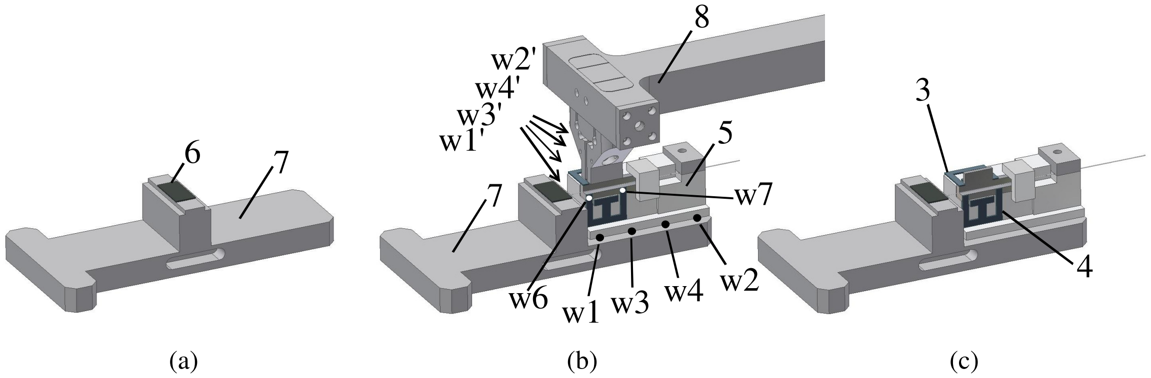


Fig. 2 Sequence of the pigtail procedure: (a) Chip (6) is bonded onto a carrier (7). (b) The fiber-subassembly (5) is aligned and welded onto the carrier (7) using weld sequence (w1) and (w1'), (w2) and (w2'), (w3) and (w3), (w4) and (w4') simultaneously. Next, the height of the fiber is fixed by weld joints (w6) and (w7). (c) After removing the pneumatic alignment tool the final fine alignment can be executed at the tuning frames (3) and (4) using laser-adjusting.

is actively aligned in the transversal direction by measuring the received optical output power and first welded at joint (w6). As a result of the post-weld-shift (PWS) the fiber tip is mechanically re-adjusted in the most optimal position. Then, the fiber-support (1) is welded for the second time at position (w7) to the tuning frame (4). Hereafter, the pneumatic alignment tool (8) is released and removed from the set-up. Due to the first and second weld joints (w6) and (w7) and relieve of the internal stress in the fiber-subassembly, when the alignment tool is released [post-release-shift (PRS)], a final re-alignment is necessary. This is performed by laser-support adjustment of the fiber tip (2) into the optimum position in the xy-plane trough material contraction in both tuning frames (3) and (4). The second left fiber-subassembly can be pigtailed at the opposite position with the same procedure without rotating the package.

Results

A QD SOA [1] is packaged and pigtailed as described in the previous section. The chip consists of straight waveguide structures and therefore an antireflection coating was applied to both cleaved facets. During the pigtail procedure the chip temperature is adjusted to 20 ˚C and a current of 30 mA was supplied to the SOA to generate amplified spontaneously emission (ASE) power. The optical coupling loss as a result of the mode mismatch between the lensed fiber with a lens radius of 10 μm and the optical waveguide is approximately 3.6 - 4 dB [3]. In table 1 are given the measured values of the PWS 1 during welding the fiber-support (1) to the tuning frame (4) at weld joint

Table 1 Measured displacement of the fiber-supports as a result of the PWS and PRS.

	Fiber 1		Fiber 2	
Displacement	X [μm]	Y [μm]	X [μm]	Y [μm]
PWS 1	-1.1	0.6	1.3	-13.5
PWS 2	-1.1	-4.3	0.8	-5.0
PRS	-6.9	+3.0	-3.2	-5.5

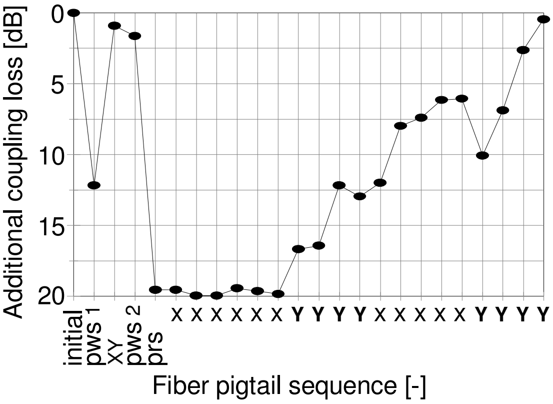
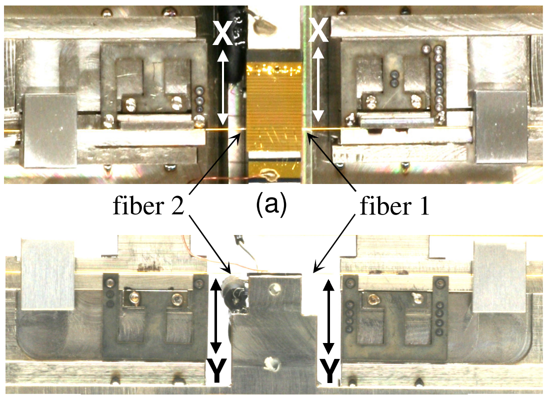


Fig. 3. Measured normalized received optical power of fiber 1 as a result of the following actions: after the first weld joint (pws1), again optimization of the fiber in the xy-plane, after the second weld joint (pws2), and subsequently after releasing the alignment tool (prs). In the next sequence, the fiber is aligned to the initial position by using laser-support adjustment.



