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Optical interconnections for short distances

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ABSTRACT

Parallel short distance optical interconnections are becoming more and more important. Integrating optical interconnections on a board level, covering distances from a few centimeters to a few meters, is however very challenging as the optical interconnection and mounting technology has to be integrated in existing PCB manufacturing technology. Fiber based interconnections are already available, but new solutions for integrating a guided-wave based optical interconnection layer in a standard FR4-based electrical printed circuit board are emerging. Besides the fabrication of these optical layers, the coupling of light in and out of these layers from and towards active components or fiber arrays is also very crucial and mostly determining final cost of the module. An interesting technology that has arisen during the past few years makes use of laser-ablation.

Keywords: optical interconnections, optical boards, laser ablation, optical alignment

1. INTRODUCTION

In present and future broadband networks, multigigabit transmission over longer distances is only feasible via optical interconnections that form the very heart of the network. Worldwide ongoing research aims at the extension of the optical interconnect to the board level and to the switching level. In spite of repeated predictions that the all optical interconnect is soon going to replace electrical interconnect on the board level, this turned out not to be yet the case. Several reasons can be given for this, but the two most important ones are that it turned out to be more difficult than expected to integrate optical interconnect in an easy and cost effective way into or onto a board. The second reason is that, as can typically be expected from a technology with a large investment base, the possibilities in terms of maximum bitrates of electrical board interconnect are continuously being upgraded, postponing the need for replacement by optical interconnect.

Many systems are rack-based backpanel configurations with interconnection lengths ranging from a few centimeters to a few meters. It is crucial that, in order to be accepted by system engineers and designers and in order to be low cost, the introduction of optical interconnections on this level should be completely compatible with existing board-technology. Therefore the optical interconnections should be integrated in FR4-based PCB's both in view of the optical layer itself as well as the coupling of light to and from this optical layer to optoelectronic components and/or fibers. The same can be said of the interconnections at even shorter distances (on MCM-level) where compatibility should be sought with existing MCM-technology, chip-packaging and Chip-on-Board technologies.

As stated above, it is clear that for achieving a low cost solution, compatibility with existing technology should be sought. This implies, in most cases, alignment tolerances of traditional electrical packaging and mounting technologies which are not in line with required optical performances. Therefore micro-optics will play a crucial role in achieving good optical performances, together with existing tolerances within the board manufacturing technology.

When discussing optical interconnections at short distance, one should keep in mind the application one is looking for:

1. the situation where optical signals are arriving into the cabinet from optical fibers coming from long haul interconnections, and which signals have to be switched, repeated or decoded. In this case the arriving signal will be on a wavelength of 1.3 or 1.55 um and the fibers will be SM, requiring similar wavelengths and modal structures on the boards, and
2. the situation where processors on the same or different boards within the same system have to communicate at high bitrates, but over short distances, which will imply a MM structure and most probably also a less stringent requirement on wavelength dependent losses.

These very different situations and applications are sometimes not clearly taken into account, but may have a very different impact on the choice of technology to be used to integrate the optical layer in the boards.

2. INTEGRATION OF OPTICAL LAYERS IN PRINTED CIRCUIT BOARDS AND MCM

In order to realize optical interconnections on a board-level, the first option people have been considered, already many years ago, was to integrate optical fibers into the FR4-stack (Figure 1.) [1-3]. This solution has reached the status of commercialization [3-6, to name only a few]. The integration of optical fibers poses however considerable problems regarding integration of deflecting and coupling structures and connectorisation of the optical interconnections. Therefore the main route which is being followed by many is to seek for the integration of waveguide-based interconnections where the waveguiding layer is integrated in the PCB-stack or deposited on top of it. The main requirements regarding these materials are the temperature stability in view of the FR4-processing steps and mounting / soldering steps of the PCB, and , naturally, low optical losses (Figure 2).

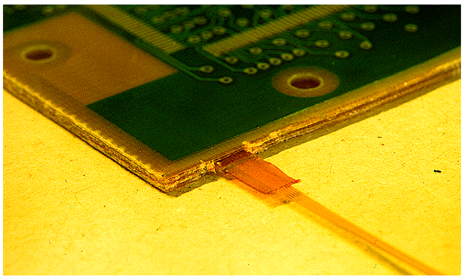

Figure 1: Optical fibers integrated in a standard FR4-stack are used to realize an optical layer. The fibers can be seen as a ribbon extending from the edge of the FR4-board. Main difficulties arise from the connectorization of these ribbons.

