ADDAPT

Adaptive Data and Power Aware Transceivers for Optical Communications

Deliverable Report D 2.3

Plans for dissemination and exploitation of results

Small or medium scale focused research project (STREP)
ICT-2013.3.2 Photonics

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Confirmation

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

Table of contents

List of Figures

List of Tables

Version Management

Version	Description	Author	Released
V0.1	First setup	P. van Leeuwen	01-July-14
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Table 1 List of Revisions

1 Executive Summary

[ADDAPT] is a technology project, co-funded by the European Commission within the Seventh Framework Programme. ADDAPT aims to adapt the cable speed in the data-center to the offered dataload, by interpreting the datastream and detect the idle data in it.

This report addresses the first ideas for dissemination ("how the spread the word"), and how to exploit (use the results in the environmental system of the partner's organisation) the findings, the know-how and the technologies developed in the framework of this project.

Each partner addresses this from his own context and expectations of the project.

Chapter 2 briefly recaps the market for the ADDAPT technology from the [D2.2] report.

Chapter 3 presents the plan for dissemination, as well as some dissemination activities already performed. This work is related to task T2.4, "Dissemination". Dissemination is about the ways and methods that will be used to "spread the word". Examples are websites, seminars, publications and the like.

Chapter 4 shows the plan for use of the project results and relates to the activities within task T2.2 "Exploitation". Within this task relevant commercial exploitation plans will be defined by the project partners in order to obtain an optimal overview of the market potential of the new optical components in electronic and photonic applications. In the various intermediate reports (D2.3, D2.4 and D2.5), and with progressive insights, several scenarios will be explored and analyzed.

Roadmaps of the new applications will be elaborated and maintained during the project and beyond.

More specifically the following activities have been or will be performed in this task:

- Making an overview of exploitable results expected from the project;
- Study of the market potential of these exploitable results;
- Define application roadmaps for these results.

In each reporting period this plan will be updated, resulting in the final plan for use and dissemination by the end of the project. This final plan will be presented in D2.6, per April 2017.

2 Market

This chapter is an extract of the report D2.2, market study, evaluation of application and product specification. It touches briefly upon the application markets for ADDAPT technology, addresses briefly the issue of network protocols, and then focusses on volumes for the various markets.

2.1 *Applications*

The envisaged market being addressed by ADDAPT is two-fold:

High-capacity inter-switching (as in data-centers)

- intra-rack communication
- rack-to-rack communication
- co-location communication
- communication to storage devices.

Supercomputers (HPC)

- inter-processor communication
- communication to storage devices

Both markets (data-centers and supercomputers) will be elucidated in a separate chapter. This chapter will focus on volumes and requirements with respect to ADDAPT type of products for the applications and protocols described below.

2.2 *Requirements for ADDAPT technology in data-centers*

The envisaged protocols where ADDAPT might be relevant are:

- Ethernet, including various flavours of Ethernet, such as:
    - Fibre Channel over Ethernet
    - Data Center Bridging
    - iWarp over Ethernet
    - RoCE (RDMA over Converged Ethernet),

    These versions are targeting the data-center space.

    On top of that, various interfaces are developed to enable Ethernet over SDH:

    - Packet over SDH (POS)
    - Ethernet over SDH (EOS)
    - 10 GbE WAN interface

    That are targeting the telecommunication between data-centers.
- Fibre Channel
- Infiniband

- SMP (a proprietary IBM protocol used for low latency traffic between cores)
- PCIexpress
- SCSI. SCSI is probably less relevant for ADDAPT, and has evaluated in the protocols below:
    - SATA, (Serial ATA, bus that connects host bus adapters to mass storage devices, SATA goes presently until SATA revision 3.2 - 16 Gbps)
    - SAS, (**Serial Attached SCSI** is a point-to-point serial protocol that moves data to and from computer storage devices such as hard drives and tape drives. SAS replaces the older Parallel SCSI)

2.3 *Market Volume ADDAPT cables for data-centers*

2.3.1 Ethernet inside the data-center

Please refer to the Projected Timeline Showing Mainstream Adoption of 40 Gigabit Ethernet-Capable Switching Equipment [[WP40GbE]] in Delivery Report D2.2 [D2.2], showing the expected volume in 40GbEe ports. This is the most important application for ADDAPT cables, because more uniform than HPC cables (see above).

protocol	market
10 GbE	It can also be noted that the market for 10 Gbps Ethernet Server Ports is really huge until 2016 (like 15 mill ports/year for server only) afterwards fast declining. It shall be investigated if 10 Gbps is still an option for ADDAPT technology. If we can make it cheap enough, due to the volume, the potential power savings are huge.
40 GbE	This diagram suggests a potential market of 5 mill ports in 2016. The market will start to pick up per 2015.
100 GbE	The market for 100 Gbps will definitely exist. Volume is expected to pick up per 2018 with a volume of several 100ds of thousands.

Table 2 Potential market for Ethernet ADDAPT cables

In other words, there is a potential market of approximately 6 million ADDAPT cables in the Ethernet world.

2.3.2 Communication between data-centers (co-locations)

For reasons of Point-of-Presence, security and backup, data-centers may want to communicate their data to co-locations. There are two basic ways the market is implementing this:

- Using a dark fibre, either self-installed and owned, or rented from a dark-fibre company. This fibre is connected to own network equipment, running a network protocol of own choice, such

as Ethernet or FibreChannel. Expected are high speed protocols such as 100 GbE or 400 GbE. Distances are between 200 m – 2 km. It has to be investigated how ADDAPT technology is applicable in this market.

- Connecting to a telecom standard interface, provided by a telecom provider, such as ATM or SDH (protocol agnostic) via the POS technology and some other Ethernet technologies. We expect there is a niche market for ADDAPT technology in the cables interfacing between the Ethernet router, and the SDH public interface.

3 Dissemination

Below the various partners describe how they plan to do the dissemination of the insights and know how gained as a result of the participation to the ADDAPT project.

3.1 *Argotech (AT)*

3.1.1 Organisation

Argotech a.s. is a company with corporate office located in Náchod, Czech Republic and with production site located in Trutnov, Czech Republic. The company is an EMS provider working in CM, ODM and OEM contractual models. Argotech is specialized for high precision micro-packaging on wafer scale and discrete component level. Delivery amount of products from single samples up to 1 - 10 million pcs per year shows high level of flexibility. On top of that Argotech provides also R&D, engineering and consultant services.

