THE FOURTEENTH MICROOPTICS CONFERENCE

TECHNICAL DIGEST

Organized by
Vrije Universiteit Brussel
Department of Applied Physics and Photonics

September 25 (Thu.) – September 27 (Sat.), 2008

Diamant Conference and Business Centre
Brussels – Belgium

Printed in Brussels, 2008

C/o Microsystem Research Centre, Tokyo Institute of Technology
R2-39, 4259 Nagatsuta, Midori-ku, Yokohama 226-8503, Japan

MOC '08

Sept. 25 (Thu.)
Sept. 26 (Fr.)
Sept. 27 (Sat.)

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Financially supported by

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OPTO-PCB: THREE DEMONSTRATORS FOR OPTICAL INTERCONNECTIONS

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Abstract: *We report on a research project targeting optical waveguide integrated PCBs conducted within the European FP6 Network of Excellence on Micro-Optics NEMO. For three identified feature requests we have built three specific demonstrators respectively addressing the integration of active components, the fabrication of peripheral fibre ribbons and the integration of multiple layers of waveguides on the board*

1. Introduction

Adopting photons for board-level interconnects has been considered since many years. Industry (IBM, Agilent, Siemens C-lab, …) recently launched considerably large R&D programs in this area. This sparked a renewed interest in the theme of optical interconnects with a sharp focus on the embedding of optical waveguides into printed circuit boards. This so-called Opto-PCB technology has been the main target of Work Package 9 in the Network of Excellence on Micro-optics (NEMO). NEMO takes a rather unique position in this field as the different technologies available among the network partners can be combined.

The first 1.5 years of board-level interconnect work in NEMO focused on solving particular technological issues and on taking care of existing incompatibilities between the partner capabilities. The Opto-PCB project then took the research to the next level. Beside basic embedded waveguide technology improvements, this project has identified three technology features that need further development: 1) integration of and coupling to active devices on the board, 2) integration of connectors for fibre and fibre ribbons to extend the optical connection between boards, 3) integration of multiple layers of optical waveguides on one board. For each of these feature requests the project is targeting a dedicated optical demonstrator. The different partners that are contributing to this project are: the Vrije Univeristeit Brussel (VUB), Ghent University (UG), VTT Technical Centre of Finland (VTT), Heriot-Watt University (HWU) and the Université Jean Monnet (TSI).

2. Basic Technology Improvements

A first important aspect of this project is the characterization and further optimization of the necessary basic technologies as building blocks for the embedding of optical waveguides into PCBs. For the waveguide fabrication, the following technologies were targeted: waveguides by laser ablation (UG), waveguides by photolithography (UG) and the photo-definition of waveguides realized by a direct laser writing process (HWU). The top surface of laser ablated waveguides was characterized to show a RMS surface roughness of R_q=35nm. The waveguide loss was also measured by a cut-back method, resulting in 0.13dB/cm loss at 850nm excitation. The embedded 45° out-of-plane micro-mirrors which were inscribed by laser ablation (UG) were characterized at the VUB, resulting in a mirror tilt of 45.52° as measured by a Dektak contact profilometer. The surface of those tilted micro-mirrors was characterized by a non-contact profilometer and resulted in an RMS surface roughness of 61nm (measured over an area of 50x50 μm^2).

We can furthermore report on two technology breakthroughs. The first is the fabrication of optical waveguides with a reduced cross-section area. HWU was able to produce a waveguide with a cross-section of 6.6x11.4 μm^2 and UG produced waveguides with a cross section of 11x13 μm^2. The second technology breakthrough we report on is an alternative approach for efficient out-of-plane coupling. This new approach uses a metal coated trapezium-shaped mirror insert fabricated with Deep Proton Writing (DPW) that can be inserted in laser ablated cavities before another top-cladding planarization step. The approach resulted in an excess mirror loss of 0.35dB for out-of-plane coupling [1]. At the fringe of the project, the possibilities offered by grating coupling into multimode waveguides were also investigated. Recently, it was demonstrated experimentally that a leaky mode mediated grating coupler can couple close to 100% power into a multimode waveguide. An experimental optical interconnect comprising in-coupling, centimeter scale multimode waveguide propagation and out-coupling exhibited less than 2 dB excess[2].

3. Demonstrator I: Integration with actives optoelectronics

A first demonstrator aims at integrating the opto-PCB waveguides with active devices such as VCSELs and detectors and solves some important packaging problems underway. This task involved the development of an optical link from VCSEL array to photodiode array. VCSELs equipped with integrated micro-lenses (delivered by CSEM, Switzerland) and optoelectronic packaging available at VTT were used. PCBs containing 4 parallel 50x50 μm^2 waveguides on a 250µm pitch with laser ablated cavities were fabricated (UG). Pluggable out-of-plane couplers [3] fabricated with DPW technology were fabricated at VUB and contained cylindrical (i.e. 1D) micro-lenses for better coupling efficiencies. VTT has furthermore packaged the active components and characterized the assembly. The measured total optical link loss was estimated to be 7.9dB [4]. In a next phase of the project, we are implementing the new approach using the embedded mirror inserts as well to further boost the system performance.

