

# Research integration and technology platforms in the Network of Excellence ePIXnet on photonic integration

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**Abstract** *ePIXnet is a Network of Excellence with a focus on photonic integrated circuits. Its objective is to serve the academic and industrial research community by building a world-class research infrastructure and to make it accessible. This is done through the creation of technology platforms.*

## Introduction

The integration of complex or high performance photonic functions will become the key enabler for a cost-effective and ubiquitous deployment of photonics in a wide range of applications, including ICT, sensors and biomedical applications. The technologies needed for photonic integrated components and circuits are characterised by high investment and exploitation cost however. This calls for more integration of research at an international level, whereby a large number of distributed research actors can contribute to top-level research by relying on complementary skills of other research actors. This is actually not unlike the on-going consolidation in the photonics industry in which the industrial actors are evolving from vertically integrated companies to focused core-business-oriented companies in a horizontally layered industry model.

On September 1, 2004 the European Commission launched, as part of the 6<sup>th</sup> framework program, a Network of Excellence (NoE) with a focus on photonic integrated components and circuits. This network, called ePIXnet, consists of 50 partners, both full and affiliate, with a good mix of universities (22), research institutes (11) and companies (17). The network has a contract for 4 years<sup>1</sup>.

The mission of ePIXnet is three-fold. The first – and main - objective is to stimulate the restructuring of the photonic integration research community from a model of independent or collaborative research towards a model of integrated research. It is the ambition of the network to have a strong and durable impact - beyond the duration of the contract - on the quality and quantity of research in integrated photonics through the creation of a horizontally layered research capacity model. The second is to stimulate training activities as well as integration of educational programs. The third objective is to

stimulate new opportunities for photonic integration in a wide range of application domains.

While the mission of the network relates more to structuring of the research community than to the research as such, this structuring can only become real in the actual research and its progress is, at least in part, monitored by means of the research achievements. These research activities cover five major interdependent themes, from basic enabling technologies to advanced applications. The scope of the network is focussed on those activities in which photonic integration technologies play a key role in advancing component and system performance. These five themes are briefly described hereafter.

### *Theme 1 Towards technologies for photonic (very) large scale integration*

This theme deals with the core technologies behind photonic integration, including monolithic integration, wafer-scale heterogeneous integration and die-level hybrid integration. Only few labs have a complete range of state-of-the-art technologies for photonic integrated components and the same holds for special technologies such as wafer bonding. Both factors call for integration of research.

### *Theme 2 Nanophotonics for advanced integration schemes*

Theme 2 focuses on wavelength-scale structures with high-index contrast, such as photonic crystal and photonic wire structures as well as microcavities. These nanophotonic structures hold great promise for ultra-compact circuits and new functionalities. However the technologies for nanophotonics require nanometer-scale accuracy and are not widely available. This calls for integration of research.

### *Theme 3 Advanced materials for photonic integration*

New materials, such as quantum-dot materials and

self-organised semiconductors, are of key importance in a variety of components with high performance. The demanding technologies needed for research on those materials are the focus of this theme. As in theme 1 and 2 the complexity and cost of those technologies are the key motivation for integration of research.

*Theme 4 Integrated and integratable light sources*

Many photonic systems depend critically on a high performance light sources: an ultra-short pulse source or a wavelength tuneable source or a single photon source etc. In many cases high performance is achieved by means of integration of sub-components. In other cases the source needs to be integrated with other elements of the system. Integration of research in this field is motivated by the fact that the know-how and/or infrastructure needed to advance this field often surpasses the capabilities of one group. The characterisation – for example - of some of these light sources requires very complex measurement set-ups.

*Theme 5 Ultra-wide band photonic signal processing*

The last theme deals with components and circuits for photonic signal processing, including ultra-fast digital optical logic, signal regeneration and conversion and all-optical routing and switching. As in theme 4 the progress in this field calls for integration of a variety of capabilities, certainly in those cases where a rather unique technology or characterisation facility is needed.

