Photonics PPP
Photonics21 Research and Innovation topics for the Horizon2020 PPP Work Programme 2016-2017

WORK GROUP No: 6

Per work group

1. Research topics: Time to market ~6-10 years
2. Innovation topic: Time to market ~3 years (optional)

Note: This document contains four proposals, two for Research topics and two for Innovation topics.

17th October 2014

1 Number of work group proposals on research/innovation topics is not limited
I. **Preamble:**

There will be at least one call per year where Research and Innovation (R&I) actions under the Photonics PPP (and under the cross-cutting KETs WP) could be supported by the EC. There is therefore a need for:

1. Defining in much more detail than the level of description provided in the SRIA each of the specific R&I actions which could be candidates for inclusion in the ICT WP 2016-2017.
2. Prioritising such candidate R&I actions (incl. the definition of the respective budget figures) for their inclusion in the ICT WP 2016-2017.

The purpose of this document is therefore to request, from each of the WG, specific inputs with regard to items 1 and 2 above. Separate inputs are requested for the research actions (topics) and for the innovation actions.
II. **Description of the area where Horizon2020 funding is requested (1 page max)**

1. **Area to be addressed**

   - **Application domains**: Photonic Components and Photonic Integrated Circuits, providing capabilities for products in a wide variety of application domains.

   - **Targeted applications**: Data communication from long reach to short reach; next generation supercomputers and data centres; Sensing and metrology systems, e.g. for medical applications, instrumentation and equipment, structural health monitoring, bio-sensing and safety systems, automotive, aerospace and consumer products.

2. **Position of Europe in the application domain (research, industry), foreseen evolution from now to 2020+: What is the challenge (in Europe) in the respective area today?**

   European research is in a worldwide leading position regarding photonic integrated circuits (PICs) at the chip level. Actual industrial use of PIC technology, especially outside telecom/datacom applications, still has significant upside potential:

   - Packaging, often representing more than half of product performance and costs, is connected with high entry costs
   - Some core optical functionalities and wavelengths are not yet available in PICs
   - Technologies for higher-density, lower-power components and circuits for next-generation PICs are not yet developed
   - Photonic software design and simulation tools and Process Design Kits need significant improvement in order to effectively support advanced PIC design
   - Integration with electronics is at an early stage; advanced electronic/photonic integration schemes are not yet in production
   - The successful PIC foundry model is only available at the chip level, not yet for package level.

   As the European strength in photonics often lies in the mid-sized companies, reducing entry barriers by pooled research and pilot line efforts is especially important.

   We note that while the European position is strong, major investments presently underway in other regions, notably in the USA and in Asia, will lead to a highly competitive scenario in the next few years. This underlines the need to consolidate and build on European strengths and bring these capabilities to market-readiness in a very timely manner.

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2 For horizontal work groups focus can be on generic technology domains
3. **What needs to be done?**

_Necessary steps to overcome the problem described, including the type of activity (research, innovation, other)?_

a. Develop generic assembly and packaging concepts for photonic integrated circuit-based components, compatible with a wide range of applications (Research activity)

b. Further extend optical functionalities of PICs (e.g. polarization handling, isolation, non-telecom wavelengths) and develop optical semiconductor devices with new functionalities and decreased footprint and power consumption for introduction into later PIC generations (Research activity)

c. Establish assembly and packaging pilot production lines providing low entry barrier access to low and medium volumes and capable of being scaled up to high volumes (Innovation activity)

d. Support and develop foundry production capabilities for next generation PICs and electronic/photonic ICs (Innovation activity).

Whilst all of these topics are of major significance and will yield important results for European industry, if priority choices have to be made, we recommend a focus on item (b) for research and item (c) for innovation.

