Adaptive Data and Power Aware Transceivers for Optical Communications

Deliverable Report D 1.2

Project Periodic Report

Small or medium scale focused research project (STREP)

ICT-2013.3.2 Photonics

Project Start Date: 1st November 2013

Duration: 42 months

Project reference: 619197

FP7-ICT-2013-11 February 26, 2015 – Version 1.0

Project co-funded by the European Commission
within the Seventh Framework Programme (2007 - 2013)

Dissemination Level: Public

Document information

Title	D1.2 - Project Periodic Report
Work package	WP1 – Management
Responsible	Technische Universität Dresden (TUD)
Due date	Project month 14 (December 2014)
Type	Report
Status	Version 1.0
Security	Public
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Project URL	www.addapt-fp7.eu

Confirmation

Any work or result described in this report is either genuinely a result of this project or properly referenced.

Version Management

Table 1: List of Revisions

Version	Description	Author	Released
V1.0	Document creation, copy of publishable summary, Executive summary	R. Henker (TUD)	February 26, 2015

Table of contents

List of Figures

Executive Summary

This public deliverable report D1.2 is referred to the Project Periodic Report which has been submitted via Participant Portal and summarizes the progress and financial expenses of the first ADDAPT project phase covering project month M01 (November 2013) to M14 (December 2015). As the project report is confidential due to unpublished and unpatented content, this deliverable report D1.2 is public. It shows the publishable summary of the project report which summarizes the project context and objectives as well as the project progress and results of the first project phase.

1 Publishable summary

1.1 *Project context and objectives*

The performance requirements of existing and future optical networks, especially of the optical links and interconnects, are not static and change over time. The individual needs of the users, applications and boundary conditions lead to a strong dynamic behaviour of data rate in today's data networks for instance. However, existing optical networks operate statically at their maximum performance to accommodate the peak traffic requirements and therefore, do not offer much adaptability. Thus, the links are not flexible and not energy-efficient. Therefore, one of the main innovations treated by ADDAPT is to adjust the performance and in turn the power consumption of the multiple optical links from system down to optical device, electrical circuit and transistor level to the actual required data load and link conditions. To achieve this, a high-speed electro-optical transceiver module will be developed whose parameters like bandwidth, modulation format, clock rate, amplitudes can be adapted as it is illustrated in Figure 1. This leads to a reconfiguration of the system according to the actual transmission requirement which in turn reduces the system power consumption. To realize this, a smart adaptivity control is implemented that decides how and when the system parameters need to or may change. The transceiver design includes novel high-speed directly modulated lasers and photodetectors equipped with low-loss low-cost near-field light coupling, novel adaptive integrated circuits like laserdiode driver (LDD), transimpedance/limiting amplifier (TIA/LA), clock data recoveries (CDR) in advanced 14 nm CMOS technology and high-speed low-loss packaging solutions using glass or ceramic substrates. A transceiver system with 4 link paths each with adaptive data rates from 7 Gb/s up to 56 Gb/s and maximum 10 m link distance is targeted. Further goals are low power consumption and high energy efficiency of the transceiver and its components as well as low latency data transmission. The development of such an adaptive optical interconnect paves the way to build flexible energy-efficient optical transmission links and networks coping with varying bitrate demands and pave the way for massive reductions of CO_2 emission and costs.

Key applications of ADDAPT are seen in optical interconnects for short range data communication as used in data-centers or high performance computing (HPC) for rack-to-rack, server-to-server and board-to-board connections. One possibility would be to replace standard active optical cables (AOC) with fixed performance and power consumption by ADDAPTive transceiver.

To achieve the project goals, the ADDAPT consortium involves a full supply chain from semiconductor technologies, component and system design over packaging, assembling and characterization to user requirements, interconnect applications and commercial markets. Complementary competences of 3 large companies, 3 SMEs and 2 universities including device manufacturers, suppliers of communication equipment and network operators are combined. Involved EU and associated countries are the Netherlands, Czech Republic, Poland, United Kingdom, Cyprus, Switzerland and Germany.