**Decision making processes in the NoE ePIXnet**

A project with more than 30 partners necessarily requires appropriate approaches for decision making. In ePIXnet a four-layer system has been implemented and operates rather smoothly. At the heart is the network office with a coordinator, a deputy coordinator and a secretary. They communicate directly with the coordinators of the Joint Research Activities and the Integration technology Platforms (see below) and they prepare all network-related decision-making processes. For decisions to be taken they forward a proposal to the Steering Committee of the Network, which consists of 8 persons who are partners of the network and who have been elected for that role by the network. The Steering Committee makes decisions about all implementation details that are consistent with the overall agreed plans and the overall budget distribution. For major changes in the planned work or in the budget or in the network composition the Steering Committee's decisions need to be approved by the General Assembly, which is the assembly of all network partners. This body has the highest authority in the network and is consulted a few times a year.

This four-layer management approach combines flexibility with consensus-based decision making. To

make this work it is very important to have a clear and well-defined vision and strategy about the basic objectives of the network and about the priorities to achieve those. This is essential to make sensible choices for every decision and to communicate these decisions to the large partnership



**Phase 1 of ePIXnet: 2004-2006**

During the first phase of ePIXnet the research activities were structured by means of two types of activities. The first type is the Facility Access Activity (FAA). In this type of activity a particular technology or infrastructure of high complexity and cost is used by a set of partners to execute joint research. The second type is the Joint Research Activity (JRA). In this type of activity a set of partners has a range of complementary skills and infrastructure to progress research in a particular field.

Both FAA and JRA activities, as defined for the first two years of the network operation, are listed hereafter:

- FAA1 : Access to monolithic integration of InP-active and passive devices
- FAA2 : From 2- to 2.5-dimensional microphotonics based on heterogeneous integration technology and 2-dimensional photonic crystal membranes
- FAA3 : Nanophotonic circuits in SOI based on CMOS-compatible process technology
- FAA4 : Single-Photon emitters characterisation facility
- FAA5 : Access to characterisation facilities for ultrafast photonic switches
  
- JRA1           Lithography limits for nanophotonic devices
- JRA2           Photonic crystals: loss analysis, tuning and technology
- JRA3           Quantum dot arrays with engineered linear and nonlinear optical properties
- JRA4           High speed transmission based on chirpless quantum dot laser source
- JRA5           Multi-GHz semiconductor light sources
- JRA6           Picosecond pulse sources for ultra-high bit-rate communication
- JRA7           External Cavity Lasers Built by hybrid integration in micro-machined packages
- JRA8           Exploration of device concepts for

- all-optical switching at high speeds
- JRA9 Photonic switches and modulators based on surface acoustic waves

All of these activities originated from a bottom-up definition process and were selected on the basis of peer review (within the network). They mostly built upon existing activities and projects from which they got the required funding to actually do the research. The network provided additional funding to strengthen the degree of collaboration, networking and interdependence and to build trust in the research community.

### **Moving towards Technology Platforms: phase 2 of ePIXnet (2006-2008)**

During the course of the first phase of ePIXnet it was recognised that the original approach was an important step towards durable research integration, but that to improve its effectiveness and durability a restructuring building upon the approach developed in phase 1 was needed. Therefore a more ambitious plan was set up for the second phase of the program, which would be to create Integration Technology Platforms for photonic integration and to organize the joint research activities in connection to those platforms.

The Integration Platforms were defined along a vision outlined hereafter:

*An Integration Platform is a facilitator for advanced research and innovation in a particular sub-field of photonic integration in which the use of complex and highly specialized infrastructure and of the associated know-how is of key importance. The platform essentially allows for joint research through (cost-sharing) access to unique and expensive facilities and for knowledge transfer between all research actors involved "*

*The platform consists of the partners that are owner of the advanced infrastructure and know-how. It includes the owners of the equipment, but also partners that play a key role for the functioning of the platform, e.g. owners of advanced design or characterization facilities that are crucial for the platform. In the case that the platform concerns advanced characterization facilities it may, for example, also include one or more expert groups on structures to be characterized. The platform is led by a permanent staff member (possibly with help of a post-doctoral researcher) belonging to one of the ePIXnet partners.*