4. Demonstrator II: Peripheral fibre ribbon connectivity

In this demonstrator we target the coupling of light from the embedded waveguides towards fibre ribbons. Many applications indeed require light, either generated on a board or brought into a rack, to be transported through the system to another board for processing. The design is schematically illustrated in Fig. 1.

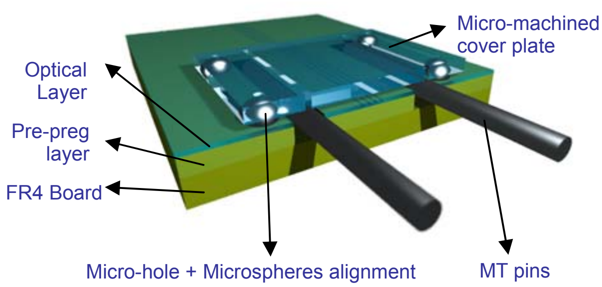

Fig. 1. Schematic design of the peripheral connector

UG fabricated the board with an extra pre-peg layer for the embedding of the copper islands as an ablation stop layer. The cavities for micro-spheres alignment and the MT-pins insertion were furthermore defined in the board together with the Truemode®-based parallel optical waveguides. With a contact profilometer, the position of the waveguides with respect to the micro-spheres was fully characterized (VUB). With this information, the design of the cover plate is currently being prepared.

5. Demonstrator III: Board with multiple optical layers

Here we demonstrate the introduction of multilayer optical waveguides. These multilayer boards allow more flexible routing of the optical signals by avoiding difficult and possibly lossy crossings. They also fully exploit the 2-D character of the optoelectronic components. The propagation and coupling of light in multilayer boards was simulated via non-sequential ray tracing [5]. UG has fabricated samples with two layers of optical waveguides and experimentally demonstrated inter-layer coupling via laser ablated embedded mirrors. VUB has designed discrete inter-layer couplers via DPW and characterized the combined mirror loss. For the embedding of the component within laser ablated cavities in the Opto-PCB, the design was adapted and components will be fabricated in the near future.

6. Conclusions

In conclusion, NEMO's internal project "Opto-PCB" allowed updating and completing the network's technological portfolio to embed optical waveguides on boards (for small waveguide cross-sections) and to achieve efficient out-of-plane coupling (with excess mirror losses below 0.35dB). Three different demonstrators are being implemented to demonstrate three different feature extensions: 1) integration with and coupling to active devices on the board, 2) integration of connectors for fibre and fibre ribbons to extend the optical connection between boards, and 3) integration of multiple layers of optical waveguides on one board.

Acknowledgement

The authors would like to thank the support the EU FP6 Network of Excellence on Micro-Optics NEMO, the FWO Flanders, DWTC-IAP, GOA, IWT and by the OZR of the Vrije Universiteit Brussel.

References

[1] N. Hendrickx, J. Van Erps, E. Bosman, C. Debaes, H. Thienpont and P. Van Daele, "Embedded Micro-Mirror Inserts for Optical Printed Circuit Boards", submitted to IEEE Photon. Technol. Lett.

[2] J. Franc, N. Destouches, D. Blanc, J.C. Pommier, S. Tonchev, G. Van Steenberge, A. Last and O. Parriaux, "High efficiency diffraction grating coupler for multimode optical interconnect", Proc. of SPIE, **6185**, 6185F (2007)

[3] J. Van Erps, N. Hendrickx, C. Debaes, P. Van Daele and H. Thienpont, "Discrete out-of-plane coupling components for Printed Circuit Boardlevel optical interconnections," IEEE Photon. Technol. Lett, **19**, 1753–1755 (2007).

[4] T. Alajoki, N. Hendrickx, J. Van Erps, S. Obi, M. Karppinen, H. Thienpont, P. Van Daele and P. Karioja, "Optical coupling and optoelectronics integration studied on demonstrator for optical interconnects on board," in Proc. of EMPC2007, 16th European Microelectronics and Packaging Conference , 258–261 (2007).

[5] N. Hendrickx, J. Van Erps, G. Van Steenberge, H. Thienpont and P. Van Daele, "Tolerance analysis for multilayer optical interconnections integrated on a Printed Circuit Board," IEEE J. Lightwave Technol., **25**, 2395–2401 (2007).