High Performance MEMS-Based Micro-optic Assembly for Multi-lane Transceivers

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Abstract *Advanced transceivers generally require multi-lane approaches, which necessitates the integration of multiple subcomponents. The use of mature, generally available, and low-cost single element components such as EMLs, silica PLCs, and direct-mod DFBs, integrated in a hybrid fashion and optically aligned with MEMS, provides a practical solution.*

Introduction

The bandwidth demand for interconnects has exceeded practical single channel data rates, thus forcing the use of multi-lane approaches, such as CWDM or advanced modulation techniques. Such transceivers require multiple functions or subcomponents in a compact footprint, and some form of optical integration is necessary.

To achieve the required density, here are generally two paths to follow. The more ambitious route is monolithic integration on InP or silicon. The challenge here is of course obtaining all the necessary functional building blocks on the same material or substrate. When working on silicon, the laser is usually the problem, while on InP, the performance of passive devices and the high costs of the processed material is the barrier. In any implementation, high yields are an absolute necessity, as any defect or burn-in failure causes the rejection of the entire assembly.

An alternative path to the monolithic approach is hybrid integration, where individual components are fabricated in different materials, tested prior to assembly, and then combined on a common substrate. The advantages are the ready supply of individual components, the higher performance of individual devices fabricated with the optimum process for that particular function, and the ability to test and yield out defective parts earlier in the manufacturing. The main issue with hybrid assembly has been the tight alignment required for single mode devices. Standard diebonding processes generally cannot achieve submicron tolerances.

In order to make hybrid integration practical, we have developed a platform where the tight alignment is achieved after standard diebonding using micromechanical techniques. Microlenses are bonded everywhere optical coupling is needed between two waveguides. These lenses are then adjusted micromechanically to optimize the coupling and locked down with integrated heaters. This is a simple and practical way to get high coupling efficiency between different devices in a compact footprint.

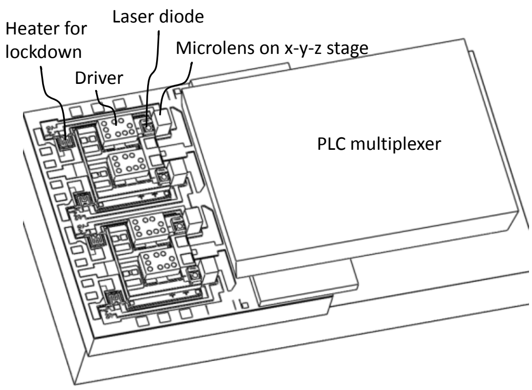

Fig. 1: 4x10Gb/s subassembly: The microlens is movable to optimize coupling from individual lasers to PLC

We demonstrate the power of this platform with the highest performance 4x10Gb/s packages for 10km applications (40GBASE-LR4). In general, this technology allows the fabrication of complex assemblies using discrete optical elements.

Fabrication

The MEMS platform provides the main substrate for the individual components. Using an SOI process, platforms are etched out and released that can hold the 250 micron diameter silicon microlenses. These platforms can move in all three axes to properly orient the microlens. For the lockdown, a heater is fabricated using NiCr, and thermally isolated from the rest of the substrate by etching out the silicon below the heater. The MEMS platform is populated with solder balls on the heater and separately fabricated silicon microlenses.

Individual DFB lasers of different wavelengths (1270nm, 1290nm,1310nm, and 1330nm), made by a commercial mature process, are diebonded using a standard AuSn solder onto silicon carriers, with two devices per carrier. Adjacent to each laser is a CMOS shunt driver bonded on the same carrier. The shunt driver obviates the need for matching resistors at the laser and thereby reduces the electrical power consumption. These lasers on the carriers are burned-in as required by the manufacturer, and then tested to specifications before the entire carrier is bonded down to the silicon MEMS platform. To get four wavelengths, two carriers, each with two lasers and two shunt drivers are used. Attached to the silicon MEMS platform is the PLC multiplexer containing an arrayed waveguide grating using mature silica on silicon technology. The device has tap waveguides where monitor photodiodes are connected. The PLC is mounted upside down on a spacer that approximately aligns to the lenses and the lasers in the vertical direction. It is important to note that all the laser, carrier, lens, and PLC bonding and alignment tolerances are +/ 10 to 20 microns, well within the capability of standard high speed diebonding equipment.

Once all the elements, including the microlenses and the solder balls are attached, the heater built in to the MEMS is activated to melt the solder ball and the assembly is aligned by micromechanically moving the microlenses on the alignment stages. This is done one at a time, and optimum coupling is verified automatically by monitoring the optical power measured in the PLC with the MPDs. Once optimal alignment is achieved, the MEMS holding the lenses are locked down by freezing the solder ball.

The 4x10Gb/s transmitter optical subassembly is completed by adding another lens to the output of the PLC, mounting the assembly in a standard package, and laser welding a receptacle with a built-in isolator to the output.

