Realization of asymmetric optical bus couplers with aerosol jet printed polymer waveguides

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This article presents an approach for an asymmetric bidirectional interruption-free waveguide coupling for optical bus systems for the use in optical short range connections. For high flexibility and large waveguide structures Aerosol Jet printed waveguides on a conditioned foil are used. The results of the manufacturing and the coupling are presented.

1 Introduction

Current roadmaps highlight optical technologies as the future backbone of short range connections in a variety of applications [1]. Especially in terms of energy efficiency (mW/Gbps) [2] and bandwidth density (Gbps/mm²) [3] optical connections are ahead of their electrical pendants. However, to establish optical short range connections new coupling and SMT-compatible manufacturing processes are needed.

A great disadvantage of optical systems is the lack of smart technologies for bus systems. Today's photonic short range systems use point-to-point connections via butt-coupling [4] or bus systems with complex design and inefficient power management [5]. In this work we present an approach for interruption-free waveguide coupling for bus systems with different coupling ratios depending on the coupling direction (module to bus or vice versa).

2 Coupling concept

For the connection of several electro-optical (e/o) modules we propose an asymmetric optical bus coupler (AOBC) as it is depicted in Fig. 1. It is based on a directional core-core-coupling where the cladding is removed at the junction and the cores get into physical contact. One of the coupling partners has a defined bending and is pressed with a defined force onto the second coupling partner. By varying the pressure the coupling ratio can be adjusted. Additionally, preliminary simulations revealed asymmetric coupling ratios depending on the direction [6]. Because of the bent waveguide, more energy is coupled from the module to the bus than in the opposite direction. This can be tuned as well according to the dependence of the asymmetry on the bending radius. In order to ensure arbitrary coupling positions, a foil with the refractive index of the cladding can be used, which is temporarily removed for coupling.

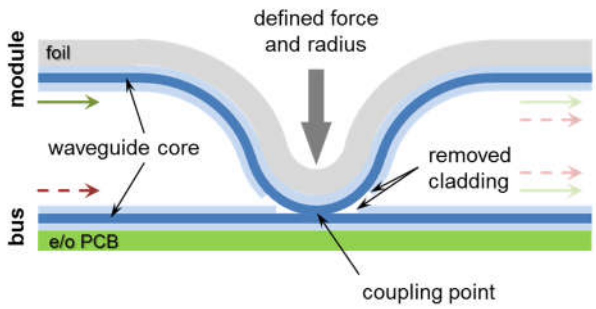

Fig. 1 *Principle for an asymmetric optical bus coupler*

3 Manufacturing process

For the realization of the AOBC an additive manufacturing process has been chosen. According to that, it is possible to fabricate long bus waveguides by a roll-to-roll process for large area optical networks. Furthermore, the highly flexible process allows for a direct waveguide printing on three-dimensional opto-mechatronic interconnected devices (3D-Opto-MID).

In Fig. 2 the process steps are illustrated. The basis is a flexible polymer substrate on which parallel conditioning lines are applied by flexographic printing to allow for higher aspect ratios of the waveguide. In the final step the waveguide is printed between the conditioning lines by an aerosol jet process.

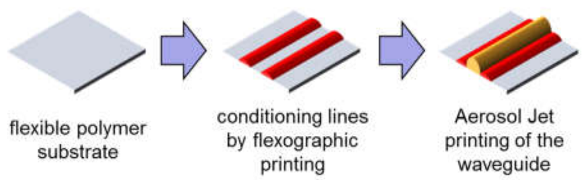

Fig. 2 *Process steps for the waveguide manufacturing*

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4 Measurement results

With the described manufacturing process waveguides were fabricated as shown in Fig. 3. Despite the low geometrical aspect ratio of 1:6, near field measurements revealed that about 70 % of the energy coupled into the waveguide is concentrated in a 45 x 100 µm² area as shown in Fig. 4. For the printed waveguides an attenuation of *a* = 0.65 dB/cm was measured.

