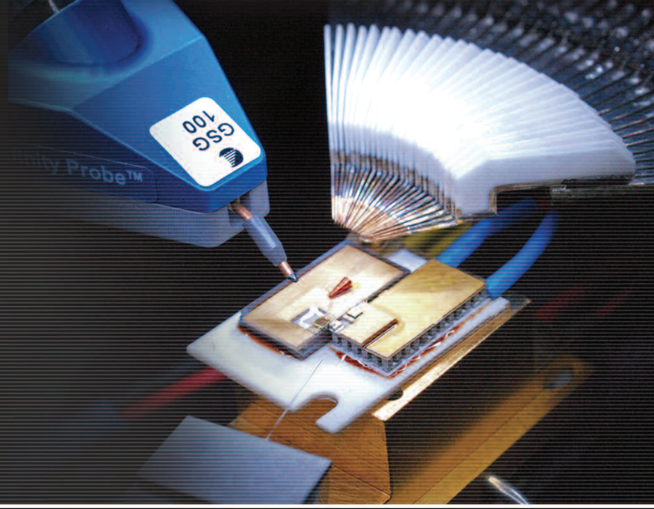


Photonic Integrated Circuits Accessible to Everyone

table of contents

Welcome to this January edition of the newsletter of the EU H2020 PICs4All project. Photonic integration is stimulating an increasing diversity of use cases, and with our coordination support action, we are supporting tens of businesses and researchers to innovate in their own areas of expertise and to make the connections to realise their own circuits. We have been actively preparing application notes to capture the latest opportunities, technology and positioning in the context of industrial product developments. Latest examples include the application notes on PICs for satellite communication and LIDAR systems, with other application notes available in the archive.

Internationally, the industry is now mobilising to make the link between research and development and future needs for PIC enabled products much more visible across sectors. This promises to drive developments in much the same way that the microelectronics industry has done over the last decades. The next chapter in this roadmapping endeavour will be at the World Technology Mapping Forum in Berlin. This global initiative is driven by PhotonDelta and the Aim Photonics Academy. PIC developers are encouraged to engage in the roadmapping process.

Many new entrant businesses are approaching PIC technology in a platform agnostic way, and technology providers and consortia including EC Pilot Lines, open access platforms providers such as ePIXfab, JePPIX.eu and PIXAPP are joining forces to present a coherent view on how to access technology and develop new photonic solutions. A richer events program is now organised by partner EPIC in 2019 to meet with experts in the open access field and catch up on the latest developments.

In this issue we present one of the PICs4All application support centers – ICCS in Greece, providing a local point of contact for the increasing numbers of innovators. Application notes are also included along with the 3rd Eastern European Workshop and the 3rd Photonic Integration Week. One final note: our coordinator for PICS4All, Aura Higuera Rodriguez steps down from her role at the end of 2018 to start the next chapter in her PIC career with Synopsis. We wish her well.

Kevin Williams (TU/e)

How to contact us:
For further information about PICs4All please look on our website http://pics4all.jeppix.eu or contact:

Kevin Williams (project coordinator): K.A.Wiliams@tue.nl
Stanisław Stopiński (issue editor): stanislaw.stopinski@pw.edu.pl

Application Support Center @ ICCS

The Institute of Communication and Computer Systems (ICCS)

(http://www.iccs.gr/eng/) is associated with the School of Electrical and Computer Engineering (SECE) of the National Technical University of Athens (NTUA). It was founded in 1989 in order to carry out research and development activities in the field of telecommunications systems and computer systems. ICCS employs more than 500 researchers including SECE faculty staff, senior research scientists, and PhD students. ICCS/NTUA participates in PICs4All with the Photonics Communications Research Laboratory (PCRL).

Photonics Communications Research Laboratory

Photonics Communications Research Laboratory (PCRL)

(http://www.photonics.ntua.gr/) was founded in 1995 as a research group of the School of Electrical and Computer Engineering, National Technical University of Athens. It is led by Prof. Hercules Avramopoulos and it currently numbers 6 Senior Researchers and 12 PhD students. Its research activities focus on the design, development and characterization of photonic devices and systems for optical communications and sensing applications, including high-capacity optical transceivers, optical switches and biophotonic sensors for food and drug analysis. PCRL runs a fully equipped laboratory with state-of-the-art test and measurement equipment and a broad range of passive and active photonic devices. PCRL has significant presence and a proven track record with successful participation and leadership in a number of European projects like BIOCDx, BIOFOS, 3PEAT, HAMLET, NEPHELE, PANTHER, POLYSYS, MIRAGE and others.

