

PRESS RELEASE

FRAUNHOFER INSTITUTE FOR RELIABILITY AND MICROINTEGRATION IZM

PRESS RELEASE

Dec, 6, 2017 || page 1 | 5

PhoxTroT: Optical Interconnect Technologies Revolutionized Data Centers and HPC Systems

The research project PhoxTroT, " Photonics for High-Performance, Low-Cost & Low-Energy Data Centers, High Performance Computing Systems: Terabit/s Optical Interconnect Technologies for On-Board, Board-to-Board, Rack-to-Rack data links", funded by the European Commission under 7th Framework Programme (FP7) – 'ICT-2011.3.5 - Core and disruptive photonic technologies', completed successfully its activities delivering the revolutionary optical interconnect solutions towards High-Performance, Low-Cost & Low-Energy Data Centers, High Performance Computing Systems exploiting existing photonic technologies in a holistic way, synergizing the different fabrication platforms in order to deploy the optimal "mix&match" technology and tailor this to each interconnect layer.

To ensure a constant availability of the Internet applications of service providers like Google, Apple, Facebook or Amazon in all areas independently if they are intended for end users or companies of all sizes, data centers of gigantic dimensions are needed. The energy consumption of such data centers is, of course, exorbitant - and precisely at this point, the now successfully completed EU project "PhoxTroT" saw enormous potential for cost reduction and efficiency.

During a period of 56 months, under the coordination of the Fraunhofer Institute for Reliability and Microintegration, IZM, a consortium with 23 project partners focused on this topic: 50% less energy consumption with a doubling of the data communication rate to two terabits per second was the main goal. This was achieved by the implementation of optical interconnections at all hierarchy levels: On-Board, Board-to-Board, Rack-to-Rack data links. The overall research and development budget of the project was about 13 Million € with 8.7 Million € EU contribution, which allowed an effort of more than 1050 person-months for the duration of the project.

In May 2017 the project was successfully finalized, bringing breakthrough developments of the PhoxTroT consortium as a whole. The main achievements include the development of data storage systems and subsystems supporting full optical interconnect migration down to end nodes (SEA) for linearly scalable, power and cost reduced data centres, the implementation of a Silicon Photonics process flow in the 200mm fabrication site of ams (AMS), the establishment of multilayer, multimode

electro-optical circuit board global platform for high volume fabrication (MAIL) and the establishment of a fabrication pilot line for single-mode electro-optical circuit boards (Fraunhofer IZM) to couple seamlessly to singlemode fibre infrastructures deployed in future exascale data centres and to support integrated silicon photonics applications, the advanced optical design and simulation packages and data centre design architectures and protocols (PHX, AUTH, ICCS, CTI), PIC and hybrid design flow optimization (BP, Fraunhofer IZM), the long wavelength VCSEL and photodiode arrays and their driving/receiving electronics deployment to address emerging singlemode parallel optical transceiver markets (VTL, Fraunhofer HHI, IMEC), the advanced active optical cable development (TE, MLNX, KIT, AMO), 3D silicon photonics switches, transceivers and their advanced 3D assembly (DAS, Fraunhofer IZM, UPVLC, AMO, AUTH) and a full suite of electro-optical circuit board multimode and singlemode waveguide couplers and board-to-board connectors (SEA, Fraunhofer IZM, CEOS and MAIL), the development of flexible, low-loss "Plasmonic Arcs"(CNRS-UB, SDU, Fraunhofer IZM), the development of first hybrid InP-on-SOI nano laser diode (CNRS-LPN).

PRESS RELEASEDec, 6, 2017 || page 2 | 5

PhoxTroT brought strong influence on international standards relevant to its core technology areas of chip level interconnect (photonic integrated circuits), board level interconnect (optical circuit boards) and rack level interconnect (AOCs) as well as data centre and HPC architectures. As well as participating in and contributing to a wide range of standardisation committees spanning the PhoxTroT technology fields, PhoxTroT has successfully supported efforts to found a Photonic Integrated Circuit (PIC) working group within the IEC and generated a standardisation roadmap on PIC technologies, "IEC 63072-1 – Photonic Integrated Circuits – Part 1: Introduction and roadmap for standardization", which was published by the IEC in May 2017. Furthermore it has created and validated a measurement methodology for optical circuit boards, and created a corresponding international standard, IEC 62496-2/Ed1: General guidance for definition of measurement conditions for optical characteristics of optical circuit boards", which was published by the IEC in May 2017.

A proactive Intellectual Property Rights management strategy has been successfully deployed resulting in PhoxTroT foreground innovations being captured in 16 patent filings so far, 7 of which have already been granted.

Regarding the dissemination of PhoxTroT foreground knowledge to the scientific community, during the lifetime of the project have been generated more than 100 publications to peer-reviewed journals and more than 100 "other dissemination actions" that include invited talks to prestigious conferences in photonics, workshop presentations etc. Moreover PhoxTroT has organized 5 successful Symposia in Optical Interconnects as well as 2 Summer Schools with more than 150 attendees to each event.

In order to exploit the project main results and technologies a new follow up initiative is now available to small and medium-sized enterprises for further development:

"PhoxLab" for deep characterization of system embedded photonic interconnect and validation in data centre environment developed into an 'European Digital Innovation Hub' at the Fraunhofer IZM in Berlin.

PRESS RELEASEDec, 6, 2017 || page 3 | 5

Following up on "PhoxTroT", the results and applications of further national and European research projects will be provided to start-ups and SMEs - for example, to carry out tests for the certification of their prototypes and developments. Fraunhofer IZM as operator and initiator sees itself as an independent platform for application areas in the field of photonics and data centers of all kinds - and thus lays the foundations for the future of the infrastructure of modern Internet applications.