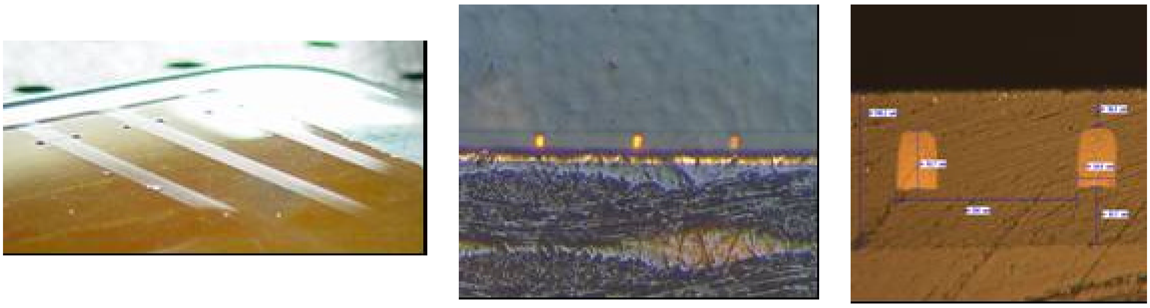

Figure 2: Waveguides in an ORMOCER®-layer on top of an FR4-substrate. The waveguides have a pitch of 250 um and a cross section of about 60 um height, 50 um width

In this work, and also amongst many other groups, several materials are being investigated from the commercially available SU-8, ORMOCER® [7-10] en Truemode® materials to in-house fabricated materials. Once these materials are deposited on the PCB-stack, the waveguides can be defined. Again several technologies are available and these can vary from traditional UV-lithography over laser-written, laser-ablated to molded or embossed structures (Figure 2).

3. COUPLING & MICRO-OPTICAL STRUCTURES

Once the waveguides are defined, it is necessary to define the deflecting and the coupling structures within these layers to allow for coupling light in and out of the layers. The choice of the structure and the technology will largely depend on the material and the application. It is clear tat a solution chosen to couple light form a 2-dimensional array of VCSEL's will be different from the coupling structure for an array of glass fibers with connector. Again the main factor in the final choice will be cost and this will imply compatibility with existing technology.

Basically 2 options are possible: using a deflecting structure (Figure 3) or using a periscope type of mounting (Figure 4). The deflecting structures can then either be defined in the optical layer of can be an insert which is separately fabricated and placed with required accuracy in the board.

To achieve optimum coupling efficiency, micro-optical elements such as micro-lenses can be used in between the waveguides and the components or fibers. Again depending on the application and the materials used, these micro-lenses can be fabricated in the board, or separately on an extra element (Figure 5), or can be integrated with the insert.

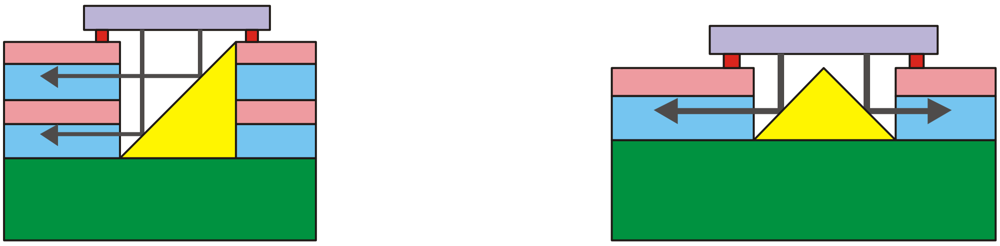

Figure 3: Schematically representation of the use of deflecting structures to couple light from VCSEL-arrays into (stacks of) waveguides. This also clearly demonstrates the possibility to fully exploit the 2-dimensional character of the arrays.

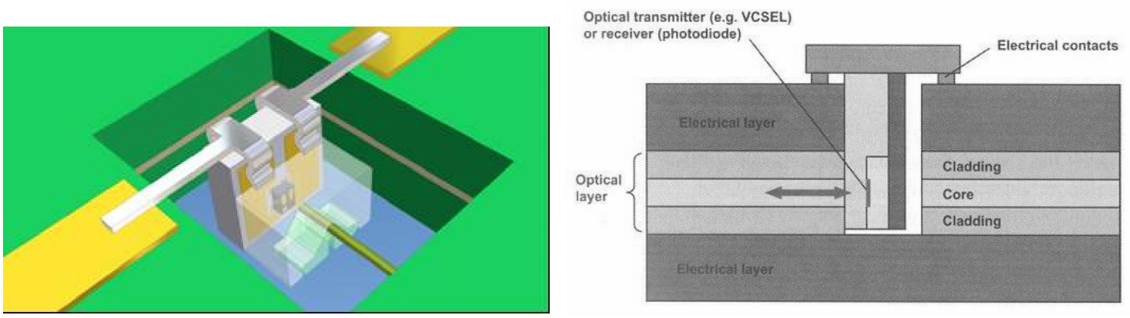

Figure 4: Coupling of light in and out of the optical layer through a periscope-type of structure. Left is a solution proposed by FZK (Germany) to couple light from a detector or laser to embedded optical fibers. On the right is a schematically view of the coupling in a spincoated optical layer [11].