ASPIC design

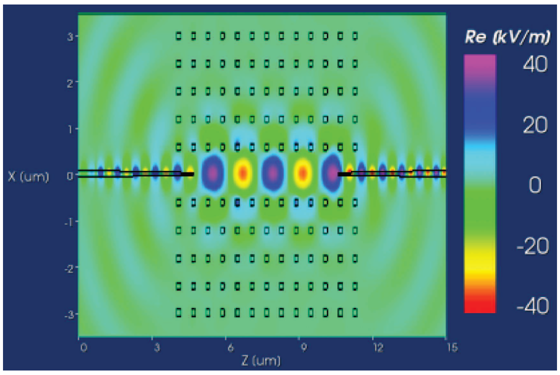
Access to photonic CAD software

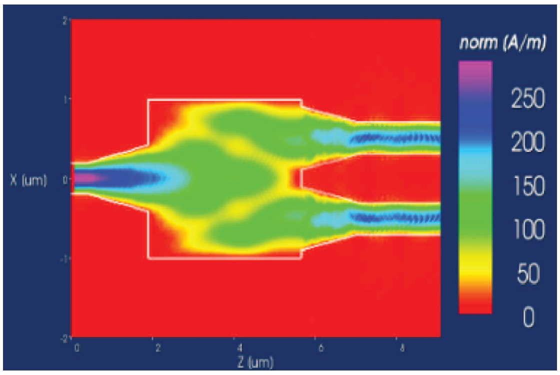
OptoDesigner: a flexible and integrated environment focused on manufacturable designs, which enables efficient, high-quality PIC device development.

ASPIC: a fast and accurate simulator for the analysis, the modeling and the design of photonics integrated circuits.

Lumerical: system design products simulate and optimize the performance of photonic integrated circuits.

VPIphotonics: a simulation and design environment for photonic integrated circuits (PICs). It provides advanced device libraries integrated with a scalable time-and-frequency-domain simulation framework for fast and accurate modeling of large-scale PICs with a mix of photonic, electrical and optoelectronic devices.





R-soft: allows users to design and simulate both passive and active photonic devices for optical communications, optoelectronics, and semiconductor manufacturing.

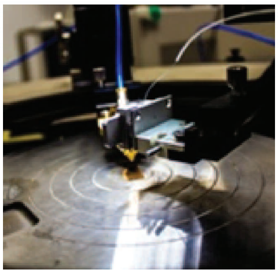
Experience in design of ASPICs for:

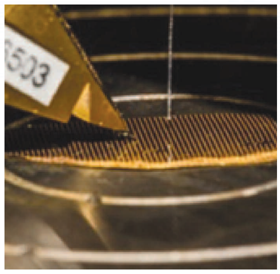
- Telecommunications
- Datacom/Computercom
- Sensing systems

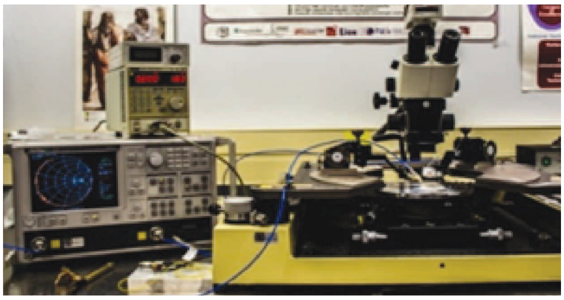
Experience in using generic Si, InP, PolyBoard and TriPleX platforms.