3.1.2 Objective of organization

Packaging of microelectronic and optoelectronic components is a key competence of Argotech with a high level of experience in this field. People at Argotech constitute a highly skilled team with experience in optoelectronic and fiber optic industry more than 15 years. The key strength of Argotech is a unique technology chain from wafer level packaging via TO-CAN packaging to optical subassemblies or customized applications. The R&D services mostly focus in customized optoelectronic units and very high speed optoelectronic components with capability to provide the final assembly on site. Also the capability of design of special technologies used for customized products is a next level of R&D services. All assembly and R&D activities have been done in Europe, Czech Republic.

3.1.3 ADDAPT Technology

(a) Parallel active alignment NFC – Argotech will setup the technology capable to do the near field coupling for parallel solutions. Argotech has a lot of experience in passive and especially active alignment processes for both worlds SMF and MMF with technology accuracies down to 200 nm together with laser welding fixation in order to achieve best connection of aligned parts in terms of long term stability and environment temperature gradient, die bonding, and wire bonding.

(b) Packaging and assembly – enhancement, verification and improvement of packaging and assembly techniques up to 56 Gbps

(c) RF Packaging design – prove the package environment design capabilities beyond 60 Gbps

3.1.4 Dissemination plan:

Exhibitions and customer chain

3.2 *Compound Semiconductor Technologies (CSTG)*

3.2.1 Organization

CSTG is a 'pure play' semiconductor foundry specialising in the design, development, and manufacture of discrete and integrated III-V opto-electronic devices, based in Glasgow, UK. Since 1999, CSTG has provided specialist foundry services to clients in the Telecommunications, Defence, Medical and Instrumentation markets. We offer full product support from design to manufacturing, levered off a comprehensive library of qualified fabrication processes and a suite of high performance device platforms. CSTG is an SME with ~30 employees servicing both fabless and vertically integrated customers in UK, US, Europe and Japan, and is recognised as a flagship project for the UK opto-electronics industry.

3.2.2 Objective of organization

Our business model is focussed on servicing optical component or sub-system vendors in the Telecommunication, Defence, Medical and Instrumentation markets. We aim to offer:

- Development capability to fabless optical component ventures
- Manufacturing capacity to fabless optical component ventures
- Ring-fenced new product development for established optical component suppliers
- Second source supply of wafers or chips to vertically integrated optical component vendors

CSTG also welcome enquiries from entrepreneurs and universities at an early stage of in their company development. The company has a well-established track record of helping emerging companies exploit their ideas and cost effectively utilise their investment finance.

3.2.3 ADDAPT Technology

CSTG has already established itself as a major European supplier of InP laser sources for GPON/FTTX applications in partnership with several European fabless component vendors over the last 10 years. In excess of 10 Million laser diodes have been shipped in this market since 2010. Therefore, CSTG sees excellent market opportunities for the design, fabrication and sale of high speed VCSELs and Photodiodes in collaboration with VIS. Although the majority of devices recently supplied are edge emitters, the company initiated development of a VCSEL chip fabrication platform in 2012. The ADDAPT project will give CSTG the opportunity to converge design and production skills learnt in the high-speed edge emitter markets and apply them to existing VCSEL device concepts to produce novel high-speed device technology targeted at the optical data communications.

3.2.4 Dissemination plan:

Product process and device know-how will be commercially exploited via several routes:

- Manufacture of high speed VCSEL and Photodiodes chip scale products in partnership with VI systems;
- Manufacture of third party high speed optical components via our existing foundry business model;
- Sale of single or multiple chip fabrication processes via our existing foundry business model.

News and novel innovation that are not commercially sensitive will be communicated in press releases and presented at international exhibitions and trade show, e.g.

- Conference on Lasers and Electro-Optics (CLEO)
- Optical Fiber Communication Conference and Exposition (OFC)
- Photonics West
- European Conference on Optical Communications (ECOC)

Together with VIS, CSTG will publish on the development and design of the high-speed adaptive VCSELs and PDs. For novel process techniques and fabrication methods, either Trade Secret or formal patent protection will be used where appropriate.

3.3 *International Business Machines (IBM)*

3.3.1 Organization

IBM is a globally integrated technology and consulting company headquartered in Armonk, New York. With operations in more than 170 countries, IBM attracts and retains some of the world's most talented people to help solve problems and provide an edge for businesses, governments and non-profits.

3.3.2 Objective of organization

Innovation is at the core of IBM's strategy. The company develops and sells software and systems hardware and a broad range of infrastructure, cloud and consulting services. Today, IBM is focused on four growth initiatives - business analytics, cloud computing, growth markets and Smarter Planet. IBM Research is dedicated not only to fundamental research, but also to exploring and creating innovative industry and customer-oriented solutions based on several key areas including; future chip technology; smarter planet; nanotechnology; storage; supercomputing; security and privacy; risk and compliance as well as business optimization and transformation.

3.3.3 ADDAPT Technology

(a) SERDES IP for ASICs: IBM plans to develop SERDES IP blocks for 56 Gbps data transmission (e.g. using the OIF-56G-USR/VSR interface standard) for its ASICs customers.

(b) High-speed optical chip-to-chip communication: IBM aims to build future computing systems where the developed optical links are directly integrated on its P- and Z-series processor to satisfy the increasing demand for bandwidth. Increasing the data rate to 56 Gbps allows IBM to decrease the $/Gbps cost of optical I/Os. Minimizing the power consumption is necessary to stay within the thermal budget of the processor package.

(c) Low-power active optical cables: ADDAPT aims to develop a low-power active optical cable, which should be exchangeable to standard (e.g. Infiniband) active optical cables. These AOCs are intended to connect multiple processing elements within a data center network. Technology/ies provided/developed in the context of ADDAPT.

3.3.4 Dissemination plan:

IBM plans to publish the results of the technologies developed for ADDAPT at leading scientific conferences and journals, such as

- ISSCC, VLSI Symposium, CICC, ESSCIRC, JSSC: circuit and system design
- OFC, ECOC, OIC, CLEO, IPC, J. Lightwave Technol.: optical components and systems

3.4 *PrimeTel PLC (PTL)*

3.4.1 Organization

PrimeTel PLC (PTL) is the largest private telecommunications provider and information Technology Company in Cyprus having branches in each city inside the island and its main offices are located in Limassol. PrimeTel was established on the 18th of June 2003 and it currently employs 300 people making it one of the biggest companies in Cyprus. Moreover, the company maintains and operates its own high performance optical network and it has also acquired the license for a 3rd mobile network in Cyprus which enables it to evolve from a Mobile Virtual Network Operator (MVNO) to a Mobile Network Operator (MNO).

3.4.2 Objective of organization

Among the key services offered by PrimeTel are the following ones:

- High-Speed Internet
- Fixed and Mobile Telephony
- Digital Television

One of PrimeTel's main goals is to strengthen its position as the biggest telecommunication provider in Cyprus. This will be achieved by introducing novel services as well as by constantly upgrading the quality of service (QoS) it currently offers to its increasing number of customers which include corporate or residential customers, mobile telephony users as well as telecommunication carriers.

