Workshop on

Micro-Optics –

Benefits for Industry

7th April 2006

Photonics Europe

Strasbourg, France

Book of Abstracts
## Program

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Optical Interconnects at PCB level

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Mo Taghizadeh, HWU, United Kingdom
Christoff Debaes, VUB, Belgium

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.

The goal of the Workpackage 9 of the NEMO-network is to investigate the potential of micro-optics for achieving this goal of integrating optical interconnections on printed circuit boards and on MCM-level. 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.
NEMO – WP9

Optical Interconnects at PCB level

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Mo Taghizadeh – HWU (UK)
Marc Schneider – FZK (D)
Pentti Karioja – VTT (SF)
Christoff Debaes – VUB (B)
Overview

1. Rationale
2. Options
3. Free space Optical Interconnections
4. Fiber-based Optical Interconnections
5. Waveguided Optical Interconnections
6. Optical coupling
7. Conclusions
Optics have proven their potentials for

- high density
- long distances

Introduction of optics into short distances:

- coupling technology is challenging
- optical technology should be compatible with existing technology
Rationale

Fiber-Board
OE-Board
Connector-Board

Telecom: Single-mode, 1.3 & 1.55 um
Rationale

- First generation: Discrete optical fiber interconnects
- Second generation: Flexfoil interconnects
- Third generation: Embedded optical & Free-space

Interconnect density (Gbps/mm²)

1990 - 2000 - 2010

BPA «OPTICAL BACKPLANES : A global market and technology review 2000-2005 », Report #762
Datacom: Multi-mode, 850 nm
VERY FIRST LEVEL INTERCONNECTION FOR ICs: WIRE BONDING in 2004

- 10 MILLION KM: 0.8 to 3 mils IN DIAMETER, MOSTLY GOLD
- 1.2 Bn US$ COST, OF WHICH 90% IS COST OF GOLD
- ABOUT 10,000 Bn WIRES, BONDED ONE BY ONE
- ABOUT 50,000 BONDERs
- FOR A NEW LINE: BONDERs ARE THE 40% OF TOTAL INVESTMENT, 60% OF SHOPFLOOR

PACKAGE TECHNOLOGY TRENDS – 2009

80% OF IC DEVICES HAS CONVENTIONAL PACKAGE OF WHICH 2% USES FLIP CHIP INTERCONNECT
• Optics on PCB-level
  – free space
  – guided wave
    • fibers
      – glass fibers
      – polymer fibers
    • waveguides
LTCC Carrier for VUB demonstrator on optical interconnect

- VUB: Design of carrier
- VTT: Carrier-fabrication
- VUB: Assembly & testing

High-density, parallel OI on (multi-)chip modules
Fiber-based

- Optics on PCB-level

Fibers require:
- length for ‘re’-cleaving
- min. $R_{\text{curvature}}$

Telecom
Fiber-based

- Fibers in flex

Telecom
Fiber-based

Telecom

( ACTS - PLATO )
In-board optical interconnections

- substrate: FR4, Ceramic, Glass, Si,...

- waveguiding material: ORMOCER (UG), polymers (HWU), SU8 (VTT)
  Sol-Gel (VTT, TSI), Fibers (FZK), glass, ....

- coupling structures: Ablated (UG), gratings (TSI), LIGA-inserts (FZK),
  DLP-inserts (VUB), Laser-writing (HWU),
  Glass inserts (VTT)....
Embedded fibers

• Fibers in FR4-boards

Connectors at the edge?

Coupling out-of-plane?
Embedded fibers

Fiber from FZK – UG for initial tests (bare fiber + embedded)

FZK FR4-substrates with embedded fibers
► UG laser-cleaving of embedded fibers
Embedded fibers (FZK) with DLP-clip system

- **FZK**: FR4-substrates with embedded fibers
- **Design of Clip-parts**
- **VUB**: DLP-fabrication of Clips
- **FZK**: Assembly & testing

**Position tolerances**
- oe-chip – substrate: 5 µm
- alignment structure – substrate: 5 µm

Demonstrator with LIGA-parts: OK
• Waveguides in FR4-boards

Connectors at the edge?

Coupling out-of-plane?
Waveguide based

- Waveguides in glass sheets?
  Thin glass sheets integrated in FR4-stack
  -> etching of waveguides
  -> UV-sensitive glass
  -> ablation of waveguides
  -> ....

www.ppc-electronic.com
Waveguide-based

@850 nm

\[ y = 0.202x + 1.5634 \]
Optical coupling

Edge emitter - VCSEL - Detector

Ferrule + fiber ribbon
Optical Coupling

- *Inserts can be any material*

(Joined development INTEC-AKZO Nobel)
Optical coupling

Truemode with ablated cavities (UG) + DLP inserts (VUB)

UG: FR4-substrate + Truemode layers
waveguides – UV-defined
laser-ablated end-facets & cavities

► VUB: fabrication of DLP-inserts
mounting
characterisation
Joint publication @ SPIE Warsaw

DLP-fabricated coupling component

TrueMode optical layer

Laser ablated hole

FR4 substrate
Waveguide based

Truemode with ablated cavities (UG) + DLP inserts (VUB)

UG: FR4-substrate + Truemode layers
waveguides – UV-defined
laser-ablated end-facets & cavities

► VUB: fabrication of DLP-inserts
mounting
characterisation
Joint publication @ SPIE Warsaw
Optical coupling
Optical coupling
Optical Coupling

E. Griese,
PC FAB,
June 2002
Where do we go from here?

parallel optical interconnect demonstrator - active, no connectors

- To demonstrate 4-channel optical interconnect on FR-4 board with integrated waveguides and fully passive alignment assembly
- Based on VTT’s demonstrator with 4-channel 10Gb/s/ch transmitter and receiver modules integrated on LTCC substrates
Where do we go from here?

parallel optical interconnect demonstrator - active, no connectors
Where do we go from here?

Rigid substrate

► flex substrate
Where do we go from here?

Single layer

► multiple layers
Conclusions

• Optics in PCB’s
  – Fibers: proven - Waveguides: to be investigated

• Optical coupling
  – Micro-optical parts required
  – Inserts or in-layer fabrication
  – Coupling to OE or connectors

• Optimise technologies for optical interconnections
  – Compatibel with FR4-processing

• Watch out: costs can be extremely high