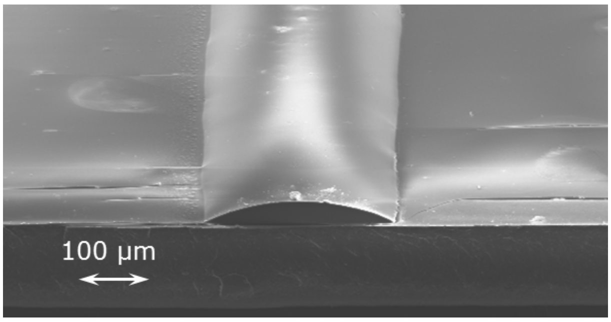

Fig. 3 *REM image of an aerosol jet printed waveguide core*

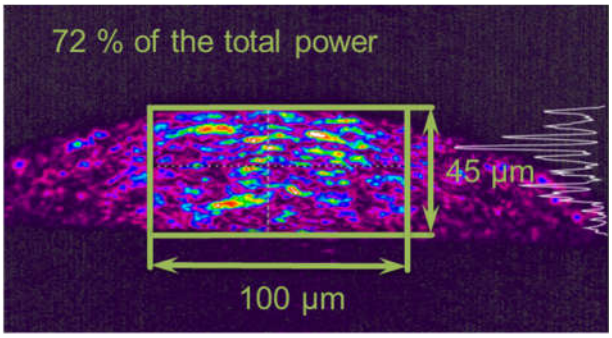

Fig. 4 *Near field image of the end face of an aerosol jet printed waveguide with the area including 72% of the total input power*

For the coupling experiments, the setup shown in Fig. 5 is used. An 850 nm laser is coupled via fiber (10 µm, *NA* = 0.1) into the printed waveguides. While coupling into the second waveguide without any interruption, the light is detected again via fiber (400 µm, *NA* = 0.39) at the output.

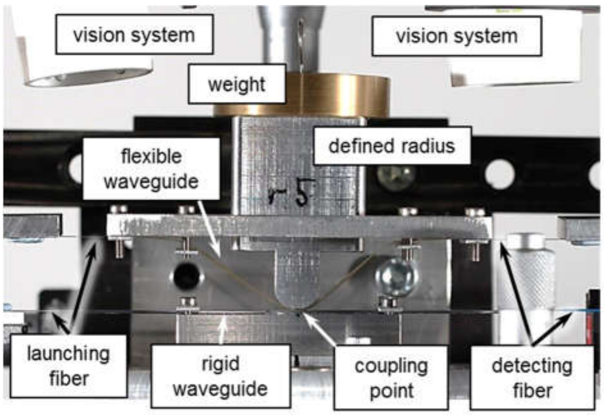

Fig. 5 *Measurement setup for the coupling experiments*

The measurements prove the asymmetric coupling behavior of the AOBC. For the bus-to-module coupling a ratio of 0.02 is obtained, while in the opposite direction a ratio of 0.14 is detected. Both coupling ratios are obtained at *r* = 5 mm and 500 g weight and are normalized to the total output power of the coupler (main and coupling energy).

5 Summary

With the presented asymmetric optical bus coupler it is possible to achieve a bidirectional interruption-free waveguide coupling with different coupling efficiencies for different coupling directions. For the realization of the coupling element additive manufactured waveguides are chosen to enable for flexible roll-to-roll processes. This new coupling approach combined with SMT-compatible manufacturing could lead to the establishment of optical technologies in short range communication systems.

Acknowledgement

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References

[1] International Technology Roadmap for Semiconductors 2.0, "Outside System Connectivity Edition 2015," ITRS, 2015.

[2] D.G. Kam et al., "Is 25 Gb/s On-Board Signaling Viable?," *IEEE Transactions on Advanced Packaging Vol.32(2)*, pp. 328-344, 2009.

[3] R. Dangel et al., "Polymer-Waveguide-Based Board-Level Opitcal Interconnect Technology for Datacom Applications," *IEEE Transactions on Advanced Packaging Vol.31(4)*, pp. 759-767, 2008.

[4] R. Krähenbühl, T. Lamprecht, E. Zgraggen, F. Betschon, and A. Peterhans, "high-Precision, Self-Aligned, Optical Fiber Connectivity Solution for Single-Mode Waveguides Embedded in Optical PCBs," *Journal of Lightwave Technology Vol 33*, pp. 865-871, 2015.

[5] A. Flores, S. Song, J. Yang, Z. Liu, and M. Wang, "High-Speed Optical Interconnect Coupler Based on Soft Lithography Ribbons," *IEEE Journal of Lightwave Technology Vol. 26(13)*, 2008.

[6] L. Lorenz et al., "Optical Beam Propagation and Ray Tracing Simulation of Interruption-Free Asymmetric Multimode Bus Couplers," *IMAPS Journal of Microelectronics and Electronic Packaging Vol. 14, No.1*, pp. 1-10, January 2017.