Furthermore, PrimeTel strives to consistently use the latest and cutting edge technologies in an effort to offer the best possible services and at the same time minimise its OPEX and CAPEX. By achieving this, the company will be able to attract additional strategic partners and form additional partnerships and business deals thus further increasing its revenue.

3.4.3 ADDAPT Technology

ADDAPT aims to address the high power consumption that takes place in today's data and communication networks due to links being statically driven at maximum power irrespective of data load. The project will introduce adaptivity to optical networks by developing a high speed electro optical transceiver module. This will facilitate the adjustment to varying data loads as well as performance requirements and thus reduce the power consumption and electrical costs to the degree that is actually needed.

PrimeTel will benefit from the technology developed within the frames of ADDAPT by minimising the energy and power consumption costs inside its data centre and core network which will lead to lowering the company's OPEX and CAPEX. In addition, such a technology will lead to better utilisation of the interfaces on switches and optical transports based on the throughput inside the data centre. PrimeTel will provide results of an extensive network analysis of its high speed network in terms of traffic variation over time and users' bandwidth requirements. These results will offer valuable information and insights for the procedures that will involve the design and implementation of the ADDAPT components that relate to adaptivity. In addition, PrimeTel will work on the development of a verification platform as well as its testing and benchmarking.

3.4.4 Dissemination plan:

PrimeTel's dissemination plans involve creating awareness and achieving the wide publicity of the project's results. On an international level the company will work closely together with the consortium partners to present ADDAPT's results in high calibre scientific conferences and journals as well as participating in related workshops and international fora.

In terms of domestic dissemination in Cyprus, PrimeTel will include in its website a section that will describe the project, its results and highlight the impact and benefits it will provide to the company. In addition, PrimeTel will include similar information in the company's monthly magazine 'PrimeTime magazine' and use additional printed mediums such as leaflets, posters etc.

In addition, PrimeTel will aim to promote ADDAPT's results among Cyprus' research community. This will be accomplished by the organization of presentations and talks in Cyprus Universities and Colleges. Moreover, PrimeTel will work towards its participation in related domestic events in order to present the project and its results.

Another facet of PrimeTel's dissemination plan is to work in close collaboration with the Research Promotion Foundation of Cyprus and the KIOS Research Center for Intelligent Systems & networks in order to achieve a fruitful cooperation and knowledge exchange with other projects as well as companies or institutes that perform closely related research to ADDAPT. By achieving this aim the project results will also be introduced into industry

3.5 *TE connectivity (TE)*

3.5.1 Organization

TE Connectivity is a $13 billion world leader in connectivity. The company designs and manufactures products at the heart of electronic connections for the world's leading industries including automotive, energy and industrial, broadband communications, consumer devices, healthcare, and aerospace and defence. TE is a company with 90,000 Employees including 7,000 Engineers, 21 Global Design Centers and $675 Million RD&E Investment, 18,000+ Patents Issued or Pending.

Headquarters based in Schaffhausen, Switzerland. Website www.te.com and operational HQ in TE Berwyn, PA, USA.

3.5.2 Objective of organization

TE wants to be the company customers turn to first to meet their connectivity needs. TE is in the business of Connecting and Protecting the Flow of Power, Data and Signal, and is active in the markets of Industrial, Transportation, Consumer and Networks.

3.5.3 ADDAPT Technology

TE's aim is to master the integration technology, and the application domain in which the adaptive cable technology will be relevant. As indicated in the market evaluation, applications can be expected in the datacentres, the HPC, and high speed networking. TE is already an OEM in these domains, and we want to be present here with adaptive cables, making use of the components and subsystems developed by partners in this project.

3.5.4 Dissemination plan:

- Presentations in relevant conferences and exhibitions (datacentre operations, data communication, photonics)
- We are having regular contacts with manufacturers such as networking equipment providers and computer manufacturers, where design-ins with this technology will be relevant. The application of adaptive technology will be discussed to gain customer insights

- We are having regular contacts with datacentre operators, where active cables with adaptive technology will be relevant. The application of adaptive cables will be discussed to gain customer insights
- For marketing purposes TE will target press releases regarding selected achievements made in ADDAPT
- Training of the TE sales force once the development of this cable passes a certain milestone

3.6 *Technische Universität Dresden (TUD)*

3.6.1 Organization

The Technische Universität Dresden (TUD) is a technical university in Dresden the capital of Saxony, Germany. Founded in 1828, TUD is one of eleven German universities that were identified as an "excellence university". TUD has about 37.000 students, 4.400 publicly funded staff members – among them over 500 professors – and approximately 3.500 externally funded staff members, and, thus, is the largest university in Saxony, today. TUD is a multi-discipline university, committed to a wide range of fields such as science, engineering, humanities and social sciences as well as medicine. In 2011 it was ranked no. 1 in electrical engineering among all universities in Germany.

The Chair for Circuit Design and Network Theory (CCN) was established in 2006 and is placed on the main campus of TUD in Barkhausen-building on Helmholtzstreet 18. CCN incorporates the experience of around 40 employees including two professors, nine post-docs (working as group leaders, project leaders and researcher), 25 research associates (working toward Ph.D. degree), three technicians and one secretary.

For more information please see: http://tu-dresden.de/, http://ccn.et.tu-dresden.de/.

3.6.2 Objective of organization

TUD is one of the strongest research and education oriented university among Germany. Its aim is to keep and improve this leading position in future. One basis for this is the intensive exchange and cooperation between the different sciences with industry and society. Within Silicon Saxony which is an area with a deep tradition and focus in microelectronics, TUD is a big partner for companies and research institutes. Successes in research results and the transfer of basic knowledge are inherent parts of education, studies, research and advanced training at TUD.

The CCN is devoted to the design of high-speed integrated circuits using advanced circuit techniques and technologies such as CMOS, BiCMOS and III/IV as well as advanced "Beyond Moore" technologies like carbon nano tubes, nanowires and organic and polymer devices. The key activities are analog and mixed signal circuit design. Moreover, the design of complete systems involving the design of PCBs and hybrid solutions, digital signal processing and algorithms for FPGAs is covered by the chair activities. Applications involve low frequency and RF systems and wireless communications up to 220 GHz as well as optical communications up to 80 Gbps, high resolution

local positioning, adaptive power saving circuits with intelligent dynamic power control and wake-up functionalities and energy harvesting circuits. In addition, the chair has experience in the development and optimization of high-end audio systems. Six lectures and one practical training course in the area of analogue circuit design and network theory are offered by the chair where the experience, insights and results of research projects are transferred. Next to the research activities, the education, training and strengthening of future leading researcher is one goal of the CCN's work.