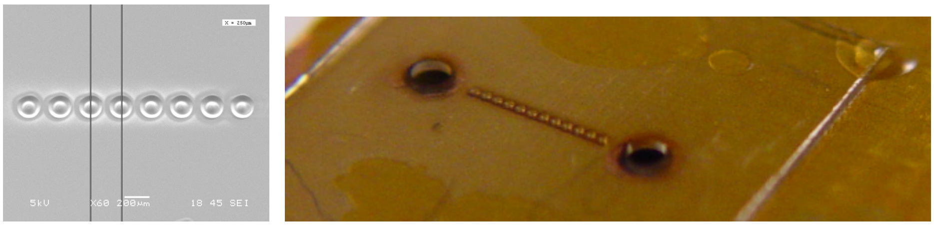

Figure 5: Laser ablated micro-lenses in a polycarbonate substrate. The pitch of the lens-array is 250 um. This polycarbonate plate is mounted on top of the deflecting mirrors in the optical layer and alignment holes are also laser-ablated.

4. DEMONSTRATORS.

Within the European Network of Excellence on Micro-Optics (NEMO), different technologies have been combined in some basic demonstrators on optical interconnections. Figure 6 illustrates just one of these.

This demonstrator combines laser-ablation, commercially available materials and micro-optical structures prepared by the DLP technique (Deep Lithography by Protons) [xx] to achieve low cost optical interconnections fabricated using materials and techniques which are compatible with standard PCB manufacturing.

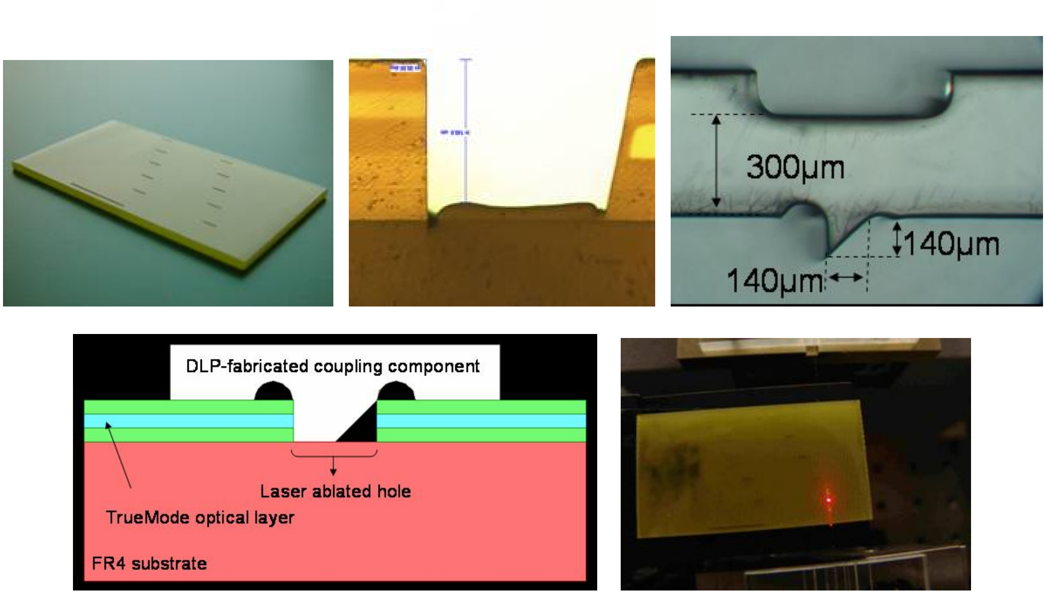

Figure 6: Use of a DLP-fabricated insert (VUB) to couple light in and from an ORMOCER-layer on an FR4-substrate. The holes for the insert are fabricated using laser-ablation. Top left: FR4-substrate with Truemode optical layer and laser-ablated holes for the insert, top middle: detail of the laser-ablated holes for the insert, top right: detail of the DLP-insert. Bottom left: schematic representation of the coupling structure, bottom right: demonstration of light coupled out of the board.

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