4. **When should it be launched and how much funding is needed?**

_In which year should the area be called: as part of WP 2016 or WP 2017?_

a,c WP 2016

b,d WP 2017

Funding requirements are discussed individually in the following sections.
III. Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2016-2017

[PROPOSAL a] Generic Assembly and Packaging Concepts [RESEARCH]

1. Description of the topic, objective:
   New concepts for generic assembly, packaging and module integration for photonic integrated circuits, compatible with a range of applications. Targets include:

   - Extending knowledge/techniques from the silicon IC world to photonics, introducing, for example, optical interposers, 3D vias, 3D assembly, chip/wafer stacking
   - Developing massively parallel high speed electro optical connectivity solutions, targeting e.g. 40x50 GHz, including electro-chip to optic-chip, electrical package feedthrough and optical feedthrough to fibres or embedded waveguides in electro-optic circuit boards
   - Develop generic packages for high optical complexity PICs, thus lowering entry barrier into low volume sensor/medical markets
   - Optical connection of PIC chips and new concepts for cost effective manufacture
   - Extending to include new materials and environments (e.g. liquid, harsh, biological, non-hermetic)
   - Extending integration to enable smart systems based on the combination of photonics with other elements, e.g. electronics, MEMS.

2. Relevant Research & Innovation present in Europe?
   European research is in a world-leading position regarding photonic integrated circuits (PICs). Its strength towards e.g. the USA is especially the collaboration between companies and research institutes with complementary skills. European SMEs and larger companies active in the datacom/telecom industry have reached leading positions worldwide in their respective high-value applications.

   Migration of production to countries with lower labour costs is presently unavoidable in electronics and high volume photonics, given existing technology. The proposed R&I targets automation and elimination of the labour intensive part, thus making European production cost-effective. European companies have world-leading capabilities in photonics, precision engineering, production tools and automation, thereby providing a comprehensive set of skills and resources to make this transition possible.

3. Impact on European economy, employment
   The proposed action will secure European industrial leadership in photonic applications and technologies, and extend European leadership into applications where assembly and packaging represents a major share in system performance and cost. The target is to keep the full value chain for high-value applications in Europe and to obviate migration to countries with lower labour costs through continuous innovation.

   Target markets include telecom and datacom ($16B 2012, worldwide, ref. 1) and a significant share of the optical sensor market ($7B 2014 worldwide, CAGR 15.9%, ref. 2).
4. **Impact on societal challenges**
   The internet is an essential ingredient of everyday work and life. Our research will make the internet faster and more reliable and help to ensure that the ever-increasing demand for bandwidth and capacity can be met. EU-based manufacturing will also help to avoid potential security issues related to dependency on countries outside the EU. Improved datacom optics will help to build faster computers, thus enabling new medical and environmental research. Improved photonic sensors with greater functionality and addressing wide-ranging applications offer opportunities to bring advanced medical technology much nearer to the patient, resulting in better, quicker and more cost-effective diagnostics. Strengthening assembly and packaging activities will support the establishment of European Value Chains (EVCs) and ensure that product innovation thrives in Europe, benefitting European society through employment and early access to new technologies.

5. **EU added value:**
   Due to the worldwide nature of the markets addressed and the height of the entry barrier to qualified industrial applications, investment at EU level is vital. European Value Chains compete well with global value chains but better coordination is needed for photonic integrated circuit EVCs, which is best achieved at the EU level.

6. **Funding:**
   EC funding available for this topic should be sufficient to support a combination of large and small projects with a total EC contribution in the region of €20M.
Photonic integrated circuit technology [RESEARCH]

1. Description of the topic: The objective is to achieve major advances in the capability and performance of photonic integrated circuit technology platforms. This encompasses forward-looking, higher-risk research up to experimental proof of concept (TRL3). To provide widest utilisation, available to the fullest range of sectors, a generic approach is required, placing a premium on availability and accessibility for the integrated circuit technologies. Anticipated technology advances include the extension to different wavelength ranges, including the mid-IR and visible regions of the spectrum, use of selective area growth for multifunction integration in PICs, wider bandgap engineering, heterogeneous integration and new approaches to small and efficient laser sources and to low-power tuning and reconfigurability, supported by advances in modelling and simulation. Circuits with improved energy efficiency, smaller footprint and with advanced functions such as isolation, polarisation handling capability, efficient nonlinear function and sensing capability are targeted. Furthermore the integration of photonic and electronic functionality using wafer-scale integration technologies is of major importance: this can be viewed as a high-performance evolution beyond hybrid/3D packaging and assembly technologies, with potential for lower cost in larger volumes.