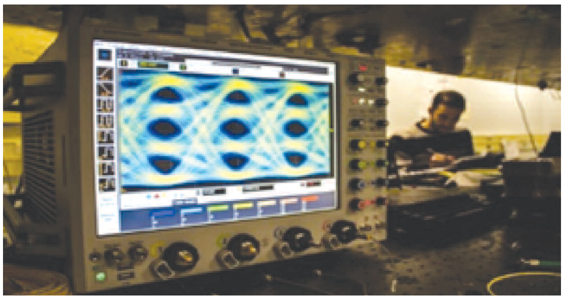
ASPIC characterization

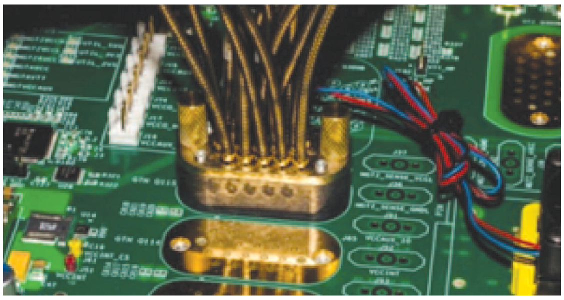
- Packaged and unpackaged passive and active chips
- In-plane and vertical coupling probe stations for unpackaged photonic chip characterization with 6-axis micro-positioners for sub-micron alignment accuracy
- Variety of optical fibers (multimode, SMF, lensed SMF, DCF, HNLF, LEAF) for coupling light into chips
- Tunable optical filters, variety of laser sources including low linewidth (100 kHz), 10 GHz and 40 GHz mode-locked lasers
- LabVIEW Data Acquisition boards with 16-bit resolution ADCs, DACs and 1.25 MSamples/sec sample rate
- Commercial MZMs and IQMs up to 40 Gbaud
- High bandwidth photodetectors up to 70 GHz, DP Coherent receivers up to 64 Gbaud, optical power meters from 700 nm to 1600 nm, optical spectrum analyzer with 0.01 nm resolution, Vector Network Analyzer (VNA) with calibration kit up to 40 GHz
- RF signal generators up to 40 GHz, real time oscilloscope with 33 GHz analogue bandwidth and 80 GSa/s rate, digital sampling oscilloscope up to 70 GHz with precision time base, advanced jitter analysis software, optical sampling oscilloscope (OSO) with 500 GHz effective bandwidth
- 40 GHz RF probe station for chip characterization (up to 8-inch wafers)











- RF spectrum analyzer up to 50 GHz
- OTDM multipliers up to 160 Gb/s
- Testbed for 56 Gbaud/s (BER test sets, RF – multiplexers/demultiplexers, RF amplifiers, 70 GHz photodiodes, coherent receivers up to 64 Gbaud), testbed for loop transmission experiments (AOMs, 4 x 25 km fiber spools)

Contact information:

Lefteris Gounaridis (ICCS/NTUA),
lgou@mail.ntua.gr

Photonic Integrated Circuits for Satellite Communication

The growth of the internet and the amount of data collected for environmental sensing, scientific exploration, and military surveillance are key drivers for the exponential growth of satellite communication bandwidth. A move to higher frequencies is required, up to 50 GHz, i.e., the Q band, to enable gigabit-per-second communications. Another recent development is the use of multiple beams, which is a form of spatial multiplexing. Antennas with high directivity are required for this. Complex on-board switches are necessary to enable flexible payloads. Key metrics for the technology are the cost per bit and the cost of delivering such capacity in space.

A recent development is to use laser-based free-space optical communications. This approach leads to less divergent beams, for longer reach, and higher capacity, in an otherwise unregulated part of the spectrum. This is, for example, implemented in the European Space Agency's (ESA) Alphasat and in Facebook's Internet.org project[1]. The low-divergence beams of optical communications also form an intrinsically secure link and can be used for stealth operations.

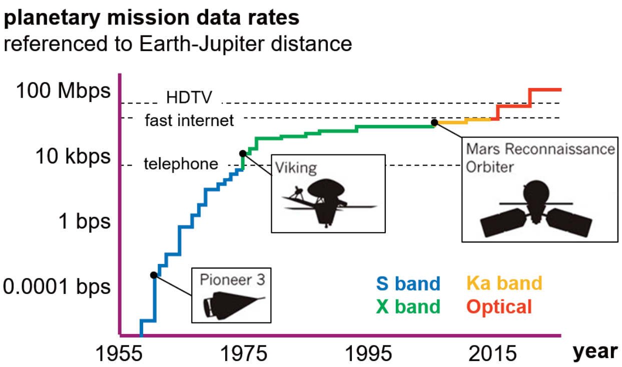


Figure 1 Interplanetary data transmission rates have shot up 10 orders of magnitude in the past 50 years. Optical communication can extend that pace, potentially enabling high-definition broadcast from Jupiter[2]. Source data: NASA/JPL-Caltech

