Indium Phosphide Integrated Photonics: From Research to Manufacturing

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Technische Universiteit **Eindhoven** University of Technology

Where innovation starts

TU

Photonic Integration

- Photonic integration is the art, science and technology of combining many optical device elements in a single circuit, interconnected by waveguides
- Technologies include
 - Compound semiconductors (InP, GaAs, ...)
 - Integrated light sources, detectors, modulators, …
 - Silicon photonics
 - Including SiGe, hybrid/heterogeneous integration with III-V
 - Dielectrics
 - SiO₂/Si₃N₄ on Si, LiNbO₃, ...
 - Low loss, wide wavelength range
- We emphasize InP-based photonic integration here, in view of its high performance, comprehensive functionality, compatibility with fibre-optic wavelengths and commercial importance





Examples of InP Photonic ICs (PICs)

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More than 400 PICs fabricated in JePPIX foundries













Microwave photonics beam-former







Fibre to the home







Many different application fields



Telecommunication, data communication, precision metrology, automotive, medical diagnostics, crop monitoring, ...





Reducing Barriers to Entry

Reduction of prototyping costs by:

- Fabless Business Model
- Shared Fabrication Costs
- Essential Building Blocks
- PDK based prototyping



- Historically InP PIC-based business has mainly been the preserve of vertically integrated companies, who have developed very capable processes for their own products
- Open-Access initiatives such as JePPIX are now making this technology more widely available







Generic Integration Philosophy







Joint European Platform for Photonics Integration of Components and Circuits **JePPIX**

Covering the whole value chain for photonic <u>ASICs</u> development since 2006:

- CAD/PDK tools
- Design Houses
- Foundries (InP, TriPleX)
- Packaging / Assembly
- Testing
- Broker / Access

www.jeppix.eu



Over 400 designs fabricated to date for more than150 customers, serving a wide range of applications

Broker



JePPIX Ecosystem







MPWs: From ideas to prototypes

http://www.jeppix.eu/multiprojectwafers/











Commercialization Example: Fibre Sensors for Aerospace

11

Technische Universiteit

University of Technology

Distributed temperature and strain measurement with embedded fibres and PIC readout circuits





JePPIX Vision



JEPPIX ROADMAP 2018



Market potential for InP PICs

- Hybrid InP-SiN integration
- Heterogeneous InP-Si electronics
- InP membrane on Si



Roadmap is available for download

http://www.jeppix.eu/vision/





The missing links: steps to full production



Major steps now underway to establish manufacturing pilot lines as steps to full production









Indium-Phosphide Pilot Line for up-scaled, low-barrier, self-sustained, PIC ecosystem





InPulse enables fabless businesses to transition from first concept experimentation to industrial prototype and pre-production with shared technology investments









InPulse will bring a new level of maturity to all aspects of open access PIC manufacturing

- 1. Create manufacturing process design kits by using smart testing to efficiently collect manufacturing statistics
- 2. Increase capacity for open access industrial prototyping and systematically improve performance of the building blocks
- 3. Establish effective operational procedures to manage all aspects
- 4. Validate the pilot line with two experienced Participants to validate and stretch the platform **performance beyond state of the art**
- 5. Demonstration through tens of external user designs
- 6. Establish a **sustainable business model** with a resilient industrial eco-system to ensure continued open-access after four years
- 7. Support businesses as they scale to volume production







Integrating the Photonic Ecosystem









InPulse Project Phasing







Design automation



Faster and fewer design cycles using advanced design tools and robust, well-developed PDKs







IP development







Commercial Design houses:

- Photonic IC
- Building Blocks for PIC designers
- PDKs for foundries
- Generate IP on top of generic technologies
- Shorten concept to prototype time





Scaling production





- Three complementary InP PIC fabs
- Reduced time in fab
- Higher frequency wafer starts
- Higher predictability, high performance metrics





Measurement automation





- High throughput test to create manufacturing grade PDKs
- Tight coupling to design tools through standardised building blocks
- Test-as-a-service offer for lab-less designers





Packaging and systems integration





- PICs to package
- Test to design
- Measurement to process centering















InPulse Pilot Line Partners





www.inpulse.jeppix.eu









Open-Innovation Photonics pilot for North West Europe

Key Information – OIP4NWE

- Lead partner organization: Eindhoven University of Technology
- Timeline: 2018-2022
- Total project budget: € 13.9 million
- ERDF-funding: € 8.3 million
- Thematic Priority on "INNOVATION"
- Countries involved: The Netherlands, Germany, France, Belgium, Ireland, United Kingdom











- Establish world-class and world-leading fabrication capabilities
- Set up an open access pilot line for InP "Photonic Integrated Circuits" (PICs)
- Validated TRL7 pilot line with improved throughput and cost
- Provide vouchers to SMEs for technology support
- Establish self-sustainable operation of an open innovation PICs ecosystem in Europe









Project Partners









OIP4NWE Timeline



The Transnational Technology Network











Conclusions

- InP PIC technology is a key enabler for today's systems
- Generic processes and open access platforms are becoming available, opening up new markets
 - Extremely wide range of applications
- Processes demonstrated to be extremely capable, high yield and performance
 - Until now, mature production has been mainly confined to vertically integrated players, who have made big investments to conquer specific markets
- Pilot line initiatives will bring open access PIC design and manufacturing to a new level, ready for transition to highvolume production
- Europe and The Netherlands once again leading the field!





Many thanks to my colleagues in The Netherlands and elsewhere for their contributions to the development of integrated photonics, to the pilot lines and for material presented here

And thank you for listening!

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www.jeppix.eu, www.inpulse.jeppix.eu, www.oip4nwe.eu

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