2. Relevant Research & Innovation present in Europe
Through significant investments in a number of FP6, FP7 and regional projects Europe has established a lead in generic photonic integration technologies in InP, silicon and low-loss dielectric waveguide circuits. H2020 projects should connect to and build on the results of those projects in order to strengthen Europe’s lead in this field.

3. Impact on European economy, employment
Generic integration technology, when made available through open access foundries, can lead to a dramatic reduction of the research and development costs of advanced photonic ICs (more than an order of magnitude), which brings them within reach for smaller companies. We expect that the introduction of advanced photonic integration technologies in novel or improved products by SMEs will provide these SMEs with a strong competitive edge over competitors inside and outside Europe. Such a development will clearly lead to a strong increase of highly-skilled employment in Europe. Because of its generic character, the technology will be applied in a wide range of business areas, including telecom and datacom as well as medical, sensing, metrology and security applications. Applications engineers and PIC designers need to be actively engaged with PIC foundries to ensure that flexibility and close coordination exists in the European Value Chains for product innovation in these markets.

Target markets include telecom and datacom ($16B 2012, worldwide, ref. 1) and a significant share of the optical sensor market ($7B 2014 worldwide, CAGR 15.9%, ref. 2).
4. **Impact on societal challenges**

Photonic integration will contribute to a significant reduction of the power consumption of the internet and it supports a further growth of the internet, which is of crucial importance for the sustainability of our modern information society, as it will extend connectivity to objects contributing to the so-called Internet of Things. Improved datacom optics will help to build faster communication within and between computers, thus enabling new medical and environmental research. Improved photonic sensors with greater functionality and addressing wide-ranging applications have the chance to bring advanced medical technology much nearer to the patient, resulting in better, quicker and more cost-effective diagnostics. Strengthening assembly and pilot line packaging activities will support the establishment of European Value Chains (EVCs) and ensure that product innovation thrives in Europe, benefitting European society through employment and early access to new technologies.

5. **EU added value**

The investment in the technological infrastructure for photonic integration foundries are too large to be supported by a single company or a single country. Europe has gained its present leading position through a strong cooperation of the key players in the field, both industrial and academic, in European R&D projects. European cooperation has been crucial to gain this leading position and it will be crucial to maintain this lead.

6. **Funding**

EC funding available for this topic should be sufficient to support a combination of large and small projects with a total EC contribution in the region of €20M.
1. **Description of the topic, objective:**

   We target a pilot line for the assembly and packaging of integrated photonic components, including all stages of manufacturing through to test and qualification. Support will be provided for advanced features including RF integration, 3D assembly and integrated sensors and antennas. Topics to address include thermal efficiency, electro-magnetic compatibility, optical coupling and manufacturability. The aim is to establish assembly and packaging pilot production lines which can provide low entry barrier access to low and medium volumes, with potential for scaling to high volumes as required. The knowledge gained from this activity will be indispensable to companies contemplating the major investments required for a full-scale manufacturing activity in Europe. (Innovation activity).

   Example outputs include:
   - Parallel high speed electro optical connectivity solutions, targeting e.g. 10x25 GHz, including electro-chip to optic-chip, electrical package feedthrough, and optical package feedthrough (TRL 7)
   - Generic packages for mid optical complexity PICs, thus lowering entry barrier into low volume sensor / medical markets (TRL 7)
   - Experience of manufacturing PIC-based components for a wide range of applications, serving the needs of SMEs and larger applications-oriented companies in Europe (TRL 7).

2. **Relevant Research & Innovation present in Europe?**

   European research is in a worldwide leading position regarding photonic integrated circuits (PICs). Its strength towards e.g. the USA lies especially in the collaboration between a wide range of players with complementary skills. The European SMEs and larger companies active in the datacom / telecom industry have reached worldwide leading positions in their respective high-value applications.

   Migration of production to countries with lower labour costs is presently unavoidable in electronics and high volume photonics, given existing technology. The proposed R&I targets automation and elimination of the labour intensive part, thus making European production cost-effective. European companies have world-leading capabilities in photonics, precision engineering, production tools and automation, thereby providing a comprehensive set of skills and resources to make this transition possible.

3. **Impact on European economy, employment;**

   The proposed action will secure European industrial leadership in photonic applications and technologies, and extend European leadership into applications, where assembly and packaging represents a major share in system performance and cost. The target is to initially keep the full value chain for high and mid end applications in Europe, and to obviate migration to countries with lower labour costs through continuous innovation.