PhoxTroT consortium partners:

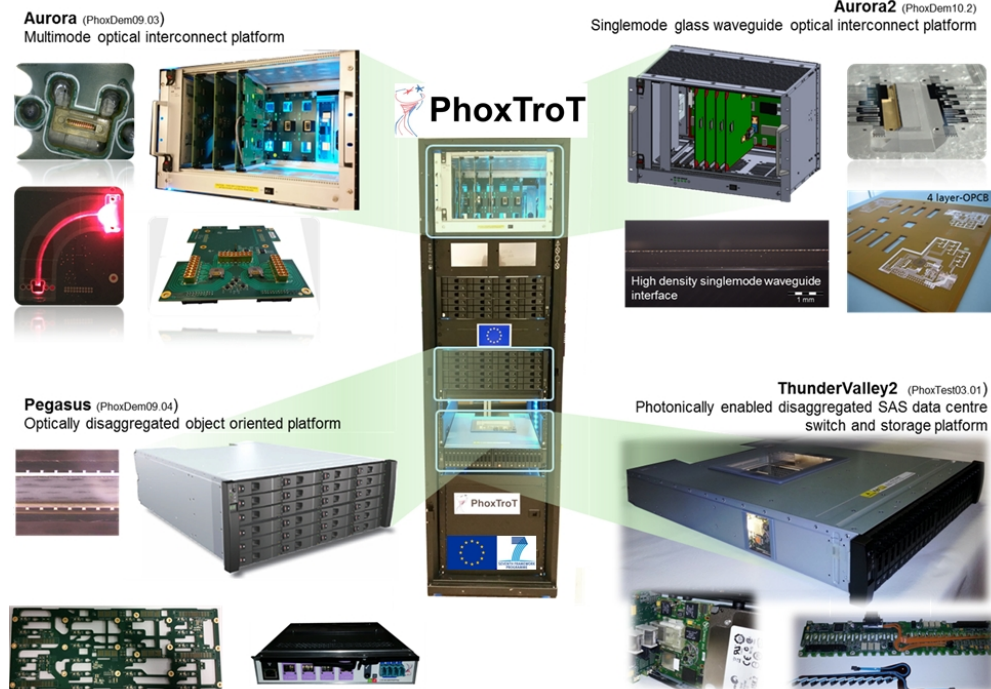
- Fraunhofer Institute for Reliability and Microintegration, Germany (Fraunhofer IZM)
- Fraunhofer Institute for Telecommunications Heinrich-Hertz-Institut, Germany (Fraunhofer HHI)
- Vertilas GmbH, Germany (VTL)
- Seagate Systems UK Limited, United Kingdom (SEA)
- ams AG, Austria (AMS)
- Meadville Aspocomp International Limited, Hong Kong (MAIL)
- Gesellschaft für Angewandte Mikro und Optoelektronik mit beschränkter Haftung mbH, Germany (AMO)
- National Technical University of Athens, Institute of Communication and Computer Systems, Greece (ICCS)
- DAS Photonics SL, Spain (DAS)
- Phoenix BV, Netherlands (PHX)
- The Centre for Research & Technology Hellas, Greece (CERTH/ITI)
- Compas Electro-Optical Systems, Israel (CEOS)
- Bright Photonics BV, Netherlands (BP)
- Computer Technology Institute and Press – "Diophantus", Greece (CTI)
- Centre National de la Recherche Scientifique Laboratoire Interdisciplinaire Carnot de Bourgogne, France (CNRS-UB)
- Centre National de la Recherche Scientifique Laboratoire de photonique et de nanostructures, France (CNRS-LPN)
- Karlsruhe Institute of Technology, Germany (KIT)
- Syddansk Universitet, Denmark (SDU)
- Universitat Politecnica de Valencia, Spain (UPVLC)
- Interuniversitair Micro-Elektronica Centrum vzw, Belgium (IMEC)
- TE Connectivity Nederland BV, Netherlands (TE)
- Aristotelio Panepistimio Thessalonikis, Greece (AUTH)
- Mellanox Technologies LTD, Israel (MLNX)

More information about the project goals and highlights can be found on its website www.phoxtroT.eu .

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PRESS RELEASE

Dec, 6, 2017 || page 4 | 5



Aurora (PhoxDem09.03)
Multimode optical interconnect platform

Aurora2 (PhoxDem10.2)
Singlemode glass waveguide optical interconnect platform

Pegasus (PhoxDem09.04)
Optically disaggregated object oriented platform

ThunderValley2 (PhoxTest03.01)
Photonically enabled disaggregated SAS data centre switch and storage platform

PhoxTroT

High density singlemode waveguide interface

4 layer-OPCB

PRESS RELEASEDec, 6, 2017 || page 5 | 5

Research of practical utility lies at the heart of all activities pursued by the **Fraunhofer-Gesellschaft**. At present, it maintains 69 institutes and research units. The majority of the 24,500 staff are qualified scientists and engineers, who work with an annual research budget of 2.1 billion euros. Of this sum, 1.9 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. Almost 30 percent is contributed by the German federal and state governments in the form of base funding, enabling the institutes to work ahead on solutions to problems that will not become acutely relevant to industry and society until five or ten years from now.

Fraunhofer IZM specializes in industry-oriented applied research. With four technology clusters, Fraunhofer IZM covers the entire spectrum of technologies and services necessary for developing reliable electronics and integrating new technology into applications. Our customers are as varied as the applications for electronics. We take on development projects for the automotive industry, healthcare and industrial electronics and even textile companies. The institute has a staff of more than 377 and saw a turnover of 29.5 million euros in 2016, of which 85.5 percent was earned through contract research. Fraunhofer IZM has two sites in Germany. Apart from its headquarters near Berlin Mitte, the institute is also represented in Dresden, a strategically important centers for electronic development and manufacturing.

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