3.6.3 ADDAPT Technology

In the context of ADDAPT the CCN of TUD develops, designs and tests ICs which are required for the operation of electro-optical transceiver module. The design focus is especially on laserdiode drivers (LDD) and transimpedance-/limiting (TIA/LA) amplifiers. For the design the following goals and strategies are followed:

- Development of ICs that can be adapted regarding performance versus power consumption trade-off. Up to now, circuits are mainly optimized for fixed dc operation leading to fixed bitrates, modulation formats and high power consumption although the network link load can also show much lower data rates.
- Bandwidth peaking techniques such as inductive series peaking, inductive load peaking, transformer coupled peaking and emitter generation with parallel RC elements to further relax the speed to power consumption trade-off.
- To match the needs for future systems and to enable a relatively low number of parallel links, up to 56 Gbps per link path is targeted mapping corresponding requirements for the circuits.
- The power consumption is reduced using aggressively scaled CMOS (32 nm or more advanced).

3.6.4 Dissemination plan:

CCN of TUD plans different dissemination actions. Some of them are already started or even accomplished. As coordinator TUD will encourage and manage joint dissemination activities among the partners. The dissemination activities include:

- Implementation and updating of a public web page on a ".EU" domain:
  The webpage has already been created (see picture of homepage below) and launched on the domain http://www.addapt-fp7.eu. This webpage opens the research results and news about the project advancement to a broad public audience. It will be updated regularly.

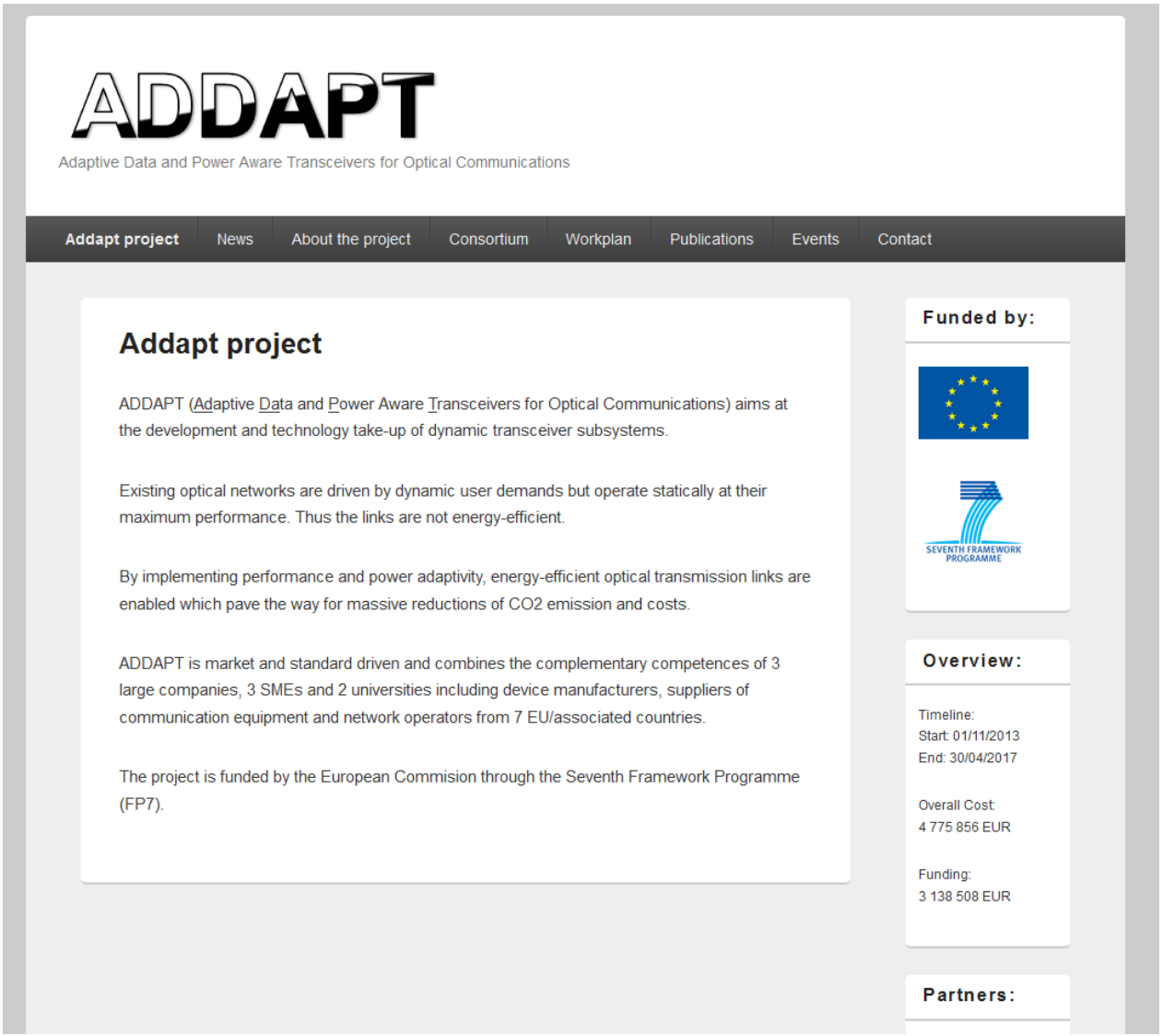

Figure 1 ADDAPT homepage

- Organization and placing of press releases or public materials (e.g. leaflets, posters etc.) in media or on technical events/conferences/exhibitions:
  At the beginning of the project TUD has already placed press releases for the launch of ADDAPT on TUD's online media and in the university journal as well as in local press. Some examples are listed in the following:

  - Announcement on Faculty of Electrical and Computer Engineering webpage (03. February 2014, in English www.et.tu-dresden.de/etit/index.php?id=765&L=1 and German http://www.et.tu-dresden.de/etit/index.php?id=765&L=0).
  - Announcement on TUD news webpage (31. January 2014) http://tu-dresden.de/en/news/addapt/newsarticle_view.
  - Article in local newspaper Dresdner Neueste Nachrichten (DNN online, 30. January 2014) http://www.dnn-online.de/web/dnn/nachrichten/detail/-/specific/4-8-Millionen-Euro-Foerdergeld-TU-daempft-bald-Stromhunger-der-Datennetze-895360478.
  - Article in Dresden university journal 02/2014 (04. February 2014, http://tu-dresden.de/die_tu_dresden/rektoratskollegium/stk/sg57/uj/bilder/pdf2014/UJ02-14.pdf).
  - A project fact sheet as well as a project presentation has been prepared for public audience. Both can be disseminated on various events and can also be found on the ADDAPT webpage.
  - Leaflets, posters etc. for disseminate on technical events/conferences/exhibitions will be produced after first practical result have been achieved within ADDAPT. Further press releases are planed when the progress of ADDAPT affords significant results.
- Organization and authoring of (joint) scientific publications in leading journals and at renowned conferences:
  Publications of project results are planed e.g. in IET Journal on Circuits, Devices and Systems, IEEE Journal on Solid-State Circuits, IEEE Journal on Circuits and Systems, IEEE Transactions on Microwave Theory and Techniques and at European Microwave Conference, IEEE International Solid-State Circuits Conference, IEEE Global Communication Conference, IEEE International Microwave Symposium, OFC, CLEO, ECOC. The focus of the contributions will be in the area energy-efficient high-speed circuit design for optical transceiver.
- Organization of student colloquiums and exchanges to allow optimum dissemination of results from educational perspective into practice:
  The experience, insights and results of the ADDAPT project will be integrated into lectures given at TUD. Several students will be involved in ADDAPT, e.g. by means of PhD and master theses. Subsequently, after graduation these students will transfer their experience into companies. Two students which will work in ADDAPT toward the PhD degree were already for a research visit at the partner IBM Zurich during June/July 2014. During their stay they learned to handle the challenging highly scaled CMOS technology which will be used in ADDAPT.
- Promoting the project (results) via research centers/clusters:
  TUD CCN is involved in the research clusters cfaed, HAEC and CoolSilicon where project information (poster, fact sheet, leaflets, overview presentation etc.) can be disseminated and presented to a broad international technical oriented audience containing students, researchers, engineers and company members.
- Organization of a workshop in the area for efficient dissemination of results and knowledge exchange with external experts or other projects (planed during or towards the end of the project)
- Organization of customer events for promoting the project results and approaches (encouraged for the industry partners)

- Organizing the participation of exhibition with ADDAPT project booths during local conferences and workshops, e.g. on IEEE International Semiconductor Conference Dresden Grenoble which takes place in Dresden every two years.
- Organization of information and knowledge transfer into scientific and technical expertise forums
- Production of "Dissemination Kit" including project results (at the end of the project)

3.7 *VI Systems (VIS)*

3.7.1 Organisation

VI Systems GmbH, based in Berlin, Germany, is a fabless developer and manufacturer of components for optical communication. The company designs and manufactures vertical cavity surface laser (VCSEL), photo detectors, integrated circuits and ultrahigh-speed packages for short reach optical interconnects. VI Systems staff consists of 7 highly experienced experts most of them holding PhD degrees. The company holds 9 patents. Website: www.v-i-systems.com

3.7.2 Objective of organization

VI Systems is a technology leader which provides the most advanced components to customers which assembly short reach optical communication links.

3.7.3 ADDAPT Technology

VI systems focus on the design of VCSELs and PDs. Key target is the power adaptivity which will be achieved by adjusting the modulation currents and modulation voltages to yield adjustable data rates from 8 up to 56 Gbps. The novel near field coupling will be investigated by IBM and applied to VCSEL and PD devices**.**

3.7.4 Dissemination plan:

- Presentations in dedicated conferences and exhibitions (Photonics West, OFC, ECOC, etc.)
- Introduction of the concept to international customers which currently implementing VI Systems short reach optical interconnect products.
- Press releases about achievements related to ADDAPT.

3.8 *Warsaw University of Technology (WUT)*

3.8.1 Organization

WUT is a leading technical university in Poland covering 28 fields of study. Founded in 1826, WUT has more than 36,000 students, more than 5,000 employees and more than 350 professors. The involved Optical Communications Group (OCG) of Institute of Telecommunications focuses on application of photonic technology in telecommunications and has considerable knowledge and experience in development of optical communication systems. Details see: http://ocg.tele.pw.edu.pl

3.8.2 Objective of organization

Core competences of the WUT OCG are the optical communication system design and realization as well as a high-speed laboratory test-bed up to 56 Gbps (including e.g. a 56 Gbps BER tester). The key research areas of WUT OCG include a high-speed transmission and MMF-based short-range transmission.

3.8.3 ADDAPT Technology

OCG will contribute to the adaptable optical interconnect system development taking into account the possessed experience in the optical communications. The performance enhancement including the higher order modulation formats and the expansion of the application area of the developed electro-optical subsystems will be studied. Moreover WUT OCG will be responsible for testing the developed devices and subsystems with the data rates up to 56 Gbps for further developments. Appropriate test-bed will be developed and the measurements will be conducted.

3.8.4 Dissemination plan:

By participating in the ADDAPT project, WUT will expand knowledge and experience on the optical interconnects and electro-optical components like VCSELs. WUT will disseminate the results obtained in the framework of the ADDAPT projects in the form of the (joined) publications in journals and conferences.

The considered journals include:

- IEEE Photonics Technology Letters
- IEEE Journal of Lightwave of Technology
- IEEE Journal of Quantum Electronics
- Optical Fiber Technology
- Microwave and Optical Technology Letters
- And other journals covering the area of electro-optical components and communication.

The considered conferences include:

- European Conference on Optical Communication (ECOC)
- Optical Fibre Communication Conference and Exposition (OFC)
- SPIE Photonics West
- And other conferences covering area of electro-optical communication and components.

The contribution to the conference workshops concerning the ADDAPT project outcome will be also provided. Further, the results will be disseminated in the form B.Sc, M.Sc and Ph.D. theses. The newly acquired knowledge and experience will be used to update the material of the courses given at WUT.

To address the general audience with the ADDAPT project outcome, the press releases for the local media (newspapers and web services) will be prepared and released.

4 Exploitation

Company	Product, Service, Method, algorithm, etc.
AT	NFL, NFD components, hybrid components, packaging, assembly
CSTG	Manufacturing, design improvements for VCSEL and PD
IBM	System know-how, design rules, modulation formats, adaptivity control, ~algorithms, ~protocol, waveguides, CDR, transmit and receive ICs design.
TE	Integrated adaptive cable
TUD	Broadband and adaptive ICs design (TIA, LA, LDD circuits), know-how in modelling, design, simulation and measurement
PTL	Network analysis, lower exploitation for data-centers, dynamic behaviour,
VIS	Low power VCSEL, PD 7...56 Gbps
WUT	Test & verification know-how & methods

The chapter describes how the various partners will do exploit (make use of) the various methods, techniques and products developed in the context of ADDAPT.

4.1 *Argotech (AT)*

4.1.1 Specific ADDAPT Know-how to be exploited

Argotech aims to prove the capability of HF design of packages and units hosting very high speed optical chips and ICs.

Enlarge the capabilities of parallel alignment on internally designed and controlled technology together with NFC capability. Focus on alignment techniques and algorithms.