Results

Fig. 2a and 2b show the fundamental advantages of this approach. In the first figure, the additional loss is shown as a function of initial error in the placement of the laser and the PLC input waveguide. Errors between the two are compensated by adjusting the lens. The compensation is not perfect however, and at 20um, there is an additional 0.6dB loss incurred. This is far better than most approaches that would require initial submicron tolerance. In the figure the calculated curve is shown together with experimental curves using three different MEMS designs. The characteristics in y and z are similar. Fig 2b shows the additional coupling loss due to shifts in the solder lockdown. If the lens were locked down directly, any shift of the solder would move the lens by the same amount and affect the coupled power. This is the dashed line in Fig. 2b, and we can see that submicron control would have been required. However, because of the mechanical demagnification in the MEMS, and the fact that we lock down at the back of the laser and not directly at the lens, shifts are decreased about 10 times, resulting in the expanded solid line and the experimental points. We can see that a 1um shift in the solder results in about 0.1dB power loss. This makes the process extremely robust and manufacturable.

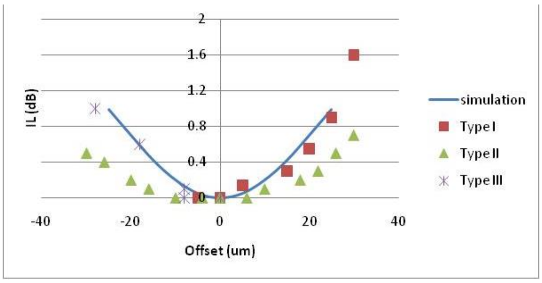

Fig. 2a: Additional loss as a function of error in x position between laser and PLC. Compensation with the lens allows loose initial positioning.

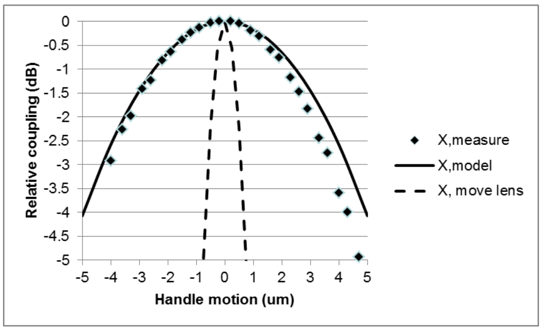

Fig. 2b: Additional loss as a function of solder shift at the heater. The dashed black line is calculated if the lens were to be locked down directly, showing high sensitivity, while the experimental points and the theoretical solid line shows the lower sensitivity of locking down the MEMS, with mechanical magnification.

The silicon microlens provides very good coupling efficiency, typically 1dB-1.5dB loss to the PLC. The PLC itself has about 3dB coupling loss, and there is another 0.5dB-1dB loss from the PLC to the single mode output fiber. Fig. 3 shows the L-I characteristics of the four lasers into the output fiber, showing 2-3mW optical power at 40mA. Fig. 3b shows a histogram of the mask margin for 10 samples.

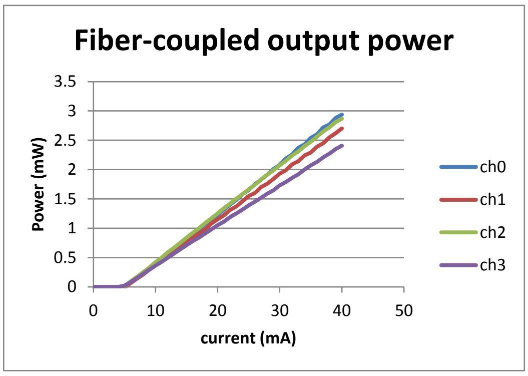

Fig. 3a: TOSA fiber coupled power.

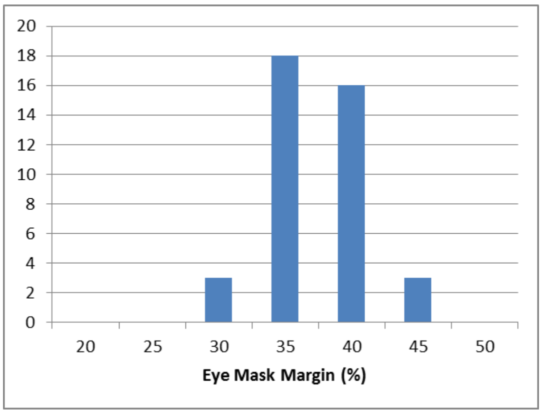

Fig. 3b: Histogram of mask margin at 40mA and 5.5dB ER for 10 samples

Conclusions

The MEMS-based coupling provides a simple way to build complex assemblies with excellent coupling efficiency between the elements. The four channel transmitter demonstrates the advantages of this approach.

Acknowledgements

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