(b)

Fig. 4. (a) Top view of the fiber-supports and tuning frames to adjust the fibers in the x-direction. (b) Side view of the tuning frames to adjust the fibers in the y-direction. Fiber 1 is laser-adjusted 19 times, while fiber 2 was only laser-adjusted five times to re-adjust the fiber back to the initial position.

(w6) and the PWS 2 at weld joint (w7) for fiber 1. Similar values/figures are presented for fiber 2. The displacements as a result of the PWS's are on the order of 0.6 μm – 14 μm, and additional shifts of about 5 μm were measured for the PRS. The impact of the PWS and PRS on the normalized received optical power for fiber 1 is shown in figure 3. Taking the normalized initial optical power as a reference, the optical power decreases 12.2 dB as a result of the PWS 1. The fiber is manipulated back using weld joint (w6) as a pivot point, which results in an additional coupling loss of 0.9 dB. After welding joint (w7), the influence of the PWS 2 on the received optical power is small. In contrast, the impact of the PRS results in an additional optical power loss of 19.5 dB. During the laser-support fiber alignment procedure the fiber is adjusted back to the initial position using 19 alignment steps. First, the fiber is laser-adjusted six times in the x-direction using the microscope. Then, by measuring the received optical power, the fiber is laser-adjusted four times in the y-direction, five times in the x-direction and finally four times again in the y-direction. With the same procedure, fiber 2 is aligned with five alignment steps: three times in the x-direction and two times in the y-direction. In figure 4 (a) are shown the alignment frames of both fibers for the x-direction whereas in figure 4 (b) the alignment frames for the y-direction are shown. Clearly visible are also the positions were laser-adjusting was performed. The micro module is mounted onto a 10.6 W TEC on a three-point support, and fixed unambiguously under constant tension in the package. By using this method, the internal stress of the micro module is minimized, compared with guidelines of traditional assembly methods of heat exchangers by bolting and applying torque in small increments.

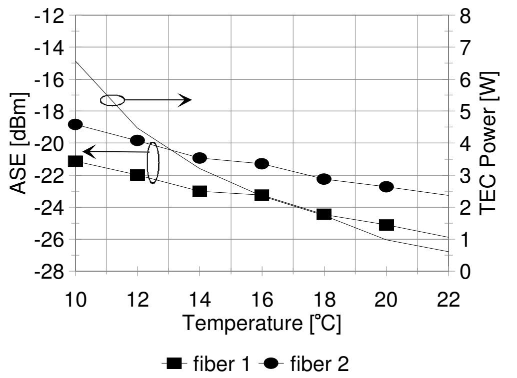


Fig. 5 ASE power as a function of the chip temperature and electrical power to control the TEC. The driving current trough the SOA is 500 mA.

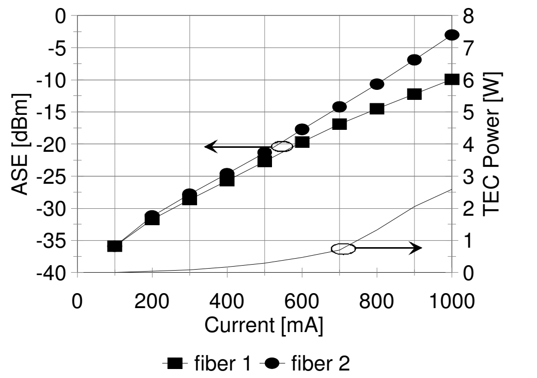


Fig. 6 ASE power as a function of the driving current trough the SOA measured at 10 ˚C and reduced electrical power to control the TEC by active cooling of the mounting plate.

Device characterization

To improve the device performance, the chip temperature is adjusted from ambient temperature to 10 ˚C and the ASE power is measured by applying 500 mA to the QD-SOA. The measured values are shown in figure 5, indicating a stable coupling connection of both fibers. When the current is further increased, we observe less ASE power of fiber 1 compared with fiber 2. This is probably caused by a technical problem during the AR coating of the device. The AR coating at the facet of fiber 1 shows more back-reflection of -18.7 dB compared with -36.1 dB for the other facet at fiber 2. The electrical power to the TEC is reduced from 6.6 W at 500 mA (figure 5) to 2.6 W at 1000 mA (figure 6) using active cooling of the mounting plate to 14 ˚C. We measured a small signal gain of 10-12 dB from fiber-to-fiber at a wavelength of 1536.8 nm, corresponding to the maximum of the ASE spectrum at a driving current of 1 A.

Conclusions

We demonstrated an effective pigtail and packaging procedure with the integration of final laser-support fiber alignment. With this procedure a QD SOA is successful packaged showing stable coupling connections at an operating temperature of 10 ˚C and supplying a current of 1 A trough the SOA.

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References

[1] S. Anantathanasarn et al., "Lasing of wavelength-tunable (1.55 µm region) InGaAsP/InP (100) quantum dots grown by metal vapor-phase Epitaxy," *Applied Physics Letters*. vol. 89, no. 7 (2006), pp. 073115-1/3.

[2] J.H.C. van Zantvoort et al, "Integration of laser-support fiber adjustment in opto-electronic modules," *2nd Electronic System-Integration Technology Conference*, vol 2, pp 803-807, Sept. 2008.

[3] J.H.C. van Zantvoort et al, "Lensed fiber-array assembly with individual fiber fine positioning in the submicrometer range," *IEEE J. Sel. Topics Quantum Electron.*, vol 12, no. 5 (2006), pp 931-939.