Photonic Integrated Circuits (PICs)

Also known as optical chips, PICs can contain tens to hundreds of optical components. While electronic ICs consist of transistors, capacitors and resistors, a PIC consists of, for example, lasers, modulators, photodetectors and filters, all integrated on a single substrate. These PICs are nowadays extensively used commercially, mainly in datacom and telecom.

PIC technology has now become accessible to users without a cleanroom, through so-called multi-project wafer runs and open foundries. Indium phosphide based technology is commercially available through SMART Photonics and Heinrich Hertz Institute. Access is coordinated by the JePPIX platform: http://www.jeppix.eu/.

The opportunity for photonic integration

The opportunities for photonic integration are well described and aligned with, for example, the ESA and Airbus roadmaps[3]. These include photonic distribution of the radio-frequency or microwave local

[1] https://info.internet.org/en/

[2] Powell, "Lasers boost space communications" Nature (2013)

[3] https://doi.org/10.1117/12.2304200

oscillator, photonic-based microwave frequency generation, conversion, filtering, routing and beamforming, and optical interconnects at 25 Gbps and 56 Gbps.

The field of microwave photonics deals with microwave signal generation, processing and detection in the photonic realm[4]. This allows for larger operation bandwidth, lower loss links, and more compact systems for selected applications. Such systems, or part thereof, can be integrated on a PIC, and microwave frequencies from below 1 GHz to well above 50 GHz can be supported. A particularly well-developed application is the use of PICs for the delay of microwave signals, as used in phased array antennas for (multiple) beamforming and beamsteering. Compact photonics-based oscillators are already amongst the lowest noise microwave oscillators[5],

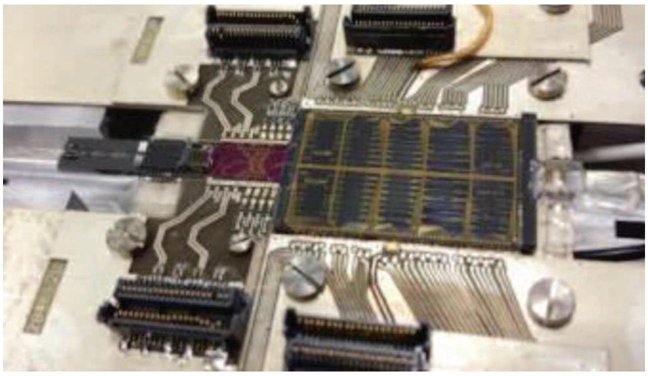


Figure 2 Photonics-based beamforming antenna system for broadband satellite communication, consisting of two PICs to generate and phase tune the microwave signals. By working in the optical domain, a thousand to a million-fold increase in processing speed is expected. Source: LioniX International[6]

and PIC technology offers the opportunity for decreasing the cost, size and weight of such oscillators and allows for larger-scale system integration, including local oscillator distribution.

For free-space-optical communications, optical phased arrays on a PIC are a prime candidate[7]. Although still experimental, initial feasibility studies have shown these can reach output powers up to 10 W. Prototypes, at lower output power, have been reported.

Technical challenges

The PIC and overall system need to be carefully designed for the target application. Although the PIC technology platforms are mature now, they have been developed mostly for telecom and datacom applications, and applications in and requirements for satellite communications might require a different design of basic components, adding to the design cycle time and investment.

Space-specific challenges such as radiation hardness, the operational temperature range, and the vacuum environment, are currently being addressed in various projects run by ESA and NASA. This is an ongoing effort. A strong body of knowledge already exists, as the PIC technology has strong similarities with the electronic integrated circuit technology, which has been space-qualified in many implementations.