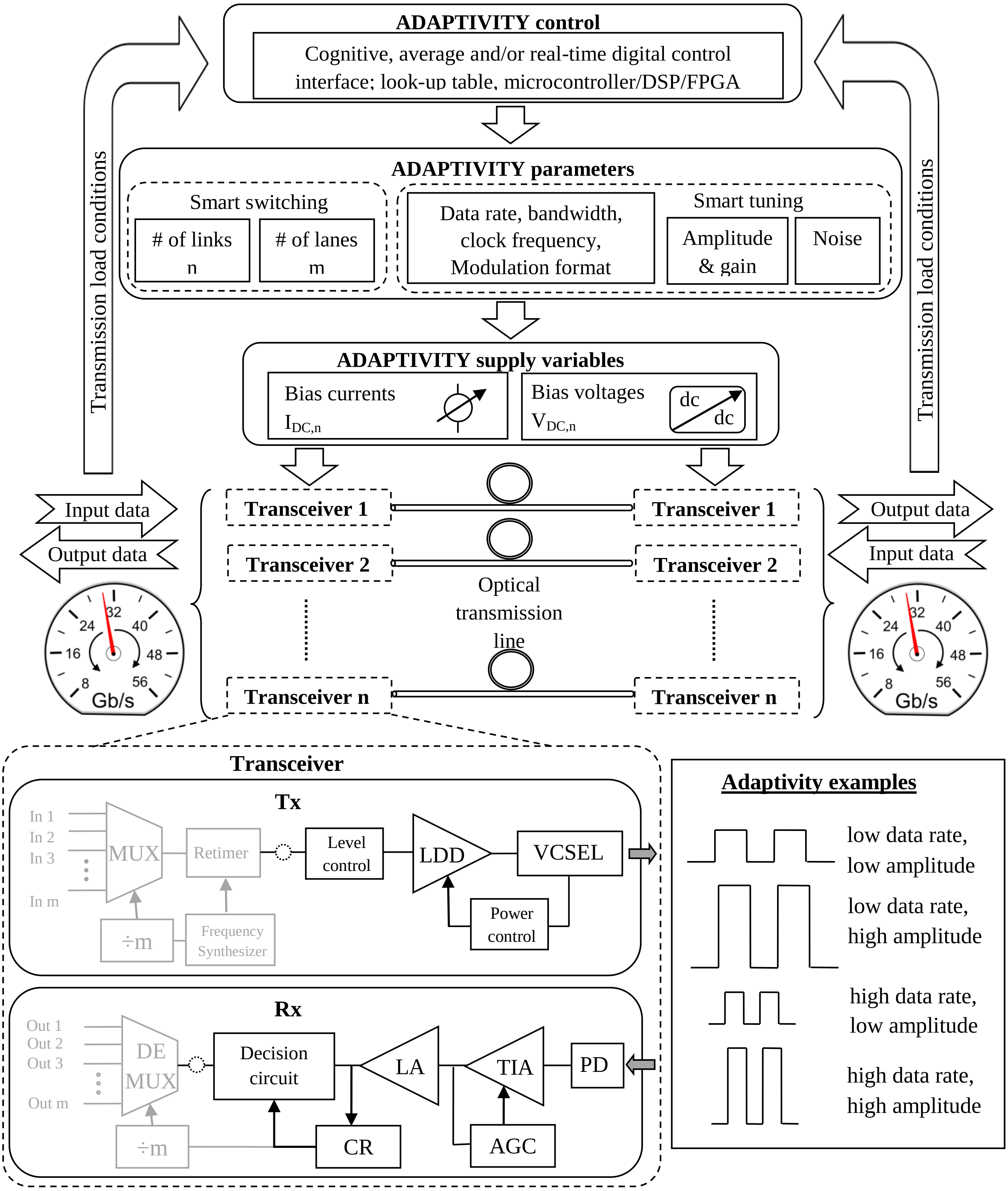

Figure 1: ADDAPT concept

1.2 *Project progress and results*

In the reported first project period from November 2013 to December 2014 the project has successfully been launched, the main system and component specifications and concepts have been defined and the design of the first components have been started. The following work has been performed and the following main results have been achieved:

In WP1 ‘Management’ the project has successfully started and contractual issues regarding the Grant and Consortium Agreements have been successfully finished. The pre-financing of the European Commission has been distributed and transferred to the partners. The project is established and appropriate communication between the partners is arranged. The kick-off, second and third project meetings were organized. Furthermore, webconferences with all or just few project partners are scheduled and performed on a regular basis. A webpage is created and updated periodically to inform the public and promote the project (deliverable D2.1). A secured data sharing system is created which can be used to exchange information and documents among the ADDAPT partners. During the reported project period, 10 project deliverables with reports have been prepared and submitted including the Interim Status Report D1.1 and the Periodic Project Report D1.2.