By contributing to ADDAPT, we expect particularly to improve our HF board design and packaging capabilities

4.1.1 Application

HF board and package design

Parallel alignment & NFC

Packaging approach for HF components

4.1.2 Market and customers

Design capabilities, assembly techniques and technology can be utilized for HF packaging of customized units which are required by supercomputing, datacentres as well as telecommunications markets.

4.1.3 Enabling conditions

Besides customized solutions the volume deployment of these techniques must be preceded by standardization activities and creation of complete infrastructure for such high speed data transfer elements.

4.1.4 Exploitation

Argotech expects deploy its position as a European provider of Manufacturing Services and Design Services in the area of high speed packaging of microelectronics and optoelectronics components.

4.2 *Compound Semiconductor Technologies (CSTG)*

4.2.1 Specific ADDAPT Know-how to be exploited

High Speed VCSEL Device fabrication Route (DFR)

Work instruction and process design for the manufacture of >10-25G Vertical Cavity Surface Emitting Lasers (VCSELs) chips and arrays

4.2.2 Application

A generic, baseline manufacturing process for high speed VCSELs which will facilitate rapid prototyping of third party VCSEL epi-wafer designs with a proven device reliability profile.

4.2.3 Market and customers

Fabless Component Vendors in the Optical Communications sector.

4.2.4 Enabling conditions

Market development for primary exploitation will be facilitated in partnership with VI Systems who will offer packaged laser products to the market. As the market matures, subsequent higher performance, next generation products will be developed by CST-VI on a common technology roadmap.

4.2.5 Exploitation

In addition to a primary partnership with VIS, CST will also offer a generic chip manufacturing platform to third party OEM component vendors as an extension to existing foundry process for <10G VCSELs. This process will be tailored to individual device needs (e.g. specific epitaxial wafer

structures, device geometries, custom optoelectronic specifications etc.) for a wide range of custom applications.

4.3 *International Business Machines (IBM)*

4.3.1 Specific ADDAPT Know-how to be exploited

(a) SERDES IP for ASICs. IBM plans to develop SERDES IP blocks for 56 Gbps data transmission e.g. using the OIF-56G-USR/VSR interface standard) for its ASICs customers.

(b) High-speed optical chip-to-chip communication for IBM server processor and systems). IBM aims to build future computing systems where the developed optical links are directly integrated on its P- and Z-series processor to satisfy the increasing demand for bandwidth. Increasing the data rate to 56 Gbps allows IBM to decrease the $/Gbps cost of optical I/Os. Minimizing the power consumption is necessary to stay within the thermal budget of the processor package

(c) Low-power active optical cables for cloud data centre communication. ADDAPT aims to develop a low-power active optical cable, which should be exchangeable with standard (e.g. Infiniband) active optical cables. These AOCs are intended to connect multiple processing elements within a data center network.

4.3.2 Application

(a) ASICs for data processing, networking, long-haul communications, accelerators for computation etc. will benefit from the high-bandwidth low-power I/Os, which will be integrated as an ASIC IP block.

(b) Several types of computing systems will benefit from increasing the processor bandwidth, such as simultaneous multi-processing systems (SMPs) for big-data analytics, high-performance computing, and cloud data centers.

(c) Active optical cables with ADDAPT functionality will be used to connect cloud data centres and HPCs.

4.3.3 Market and customers

The market for ASICSs was 14 billion $ in 2013 (source: IC insight). The worldwide market for servers is predicted to be 54 billion$ in 2014 (source: IC insight). Customers include a large spectrum of small to big companies in all sectors.

4.3.4 Enabling conditions

One requirement is to have a stable supplier and second source for optical components such as VCSELs and PDs, optical subsystem, and active optical cable assemblies, being able to deliver the parts at large quantities and production level reliability.

4.3.5 Exploitation

IBM expects to remain the leading supplier for cloud data centers and high-end computing, which will result in a large number of produced P- and Z- processors and associated systems using several 10x millions of optical connections. The SERDES IP blocks will enable ASIC customers to develop there chips with unprecedented bandwidth requirements with IBM.

4.4 PrimeTel PLC (PTL)

4.4.1 Specific ADDAPT Know-how to be exploited

One of ADDAPT's main goals is to bring flexibility to optical networks. The traffic load in data networks varies over time and if the network components were able to adapt their performance to facilitate the actual network needs it would render the network's operation more flexible and efficient. Therefore, one of ADDAPT's key aims is to develop a high speed optical transceiver module that will be able to respond to such varying data loads. The transceiver module will be able to adjust parameters like bandwidth, modulation format and clock rate in order to address the actual network needs. Moreover, the transceiver module will support data transmission with data rates of up to 56 Gbpswhile the power consumption will be at the lowest possible level due to the transceiver's performance adaptation capabilities.

4.4.2 Application

As the biggest private telecommunications operator in Cyprus, PrimeTel owns and manages a high performance fibre optic network with points of presence in Cyprus, Greece, Russia and United Kingdom. It combines key components that that are critical for the provisioning of state-of-the-arts services: a high capacity backbone, a 24 hour Network Operations Centre and superior engineering. PrimeTel's network has been engineered from the ground up to accommodate the high availability demands of the most strict service level agreements.

ADDAPT aims to produce a transceiver module that will render current networks more flexible, since it will be able to adapt to the networks actual needs, and more efficient since it will reduce the power consumption and energy costs to the degree that is required. Hence, PrimeTel could apply the technology developed within ADDAPT to its high speed fibre optic network both inside the data centre and its backhaul network. More precisely, the high speed optical transceiver module could be utilized in the company's optical transports and switches.

4.4.3 Market and customers

Network operators such as PrimeTel could benefit from the technology developed in ADDAPT. Adopting the results produced inside the frames of the project and applying them onto their core network and data centres could yield in a decrease of their CAPEX and OPEX as well as facilitate the offering of better quality of service to their customers.

4.4.4 Exploitation

ADDAPT's results will enable PrimeTel to gain a deeper knowledge regarding future networks which will enable the further improvement of the services it offers. More precisely, ADDAPT's results will be exploited by PrimeTel in terms of utilizing the capabilities offered by the high speed optical transceiver module. The company will be able to upgrade its telecommunication and data services since the high speed optical transceiver module will allow high data rates of up to 56 Gbps. This will allow PrimeTel to attain strategic as well as economic gains, meet increasing customer needs in terms of increased bandwidth at lower prices, remain competitive and ultimately promote novel business opportunities.

Moreover, studies have shown that 2% of the world wide electrical costs and consumption can be attributed to Information and Communication technology (ICT). Furthermore, these costs have seen an increase of 10% during a five year span starting from 2007. In addition, it is expected that during the next years the power consumption and energy costs of core networks as well as data centres will increase [2], [3] and [4]. More precisely, this anticipated increase is mainly attributed to a growth of multimedia content distribution and it is also projected that in 2018 IP video traffic will constitute 79% of all consumer Internet traffic [1].