Packaging of the PIC with electronics and, potentially, with fiber coupling, is also a challenge. However, commercial solutions, e.g., as offered by PHIX Photonics Assembly, Technobis IPPS and Linkra, and through the PIXAPP Photonic Packaging Pilot Line[8], are now available. Again, efforts are being set up to make these packaging solutions space qualified, including, e.g., hermetic sealing, and avoiding epoxies.

Discuss your application with us

If you are interested to know more about the use of PIC technology for satellite communications, please

[4] https://www.photonicssociety.org/images/files/publications/Newsletter/Photonics_June_web2012.pdf

[5] http://www.oewaves.com/micro-oeo

[6] https://www.lionix-international.com/

[7] https://doi.org/10.1515/nanoph-2015-0152

[8] http://pixapp.eu/

contact Martijn Heck, coordinator of the PICs4All Application Support Center (ASC) at Aarhus University, Denmark. We are currently running projects in the field of microwave and terahertz photonics, funded by the Independent Research Fund Denmark DFF. A roadmapping effort to map the opportunities and requirements for PICs in space is currently underway[9]. We are set up to help you do a feasibility study for the use of PICs for satellite communication applications.

The PICs4All consortium[10] is funded under the Horizon 2020 framework and brings together expertise to support end-users, like academia, research institutes and industry, with PIC technology. The ASCs can help you connect to the eco-system of designers, foundries, packaging and test services.

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[9] https://euimwp.eu/

[10] http://pics4all.jeppix.eu/

Contact information:

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Aarhus University, Department of Engineering
Finlandsgade 22, 8200, Aarhus, Denmark

Photonic Integrated Circuits for LIDAR

Lidar, short for light detection and ranging or "light radar", is used to measure distances with high resolution and precision. This is achieved by illuminating the object with a scanning laser beam, and consequently measuring the reflections. Complete three-dimensional mappings can be made. Various techniques are used, such as pulsed, flash and frequency-modulated Lidar.

The opportunities for using Lidar are plenty, most notably in automotive, where it is used in advanced driver-assistance systems (ADAS) and in autonomous driving, providing a better resolution than radar. It is furthermore used in wind farms, to monitor wind speeds, and in remote sensing, mapping the environment and atmosphere.

A Lidar consists of a laser source, a laser beam scanner, and the detection optics. Traditionally, such systems were bulky and costly (see figure below). Over the last decade, pushed by the automotive market, the price of Lidar systems has come down by more than an order of magnitude. Solid-state Lidars are promising in bringing the cost down by another order of magnitude. Moreover, these Lidars are more robust, with no moving parts, and compact.

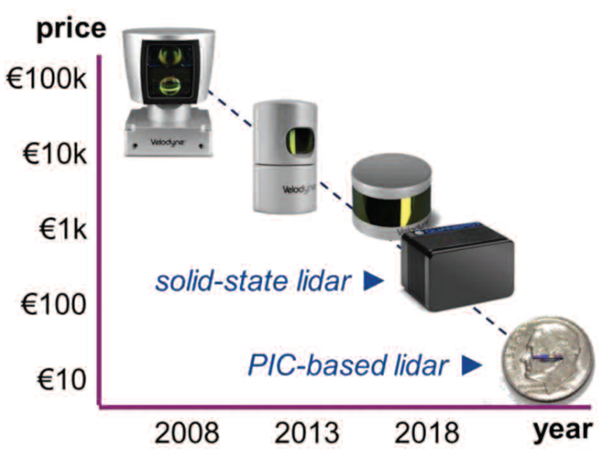


Figure 1 Evolution of the Lidar cost, including forecast. Source data: Velodyne, Quanergy and Massachusetts Institute of Technology

The opportunity for photonic integration

PICs offer some very concrete opportunities for Lidar. In solid-state Lidars, PICs can be used as the laser source. When combined with the on-chip components typically used in communications technology, pulsed lasers and frequency-modulated lasers can be realized. As an example, Blackmore[1] is bringing a frequency-modulated continuous-wave (FMCW) Lidar to the market, based on PICs. Such a Lidar provides both range and velocity measurements, through the Doppler effect. Coherent detection allows for highly-sensitive measurements, with high dynamic range. An added advantage is that PICs are designed for operation around wavelengths of 1550 nm, which is a sweet spot for Lidar due to eye-safety requirements. This allows the range to be extended significantly, to over 200 m, as argued by, e.g., Luminar[2].

