MEMS-assisted fiber-chip coupling

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***Abstract* -** A long standing problem in integrated photonics is the attachment of optical fibers to an integrated photonic IC. The EU-funded project PHASTFlex takes an innovative approach to this and uses micro-electro-mechanical systems that actuate the silicon oxide-nitride optical waveguides to provide the required sub-micron alignment accuracy. Here we report on the measured movement range and coupling efficiency.

Introduction

Optical mode dimensions in single-mode waveguides are typically in the order of a few micrometer. For a low-loss connection to an optical fiber an alignment of sub-micron is required, which is beyond the capability of state-of-the-art pick-and-place assembly equipment.

The PHASTFlex project[1] tries to solve this problem with an intermediate TriPleX[2] interposer that has waveguides which match the size of the waveguide mode of the PIC on one side and that of a standard single-mode fiber (SMF) at the other side. To achieve the sub-micron alignment accuracy between the PIC and the interposer, we exploit micro electro-mechanical systems (MEMS) that are integrated in the TriPleX interposer, and which can move flexible ends of the optical waveguides. The alignment between TriPleX and SMF is not so critical because the mode dimensions are in the order of 10 μm.

Alignment is now a two-step procedure: firstly, the assembly machine positions the PIC and the interposer with an alignment accuracy between one and two microns; secondly, the MEMS move the flexible waveguide ends to provide the sub-micron alignment; thirdly. The concept is shown in figure 1.

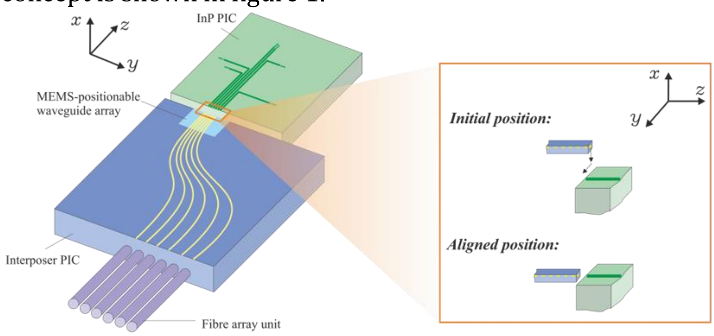

Fig. 1. Concept of alignment.

Experiments

We have conducted a number of experiments on the MEMS movement. For this we have used a TriPleX sample with out-of-plane thermal actuators. These are heaters on top of flexible SiO_2 beams. Figure 2 shows a microscope image of one set of short actuators with optical waveguides in between. We also characterized a set of long actuators, where the heaters extend over the full length of the flexible beams.

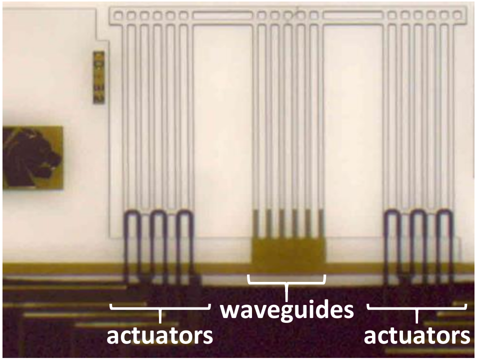

Fig. 2. MEMS inTriPleX with actuators for out-of-plane movement and optical waveguides in between.

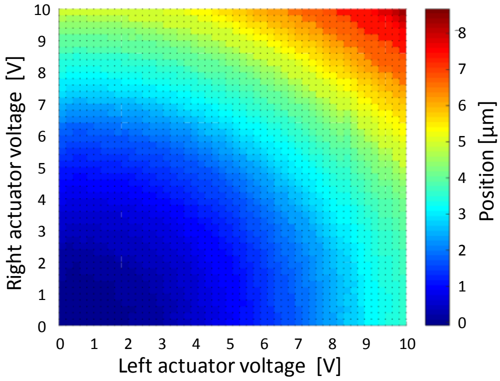

Fig. 3. Movement versus left and right actuator voltage.

The difference in thermal expansion between the poly-silicon, the metal and the SiO_2 causes the beams to deflect. By providing different powers to the left and right actuators, the end of the beams, and hence the waveguide ends, can be tilted, to compensate for an initial angular misalignment. Microheaters with an electrical resistance of approximately 1 kΩ are part of two actuators that are mechanically connected with a T-bar to displace the waveguides. Figure 3 depicts the achievable waveguide deflection in the out-of-plane direction as a function of applied voltage, showing a movement range up to 8 µm, which is more than sufficient to overcome the positional misalignment due to the accuracy of the assembly machine. The alignment requirements depend on the size of the optical mode in the waveguides. We have used an InP PIC for testing which has waveguides with a mode size which is expanded at the facet to approximately a $1/e^2$ diameter of 2.8 µm. The TriPleX mode size is similar. A requirement of a maximum excess coupling loss of 1 dB translates to a maximum out-of-plane misalignment of 1 µm. From the measurements shown in Figure 3, a voltage change of 0.1 V results in a displacement of less than 100 nm, which is already adequate for an optimized coupling.
The coupling concept was tested in a lab bench where the PICs were mounted in two alignment stages. The two chips were aligned coarsely and the final alignment was achieved using the MEMS structures. This allowed for precise alignment and an 80% coupling efficiency was achieved. The remaining loss is attributed to a residual mode-size mismatch and reflection loss in the non-coated TriPleX waveguides.

Conclusions

In this work a novel concept for attaching an optical fiber to a InP PIC has been exploited. The MEMS structure showed movement range of more than 8 µm. This movement range is much larger than the position accuracy of the automated assembly tools enabling optimization of the coupling between the two chips. We acknowledge the support from the EU through the FP7 Programme FP7-ICT-2013-11 Project 619267-PHASTFlex.

References

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