   Target markets include telecom and datacom ($16B 2012 worldwide) and a significant share of the optical sensor market ($7B 2014 worldwide, CAGR 15.9%), refs. 1,2 below.
4. **Impact on societal challenges**
   The internet is an essential ingredient of everyday work and life. Our research will make the internet faster and more reliable and help to ensure that the ever-increasing demand for bandwidth and capacity can be met. EU-based manufacturing will also help to avoid potential security issues related to dependency on countries outside the EU. Improved datacom optics will help to build faster computers, thus enabling new medical and environmental research. Improved photonic sensors with greater functionality and addressing wide-ranging applications have the chance to bring advanced medical technology much nearer to the patient, resulting in better, quicker and more cost-effective diagnostics. Strengthening assembly and pilot line packaging activities will support the establishment of European Value Chains (EVCs) and ensure that product innovation thrives in Europe, benefitting European society through employment and early access to new technologies.

5. **EU added value:**
   The scope of activities involved in assembling and packaging photonic ICs, and the diversity of applications, mean that no single country has the range of leading industry and expertise which is necessary to make impact. Furthermore, the worldwide nature of the markets addressed and the very high entry barrier to qualified industrial applications require investments at the EU level.

6. **Funding:**
   EC funding available for this topic should be in the region of €20M, with corresponding cost-sharing under the Horizon 2020 rules for innovation projects. Additional funding from initiatives such as the ECSEL Joint Undertaking may also be sought and will assist in accelerating and extending the scope of this pilot line initiative.
1. **Description of the topic, objective:**
   This innovation topic addresses the need for a pilot line for photonic integrated circuits which are intimately integrated with electronic circuits. The scope of techniques includes photonic integrated circuits, the incorporation of generic electronic integrated circuits and the associated wafer-scale 3D integration. The full chain from design through to qualification should be developed, with particular attention to component libraries with matched electronic/photonic building blocks, design for test and on-wafer testing, the full chain of modelling, simulation, design and layout tools in a seamless design environment, standards for libraries and tools and a study of reliability and means for qualification. The activity aims at TRL7.

2. **Relevant Research & Innovation present in Europe?**
   Through significant investments in a number of FP6, FP7 and regional projects Europe has established a lead in generic photonic integration technologies in InP, silicon and low-loss dielectric waveguide circuits. H2020 projects should connect to and build on the results of those projects in other to strengthen Europe’s lead in this field. These skills in the optical domain are complemented by world-leading expertise in CMOS IC technology, design and development. Europe is accordingly ideally place to establish a leading position in combined electronic-photonic IC manufacturing.

3. **Impact on European economy, employment**
   Photonic integration will contribute to a significant reduction of the power consumption of the internet and it supports a further growth of the internet which is of crucial importance for the sustainability of our modern information society. Improved datacom optics will help to build faster computers, thus enabling new medical and environmental research. Improved photonic sensors with greater functionality and addressing wide-ranging applications have the chance to bring advanced medical technology much nearer to the patient, resulting in better, quicker and more cost-effective diagnostics. Strengthening assembly and pilot line packaging activities will support the establishment of European Value Chains (EVCs) and ensure that product innovation thrives in Europe, benefitting European society through employment and early access to new technologies.

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packaging activities will support the establishment of European Value Chains (EVCs) and ensure that product innovation thrives in Europe, benefitting European society through employment and early access to new technologies.

5. **EU added value:**
The scope of activities involved in the development, assembly, packaging and integration of photonic ICs with electronic ICs, and the diversity of applications, mean that no single country has the range of leading industry and expertise which is necessary to make the required impact. European collaboration is indispensable in the race to maintain leadership in the face of large investments elsewhere (USA, Asia). The worldwide nature of the markets addressed and the very high entry barrier to qualified industrial applications require investments at EU level.

6. **Funding:**
EC funding available for this topic should be in the region of €20M, with corresponding cost-sharing under the Horizon 2020 rules for innovation projects. Additional funding from initiatives such as the ECSEL Joint Undertaking may also be sought and will assist in accelerating and extending the scope of this pilot line initiative.

**Sources:**