PICs can also be used to replace the beam-steering part of the Lidar, through the use of optical phased arrays, as shown in the figure to the right. Much like phased-array antennas in wireless communications, such optical phased arrays can shape the laser beam and steer it fast for video-rate three-dimensional imaging[3]. The system has no moving components, as compared to using mechanical and micro-mechanical (MEMS) scanning devices, making it robust, and is lens-free. Laboratory-based implementations have already shown the feasibility, and the technology is now moving to the market, e.g., by Analog Photonics[4]. Initial feasibility studies have shown

[1] https://blackmoreinc.com/
[2] https://www.luminartech.com/
[3] https://doi.org/10.1515/nanoph-2015-0152
[4] http://www.analogphotonics.com/

these optical phased arrays can reach output powers up to 10 W[3]. Sources and detectors can be integrated on the PIC, with the potential of realizing a fully integrated, single-chip Lidar, and allowing unprecedented high volumes at low cost. Moreover, this technology allows for close integration with electronics.

Current technical developments

The PIC and overall system need to be carefully designed for the target application. Although the PIC technology platforms are mature now, they have been developed mostly for telecom and datacom applications. Lidars require a different design of basic components.

There are application-specific operational parameters that are different from the communications field. For example, for automotive applications, a target operating temperature range of −40 °C to 125 °C is often required. The PICs need to be designed for that.

Packaging of the PIC with electronics and, potentially, with fiber or free-space coupling, is also a challenge. However, commercial packaging solutions are now available, e.g., as offered by PHIX Photonics Assembly, Technobis IPPS and Linkra, and by the PIXAPP Photonic Packaging Pilot Line[5]. Specifically for optical phased arrays, the electronics for fast beam-steering into the 10 s of MHz range, with many closely-integrated channels, pose a challenge. Side-lobe suppression and beam width are design trade-offs for optical phased arrays[3].

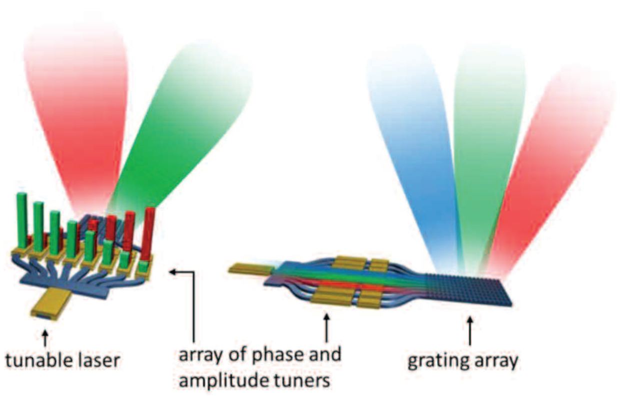


Figure 2 Schematic of an optical phased array, using optical phase control (left) and wavelength control (right) for beam steering[3]

Discuss your application with us

If you are interested to know more about the use of PIC technology for Lidar applications, please contact Martijn Heck, coordinator of the PICs4All Application Support Center (ASC) at Aarhus University, Denmark. We have experience with pulsed and frequency-modulated lasers, as well as with optical phased arrays. We are set up to help you do a feasibility study for the use of PICs for Lidar applications.

The PICs4All consortium[6] is funded under the Horizon 2020 framework and brings together expertise to support end-users, like academia, research institutes and industry, with PIC technology. The ASCs can help you connect to the eco-system of designers, foundries, packaging and test services.

[5] http://pixapp.eu/
[6] http://pics4all.jeppix.eu/

Contact information:

Martijn Heck Associate Professor, mheck@eng.au.dk, phone: +45 21186394
Aarhus University, Department of Engineering
Finlandsgade 22, 8200, Aarhus, Denmark

Events

3rd Eastern European Workshop “Generic Integration Technology for Photonics“

14 November 2018 – Warsaw (Poland)

The Institute of Microelectronics and Optoelectronics of Warsaw University of Technology (IMiO WUT) organized on 14th November 2018 **3rd edition of Eastern European Workshop “Generic Integration Technology for Photonics”**. The event was successfully held at the Centre for Innovation and Technology Transfer Management of Warsaw University of Technology and gathered more than fifty participants from universities, research institutes and companies.