In WP2 ‘Market studies, exploitation and dissemination, standardization’ the performed work consists of: a) understanding the market and specification of ADDAPTive cables, b) how to exploit the results of the ADDAPT work, c) what standards are to be influenced as a result of insights learned developing the ADDAPT technology, and d) how to disseminate those results. It has been determined that the market for this technology is existing, the potential is huge (hundreds of thousands of cables), and is predominantly to be found in the HPC and data-center environments. The implementation of the ADDAPTive approaches can only be achieved if the relevant standardization bodies adapt this technology in the various standards. All partners have clear ideas how exploitation and dissemination of the insights, know-how, capabilities and products can contribute to their objectives. To inform the public about the project, its objectives and results has been launched e.g. via press releases and first publication. Detailed information can be found on the ADDAPT webpage. The results are summarized in the deliverable reports D2.2, D2.3 and D2.4.

In WP3 ‘Network analysis, system design and verification platform’ an intensive study on the system concept has been proceeded on the basis of the market and application review as well as on technical conditions like the optical link budget. Most suitable standards for the ADDAPT transceiver module seem to be Infiniband and Ethernet. The system concept consists of a 4 channel transceiver with novel master and slaves architecture as shown in Figure 2. Each channel is designed for data rates of up to 56 Gb/s incorporating equalization techniques, with high energy efficiency of maximum 4 pJ/bit (including additional digital control and clocking circuitry) and equipped with adaptive rapid on/off switching and smart speed tuning functionality between different data rates (56-28-14-7 Gb/s) for additional power savings. For the bandwidth and power adaptivity of the transceiver a rapid switch on/off approach by detecting IDLE packets of the protocol (e.g. Infiniband) has been developed. Furthermore, an intensive, long-term network analysis over one year has been performed which determined a link utilization below 50 %, a highly varying data load and static link performance which underlines the potential of the ADDAPT approach for huge power savings. Simulations of the expected power for an ADDAPTive link consisting 4 optical channels (see Figure 3) revealed that for low link utilization power savings up to 50 % are possible by combining rapid on/off with a dynamic speed and power consumption adaptation. The results of WP3 are summarized in deliverable report D3.1.