In this context, PrimeTel offers an IPTV service (PrimeTV) as part of its triple-play bundle and it constitutes one of its key business options. PrimeTel's IPTV service can benefit by the use of ADDAPT technology which can offer data rates of up to 56 Gbps. Similarly, HD video streaming is a service that requires high link bandwidth with high reliability. By employing the results of ADDAPT PrimeTel could benefit from the 56 Gbpslink bandwidth in order to offer a high QoS to its clients. Moreover, an adjustment of its network performance to actual client demand will be possible since the transceiver module developed within the frames of the project will poses the required adaptive capabilities. This will allows PrimeTel to reduce its OPEX and CAPEX since the power consumption and energy costs (a decrease of 50% in power consumption and 30% of energy cost is expected within the frames of the project) can be kept at the levels that are required based on the data load. Finally, PrimeTel can take advantage of the speeds of 56 Gbps to provide fast access to data and storage cloud facilities.

4.5 *TE connectivity (TE)*

4.5.1 Specific ADDAPT Know-how to be exploited

TE connectivity intends to develop the following product with ADDAPT technology

(a) Adaptive Active cables, to be extended with the adaptive feature.

(b) Adaptive Mid Board Optics module with the adaptive feature integrated in the logic managing the VCSELs and photodiodes.

4.5.2 Application

Application is in those domains where the adaptive technology will have a significant advantage in power consumption. Technically speaking, it works for lane speeds at 56 Gbps, and present insights say best operational improvements will show at aggregated speeds of 300 Gbps or higher. If technology gets cheaper and more efficient over time, this might go down to the base speed of 56 Gbps.

Applications are:

Interfacing as adaptive AOC between high-speed interconnects for Infiniband and Gigabit Ethernet:

- As backbone between the top-of-rack and higher hierarchy Ethernet switches,
- As backbone between the top-of-rack and higher hierarchy Infiniband switches,

Interfacing as Mid Board Optics:

- As access to processors and communication hubs, running protocols like SMP, Infiniband, and Ethernet.
- It is expected that PCIexpress 4.0 products will appear per end of 2016. Speeds mentioned are in the range of 250 Gbps. PCIexpress lines are generally speaking short, hence with relative low energy consumption. It is the access to network and storage applications, hence sensitive to delay. We do not expect that PCIexpress will be suitable to exploit the advantages of the adaptive technology (compared to the costs associated with it).
- We think there will be a limited solution-space for protocols like FibreChannel. It is used mainly in storage applications, roadmap goes up until 128GFC = 25.6 Gbps (205 Gbps) end of 2016. Storage devices will become more and more concentrated in concentrated locations. That will mean that length gets higher, hence energy consumption more important. Then Adaptive technology might become relevant. Many Fibrechannel communications run over Ethernet though.

4.5.3 Market and customers

Markets:

- manufacturers such as networking equipment providers and computer manufacturers (Infiniband, Ethernet, SMP, PCIexpress, FibreChannel)
- storage manufacturers (FibreChannel, SATA, SCSI)
- datacentre operators (AOCs), running all the protocols mentioned above.

4.5.4 Enabling conditions

- Standardisation on how to communicate idles to the adaptive control will be crucial. This saves implementations in the logic of the transceiver, and it saves buffers to address temporary misalignment between calculated speed and actual speeds.

- The availability of VCSELs that are capable of very fast changing in NRZ coding speed
- The availability of CRS circuits that are able adapting to very fast changing in clock speeds in a range of 12.5%, 25%, 50%, 100% of the max speed.
- Circuits that scale in energy consumption with the speed of communication.
- Logic that can determine idles (protocol specific)
- Logic that can remove idles on a controlled manner from the data-stream in the Tx side
- Logic that can insert idles on a controlled manner in the data-stream at the Rx side
- Packaging and assembling methods suitable for the increased lane speeds (40 or 56 Gbps) and energy consumption levels that we target (2 pJ/bit)
- An industry acceptance of balancing delay against energy consumption in the cable, and the willingness to spend a premium on the technology against energy reduction

4.5.5 Exploitation

- Participation in standardization bodies with focus on high-speed transmission and adaptive low power consumption optical transceivers. Examples are FiberChannel Energy Efficient (FC-EE), IEEE Energy-Efficient Ethernet standardization, InfiniBand® Trade Organisation, and Optical Internet Forum (OIF).
- Sales of Active Optic Cable with Adaptive technology.
- Sales of Mid Board Optics with Adaptive technology.

4.6 *Technische Universität Dresden (TUD)*

4.6.1 Specific ADDAPT Know-how to be exploited

- High-speed/broadband integrated circuits
- Know-How on IC design techniques
- Adaptive IC design techniques
- Device modeling, schematic design, (circuit) simulations and measurements
- Education and studies of young academics

4.6.2 Application

- ICs for transceivers for optical data-communication e.g. in data centers, HPC, etc.
- Adaptive techniques could also be implemented in non-optical communication components.
- Suitable for optical interconnects (rack-to-rack, board-to-board, on-board, inter-chip, chip-to-chip)
- Research and education (provision of know-how and expertise)

4.6.3 Market and customers

- Engineering and communication techniques
- Component and transceiver manufacturers

- IC foundries
- Research institutes
- Relevant student population, industrial and academic partners

4.6.4 Enabling conditions

- Access to advanced CMOS technologies and design kits
- Availability and use of design and measurement environments
- Courses to be provided to students, engineers, researchers or other interested parties

4.6.5 Exploitation

TUD CCN as non-profit institution, research and educational oriented university cannot sell a product directly. However, within ADDAPT CCN of TUD mainly strengthens and enhances its experience and skills in the field of broadband IC design for optical interconnects, e.g. by gaining novel know-how on adaptive circuits approaches. This includes basic circuits of the optical transceiver up to complex system implementations. In addition the modelling capabilities of optical components and electrical interconnections for high-speed data transmission will be improved. On the one hand, this enables the continuation of national/international research in the field after ADDAPT. On the other hand, all those expertises can directly be incorporated into lectures and thus will gain the knowledge and skills of upcoming young academics. Therefore, well-educated and highly-skilled PhDs, researchers and engineers can be offered to industry after the project finishes. Moreover, the know-how will be provided to chair partners and the work in the project will also improve the connections and relationship to international industrial and academic/research partners.