The scope of the workshop covered the main aspects of generic approach to photonic integration – potential application fields (telecom, sensing and others), current capabilities of indium phosphide technology platforms, design tools and testing methods. The general concept and all consecutive stages of the generic manufacturing chain were presented and discussed in detail by top-level experts in the field from **Eastern Europe Design Hub of IMiO WUT**, **Eindhoven University of Technology**, **Fraunhofer-Heinrich Hertz Institute** and **VPIphotonics**. The participants were also advised of the funding mechanisms available as well as possibilities of gaining expert support within the framework of two EU Horizon 2020 projects – PICs4All and Actphast 4.0.

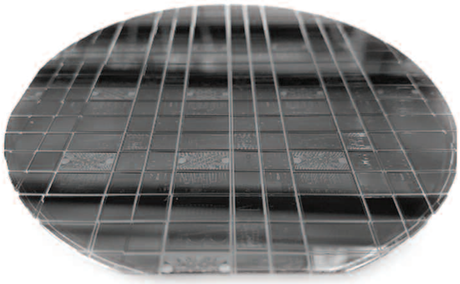
IMiO
Institute of Microelectronics and Optoelectronics
Warsaw University of Technology

WUT

Centre for Innovation and Technology Transfer Management
WARSAW UNIVERSITY OF TECHNOLOGY

PHOTONIC INTEGRATION WEEK 2019
14–15 January 2019 – Valencia (Spain)

UNIVERSITAT POLITÈCNICA DE VALÈNCIA



The Universitat Politècnica de València continues contributing to the development of the Photonic Integration value chain in Spain through a **3rd edition of the Photonic Integration Week** (**https://piw.webs.upv.es/**) organized on 14th–15th January 2019. PIW brings together experts around photonic integration technologies for tele/datacom, sensing and bio-technology applications. It will provide a great networking opportunity with a balanced mix of topics, sessions, social gathering and business to business meetings. On this 3rd edition, while keeping the previously achieved mix of industry, research and academic speakers, the aim is to internationalize the event further.

Monday 14/Jan

TIME	SESSION	SPEAKER PROFILE	COMPANY / INSTITUTION	TALK
08:00 h			**WELCOME AND REGISTRATION**	
08:45 h	Opening	**Pascual Muñoz**	Universitat Politècnica de València	Welcome and event overview
09:00 h	Tele & datacom	**Antonio Pastor**	Telefonica	Quantum key distribution: a telco operator perspective
09:30 h		**Demetrio López**	ALTER Technology Group	Optical intersatellite communications
10:00 h		**Juan Pastor Graells**	Indra	Photonics assisted EW technologies
10:30 h		**Josep Mª Fábrega**	CTTC	Scalable spectrum/space transmission for future agile high capacity metro fiber optic networks
11:00 h			**COFFEE BREAK**	
11:30 h	Sensor technologies	**Arne Leinse**	Lionix International	Silicon nitride photonic integrated circuits for life sciences
12:00 h		**Germán Vergara**	New Infrared Technologies	Un-cooled MWIR imaging sensors: technology and applications
12:30 h		**Robert Weih**	nanoPlus GmbH	Laser technology for the mid-infrared and applications
13:00 h		**Pim Kat**	Technobis group	Commercializing PIC technology for sensing
13:30 h			**LUNCH**	
14:30 h			**Business to business meetings 1**	
16:00 h	PIC technologies	**Timo Aalto**	VTT Finland	Photonics integration on silicon for sensing, imaging and communication
16:30 h		**Valery Tolstikhin**	Intengent, Inc.	Fabless manufacturing of PICs in InP based on TAVI: technology and applications
17:00 h		**Michael Geiselmann**	Ligentec	Non-linear photonics applications on a silicon nitride platform
17:30 h		**Aitor Villafranca**	CSIC / Alcyon Photonics	Polarization and mode handling building blocks on chip
18:00 h			**Business to business meetings 2 / Lab tour / Clean room tour**	
19:30 h			**WELCOME RECEPTION**	
21:00 h			**CLOSING**	