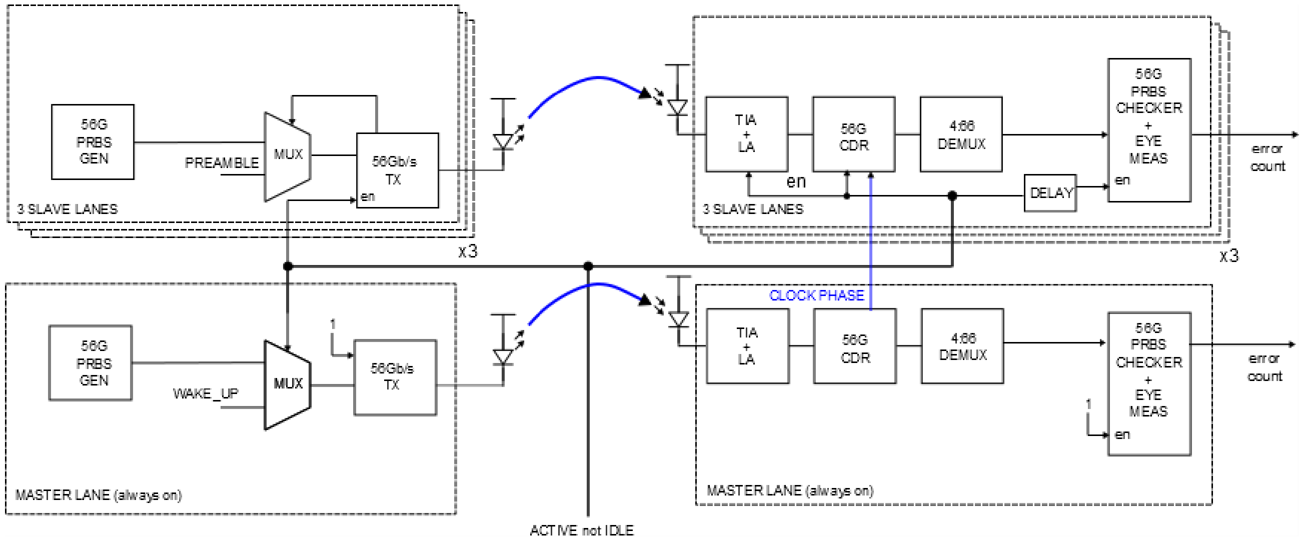

Figure 2: ADDAPT system architecture

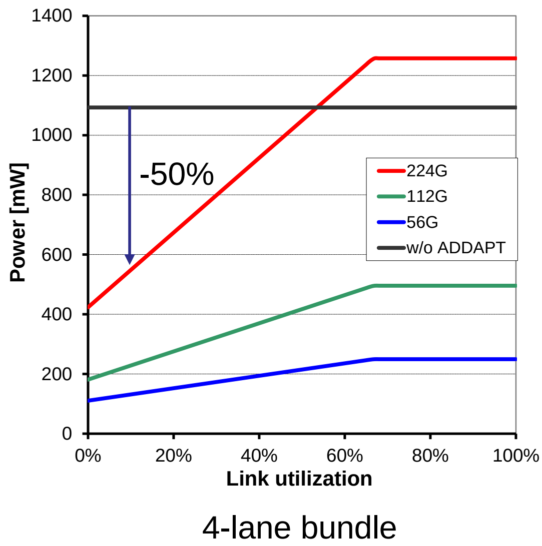

Figure 3: Simulated power consumption in ADDAPT link

In WP4 ‘Adaptive optical components’ first concepts and specifications for optical components were stated and discussed which are summarized in the deliverable report D4.1. A close collaboration between the development of optical components and analog electronics is required which include equalizing functions to achieve an adaptive optical connection up to 56 Gb/s. Current optical chips are provided to the partners which derived new circuit models for the design of the analog electronics. Discussions about near field coupling (NFC) concepts of the optical components and close collaboration of VIS and IBM on this topic were started. A first design for a near field VCSEL is developed, as shown in Figure 4 and Figure 5, and first epitaxy wafer are manufactured based on that design. To measure the optical components suitable testbeds have been developed and evaluated.