In particular, the following actions are considered to exploit the ADDAPT project results:

- Offer of design, modelling, simulation and measurement know-how and services for broadband ICs to academic and industrial partners or other interested parties
- Provide IC IPs to interested companies/foundries and project partners
- Knowledge transfer to and education of students/PhDs, engineers and researches who will take leading positions in industry in future
- Offer for sale of patents generated in ADDPT to interested parties
- Establishing a start-up company for electro-optic circuit design where the project results of ADDAPT could be commercially offered

4.7 VI Systems (VIS)

4.7.1 Specific ADDAPT Know-how to be exploited

Oxide-confined 850 nm, GaAs technology based vertical cavity surface emitting lasers (VCSELs) and photo-detectors chips with power adaptivity that will be achieved by adjusting the modulation currents and modulation voltages to yield adjustable data rates from 8 up to 56 Gbps. For signal

transmission the use of feed forward equalization or pre/deemphasize techniques and advanced modulation coding schemes will also be considered. To obtain easy coupling and low power consumption of the entire optical transceiver, a novel near field coupling will be investigated.

4.7.2 Application

The VCSEL and photodetector chips are enabling key components in optical transceivers products (e.g. transceivers products, active optical cables, midboard transceiver products).

4.7.3 Market and customers

The market application segments include supercomputers, large size data-centers and networking equipment. Customers are high performance computer (HPC) systems and networking equipment manufacturer as well as suppliers of data interconnect products for HPC systems and network systems.

4.7.4 Enabling conditions

The availability of energy efficient VCSEL driver electronic that is capable of transmitting up to 56 Gbps and the availability of energy efficient amplifier electronics at price points which enable data transmission at the cost of less than $1 per Gbps.

Standardisation of optical interconnect technologies by standard bodies or industry partners typically increase the customer adaption rate rapidly.

VIS as Foundry partner for epitaxial growth of GaAs wafer structures and foundry partners for wafer processing. Closer co-operation with test laboratory for wafer characterisation and high speed transmission tests.

4.7.5 Exploitation

- Sales of vertical cavity surface emitting lasers (VCSELs) and photo-detectors chips for the adaptive IC technology.
- Sales of subassemblies which consist of VCSEL chip or photo-detectors chips and the adaptive IC technology.

4.8 *Warsaw University of Technology (WUT)*

4.8.1 Specific ADDAPT Know-how to be exploited

- Evaluation Platform for electro optical components and systems up to 56 Gbps
- Development of an appropriate test-bed. Measurements of devices and subsystems with data rates up to 56 Gbps.

4.8.2 Application

Research and education. Provision of know-how and expertise.

4.8.3 Market and customers

The relevant student population, industrial and academic partners.

4.8.4 Exploitation

In the framework of the ADDAPT project, WUT will gather unique know-how and skills, which can be applied in the further research as well as education. First, WUT will significantly improve its capabilities to conduct reliable and precise measurements of the optical transmission systems from a very early stage up to complete system and demonstrator tests at a final stage. Second, WUT will expand knowledge and experience on the optical interconnects and electro-optical components like VCSELs. This will allow WUT to conduct further research on this topics in the framework of the national and international initiatives. Moreover, know-how and expertize will be provided to the interested industrial and academic partners. Further, relationships with the foreign academic and industrial partners will be established boosting future international collaboration. In the ADDAPT project WUT will train well educated researchers and engineers, providing highly skilled workforce to the European market. The patents generated within the ADDAPT project will be offered for sale to interested parties. The courses given at WUT, will be expanded with knowledge gathered in the ADDAPT project.

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Acronyms

Acronym	Definition
100GbE	100 Gigabit per second Ethernet
40GbE	40 Gigabit per second Ethernet
ATM	Asynchronous Transfer Mode (ATM) is, standards for carriage of a complete range of user traffic, including voice, data, and video signals".[1]. ATM is a core protocol used over the SONET/SDH backbone of the public switched telephone network (PSTN) and Integrated Services Digital Network (ISDN), but its use is declining.
CLEO	Conference on Lasers and Electro-Optics
DBC	Data Center Bridging. An Ethernet specification for the data-center environment
ECOC	European Conference on Optical Communications
EoS or EoSDH	Ethernet over SDH. Refers to a set of protocols which allow Ethernet traffic to be carried over synchronous digital hierarchy networks in an efficient and flexible way. The same functions are available using SONET (a predominantly North American standard).
HPC	High Performance Computing (supercomputing)
IEEE	Institute of Electrical and Electronics Engineers. It amongst others standardized the Ethernet protocols
iWARP	The Internet Wide Area RDMA Protocol (iWARP) is a computer networking protocol for transferring data efficiently. It is sometimes referred to simply as "RDMA", though RDMA is not a feature exclusive to iWARP.
KPI	Key Performance Indicator. An easy metric that shows a performance on a particular subject.
MSA	Multi-source agreements (MSAs) are not official standards organizations. Rather, they are agreements that equipment vendors assume when developing form factors for communications interfaces.
NCSA	National Centre for Supercomputing Applications, University of Illinois
OFC	Optical Fibre Communication Conference and Exposition
PD	A photodiode is a semiconductor device that converts light into current. The current is generated when photons are absorbed in the photodiode.
PoS	Packet over SDH, a way to transport (IP) packets over SDH / SONET
PUE	Power Use Effectiveness. A KPI developed by The Green Grid Association , a nonprofit, open industry consortium
RDMA	Remote Direct Memory Access
RoCE	RDMA over Converged Ethernet (RoCE) is a network protocol that allows remote direct memory access over an Ethernet network. RoCE is a link layer protocol and hence allows communication between any two hosts in the same Ethernet broadcast domain. Although the RoCE protocol benefits from the

Acronym	Definition
	characteristics of a converged Ethernet network, the protocol can also be used on a traditional or non-converged Ethernet network. [Wikipedia]
SAS	Serial Attached SCSI (SAS) is a point-to-point serial protocol that moves data to and from computer storage devices such as hard drives and tape drives
SATA	Serial ATA (SATA) is a computer bus interface that connects host bus adapters to mass storage devices such as hard disk drives and optical drives.
SCSI	Small Computer System Interface is a set of standards for physically connecting and transferring data between computers and peripheral devices. The SCSI standards define commands, protocols and electrical and optical interfaces. SCSI is most commonly used for hard disks and tape drives, but it can connect a wide range of other devices, including scanners and CD drives, although not all controllers can handle all devices.
SDH	Synchronous Digital Hierarchy, in telecommunications
SMP	Internal IBM protocol between processor of the Power7 family
VCSEL	The vertical-cavity surface-emitting laser, or VCSEL is a type of semiconductor laser diode with laser beam emission perpendicular from the top surface, contrary to conventional edge-emitting semiconductor lasers (also in-plane lasers) which emit from surfaces formed by cleaving the individual chip out of a wafer.
WAN	Wide Area Network, in telecommunications