Tuesday 15/Jan

TIME	SESSION	SPEAKER PROFILE	COMPANY / INSTITUTION	TALK
08:00 h		**WELCOME AND REGISTRATION**		
09:00 h	Packaging, assembly & test	**Torsten Vahrenkamp**	ficontec Service GmbH	Photonic device assembly and test solutions for the next generation integrated optics
09:30 h	Packaging, assembly & test	**Gunther Vollrath**	Aifotec AG	High throughput assembly of photonic devices
10:00 h	Packaging, assembly & test	**Andrea Annoni**	Cordon Group / Linkra	Photonics packaging for Telecom, Aerospace, Defense and more
10:30 h	Packaging, assembly & test	**Joost Vankerkhof**	PHIX PA	Automating packaging and assembly for hybrid photonic integration
11:00 h		**COFFEE BREAK**		
11:30 h	Sensor technologies	**Peter Goetz**	AIM Photonics	AIM Photonics integrated technology for chemical and biological sensors
12:00 h	Sensor technologies	**Martijn Heck**	Aarhus University	PIC technologies for gas sensing
12:30 h	Sensor technologies	**Moritz Baier**	Fraunhofer HHI	InP PICs for sensing
13:00 h	Sensor technologies	**Pere Pérez-Millán**	FYLA	Ultrafast Fiber Lasers for Industry
13:30 h		**CLOSING & LUNCH**		
15:00 h		**Business to business meetings 3**		

About PICs4All

PICs4All (Photonic Integrated Circuits Accessible to Everyone) is a Coordination and Support Action from the EU H2020 ICT-27-2015 programme. The prime objective of PICs4All is to increase the impact of photonics and enable an access to the advanced photonic integrated circuit (PIC) technologies for academia, research institutes, SMEs and larger companies. This will be achieved by establishing a European network of Application Support Centres (ASCs) in the field of PIC technology. The main task of the ASCs is to lower the barrier to researchers and SMEs for applying advanced PICs, and thus to increase the awareness of the existence of the worldwide unique facility provided by JePPIX (InP and TriPleX PIC design, manufacturing, testing and packaging).

The main PICs4All objectives:

- scouting, acquiring and supporting new PIC users;
- promoting the use of the European photonic integration platforms;
- strengthening Europe's industrial lead in the business of integrated photonics;
- bringing together academia to explore photonics and promote its critical importance.

The PICs4All consortium:

- actively explores the market, searching for new application fields for ASPICs;
- offers guided access to Multi-Project Wafer runs for ASPIC fabrication;
- provides support in ASPIC design and prototype testing;
- connects users to professional design houses and packaging vendors;
- organizes ASPIC design courses and workshops.

PICs4All ASCs will actively support users in taking full advantage of the PIC-technology and its deployment in existing and new applications. For this reason, it combines two targets of an EC supported CSA, i.e. enabling the access to advanced design, fabrication and characterisation facilities, and stimulating the innovation potential of users, esp. SMEs, by supplying hands-on support in developing their business cases. All this is achieved by connecting existing PIC-development infrastructure throughout Europe and by lowering the risk at the investment stage in PIC development by enabling access to low-cost prototyping.

Fact and Figures:

Project reference:	EU H2020-ICT-27-2015 CSA no 687777
Project acronym:	PICs4All (Photonic Integrated Circuits Accessible to Everyone)
Timeline:	1 January 2016–31 December 2018
Budget:	1 051 895,- EUR
Website:	http://pics4all.jeppix.eu
E-mail:	pics4all@jeppix.eu
Coordinator:	Kevin Williams (TU/e) K.A.Williams@tue.nl

Partners:

The PICs4All consortium consists of nine academic research institutes with a good regional balance throughout Europe, enabling Application Support Centres in Germany, United Kingdom, France, Denmark, Spain, Poland, Italy, Greece, the Netherlands. It also includes the EPIC association located in France and Berenschot in the Netherlands.

Members of the consortium:

Eindhoven University of Technology
University of Cambridge
Universitat Politècnica de València
Politecnico di Milano
Warsaw University of Technology
Technische Universität Berlin
Aarhus University
Telecom ParisTech
National Technical University of Athens
European Photonics Industry Consortium
Berenschot

editors: Ryszard Piramidowicz, Stanisław Stopiński
dtp: Hanna Sater