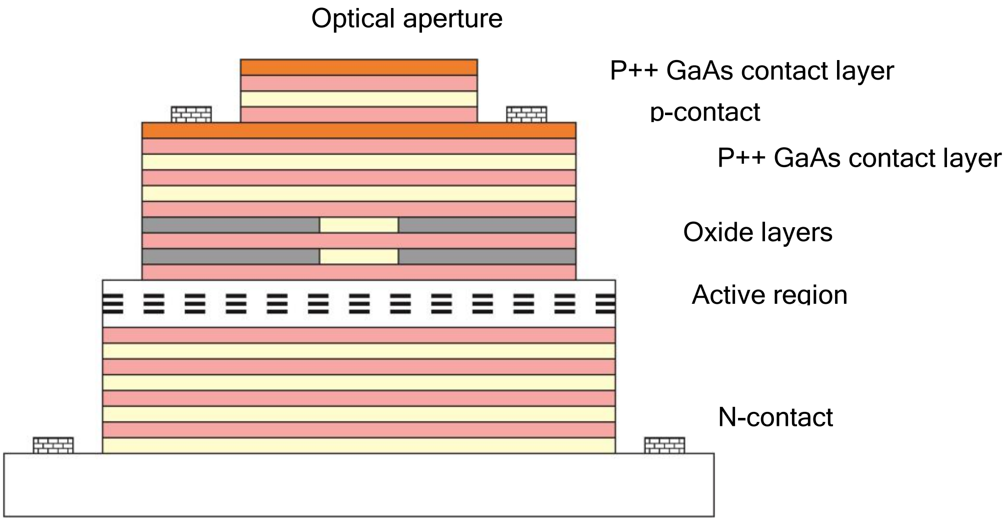

Figure 4: Concept of VCSEL for near field coupling

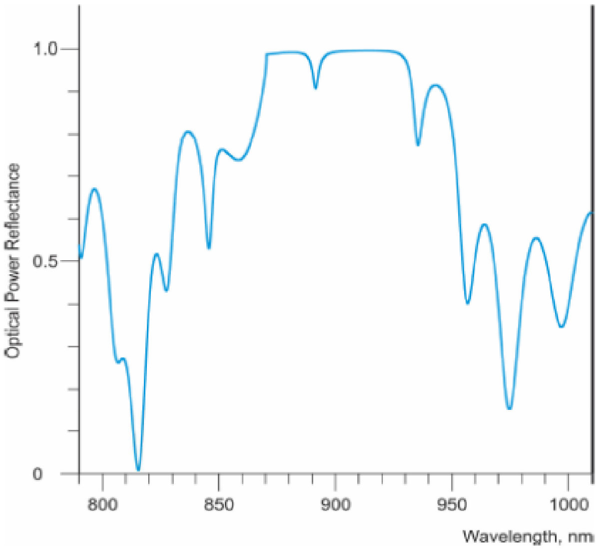

Figure 5: Simulated reflectance

In WP5 'Adaptive IC design' the initial concepts and specifications for the adaptive transceiver ICs have been derived from different requirements which include potential markets and applications, the system concept, the optical components and the assembling/packaging techniques which have been summarized in deliverable report D5.1. A high data rate of up to 56 Gb/s and a high overall energy efficiency of maximum 2.5 pJ/bit is targeted and subject to be optimized for the LDD, TIA/LA and CDR. Adaptivity in terms of on/off switching and bandwidth/power scaling is implemented into the circuits. The main challenge for the LDD is to enable high data rates together with lower bandwidth VCSEL using equalization technique. Therefore, a VCSEL model was development in cooperation with WP4. The TIA at the receiver side has to deal with very weak input currents and should have a high sensitivity and low noise. To provide this a new configuration of low bandwidth TIA, bandwidth compensating DFE and regulating VGA is implemented. The key functionality of the CDR is the rapid on/off switching below 20 ns. The realization of the different IC concepts and the design is in an advanced state. A first tape-out and fabrication of the chips is planned in April 2015 containing a one lane transceiver sub-system (see Figure 6) for the verification of the high speed, low power consumption and rapid on/off switching functionality.

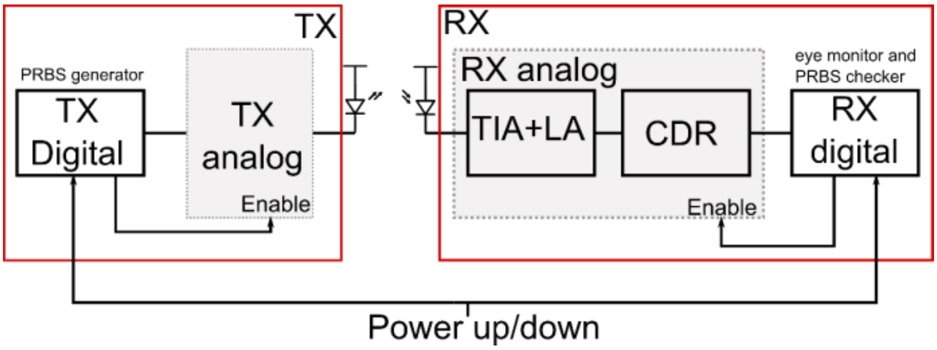

Figure 6: High level block diagram of adaptive optical link path for the first chip fabrication

In WP6 ‘PCB and packaging’ the electrical interface has been concluded to be based on coaxial connectors in early stage of the project, as shown in Figure 7. Other options to utilize any pluggable interfaces for data transfer at 56 Gb/s at least for 4 lanes in parallel are under investigation. This should be met for the Infiniband HDR standard which has been under development. Solutions based on Mid-Board-Optics (MBO) should also be taken into account due to their short high speed electrical signal lines and suitability for very high data rates. The first HF design iteration focusing on the demonstrator board/packaging concept without active components has been finished. The simulation results (see Figure 9) show the total insertion loss of demonstrator between ports of IC pad to coaxial connector interface within range of 2.5 dB to 3.0 dB. Based on this, first boards of hybrid solution have been designed in order to verify and measure their real performance (see Figure 8). These boards are expected to be manufactured early 2015 and then will be measured in cooperation with WUT and TUD. Thermal simulations of the transceiver components revealed that due to the low power consumption the maximum temperature change is just ~ 25 K and therefore thermal inter-component influence is marginal. The optical link specification has been under definition in terms of optical budget and all related parameters. It revealed that optical budget has a low margin. Thus improvements of the optical coupling have to be achieved. The packaging concept and interface specifications have been summarized in deliverable report D6.1.