*A platform should cover access to all the specialized facilities that are relevant for research activities in the sub-field. It should be able to support a range of*

*research activities, but it should be sufficiently coherent, i.e. a variety of activities should be able to make use of the same infrastructure and the same (or at least very similar) processes. These platforms embody the durable integration that is a major target of ePIXnet, with the research activities being focused on project-like activities making use of the integrated platform infrastructure. It should be feasible to embed these activities in the regular national and European funding structures.*

*A mid- to long-term goal beyond the common use of expensive technological research facilities will also be to promote and advance the (industrial) foundry concept, similar to the current situation in Silicon micro-electronics. Therefore the coordinator will establish a relationship with potential owners of such foundries with the aim to identify all the issues that arise when moving towards a foundry scenario. Compatibility and standardisation of processes will be very important in this context. The expectation is that a foundry model could indeed work if on one hand there is a critical mass of users and if on the other hand the foundry does not have to deal with individual (research) users. The platform could play a key role as an interface between this user group and the foundry...*

As a response to the call for Integration Technology Platforms by the ePIXnet Steering Committee, the ePIXnet secretariat received 21 proposals for platforms. The Steering Committee has used the following criteria to select platforms with a high potential for research integration:

- Platforms should be strategically relevant for the field of photonic integration
- They should be based on very expensive infrastructure (and associated non-trivial know-how), which should be rather unique.
- The platform offers relatively stable and mature processes.
- The functionality of the platform should be precisely defined.
- The platform functionality should have an economic viability (during and after ePIXnet).
- The key partners (and the coordinating partner in particular) should be credible on the basis of past performance and should be recognized leaders with respect to the functionality of the platform.
- The access to the platform should be manageable.
- Each platform should cover a sufficiently complete set of facilities and should have a strong group of users around it, not necessarily restricted to ePIXnet members.
- The number of platforms should be relatively small.

The steering committee has decided to launch 3

photonic integration technology platforms and 3 supporting platforms:

Photonic integration technology platforms:

- InP photonic integrated devices
- Silicon photonics platform (CMOS-compatible)
- Nanostructuring technologies for photonic integration

Supporting platforms:

- Packaging platform
- High speed characterisation platform
- Modelling platform

As soon as the platforms were defined, a project-internal call was launched to propose research activities in connection to the platforms. The criteria for selection by the Steering Committee of these activities were:

- Scientific relevance
- Degree of research integration (better or more research by building upon existing research activities and exploiting win-win situations made possible through ePIXnet, junior exchanges, senior exchanges...)
- Degree by which platforms are involved
- Direct benefit to as many partners as possible.
- Value for money

On the basis of these criteria 15 new joint research activities were defined as listed below:

- JRA PhC infil: Infiltration and optical properties of photonic crystals.
- JRA Sensors: Compact integrated optical sensors for visible and IR applications
- JRA SAW: Photonic Switches and Modulators based on Surface Acoustic Waves
- JRA Short Pulses: Short pulse dynamics and

applications of integrated semiconductor devices

- JRA QD-Arrays: Quantum dot arrays with engineered linear and nonlinear optical properties for selective optical signal processing
- JRA iPQD: Indium Phosphide Quantum dot Devices
- JRA Signal Processing: Integrated devices for optical signal processing
- JRA SOI pasive : Passive nano- and micro-photonic SOI circuits
- JRA SOI modulator: Route to develop high performance compact silicon modulators
- JRA FIB: Focused Ion Beam etching for Photonics
- JRA NIL: Joint Research on Nanoimprint Lithography for Photonic Applications
- JRA SOI non linear: Nonlinear integrated SOI nanophotonic devices

Both the 6 platforms and the 15 new JRA's start on September 1 2006.

### Conclusions

While original expectations for ePIXnet were very diverse, it is becoming clear that the network is on a solid track to achieve what it is meant for : durable integration of research in the field of photonic integrated components. The creation of technology platforms is seen as a key tool to achieve this goal. By the end of the network contract these platforms should have gained a large degree of momentum and visibility.

### References

1. ePIXnet website: <http://www.epixnet.org>