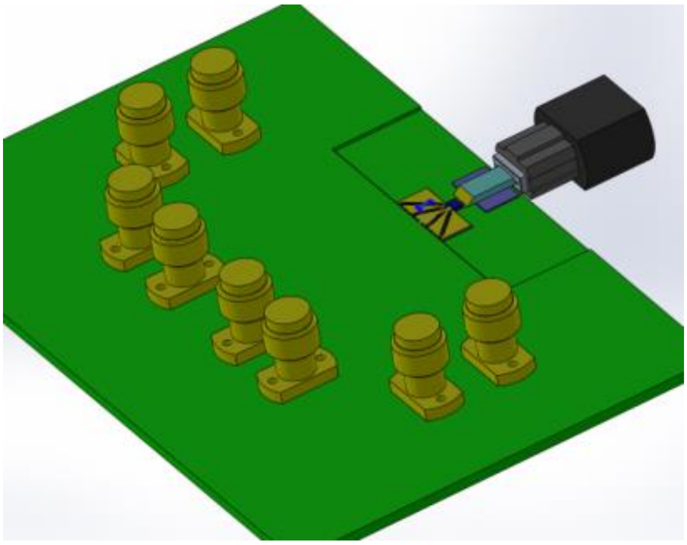

Figure 7: Packaging concept of the system demonstrator

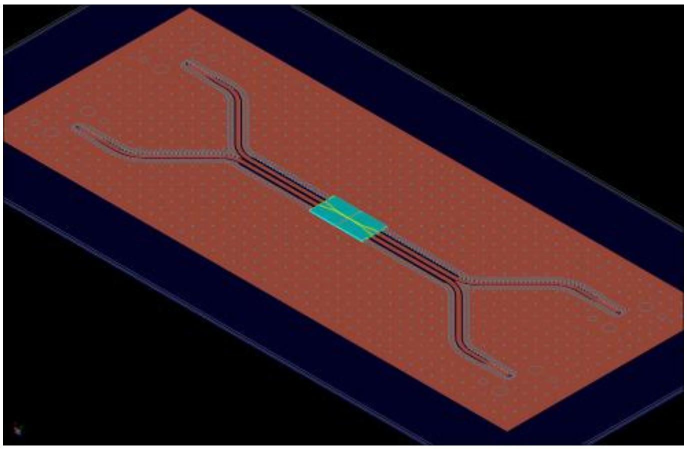

Figure 8: Test board hybrid concept

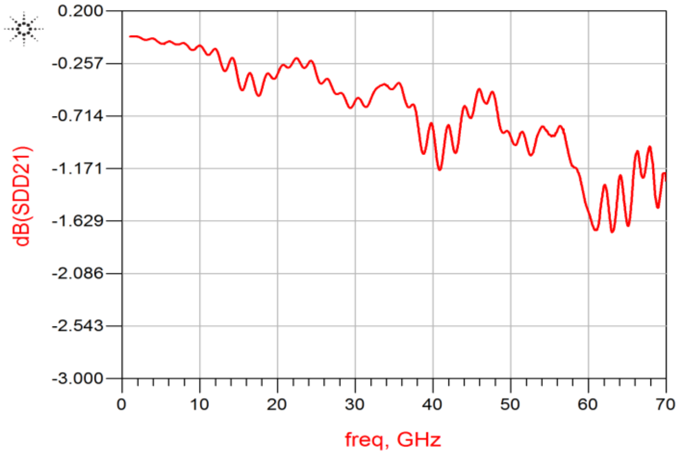

Figure 9: Test board insertion loss excluding coax connectors

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Acronyms

Acronym	Definition
AOC	Active optical cable
CDR	Clock data recovery
HPC	High performance computing
LA	Limiting amplifier
LDD	Laserdiode driver
MBO	Mid-Board-Optics
NFC	Near field coupling
TIA	Transimpedance amplifier