PHOTONICS PUBLIC PRIVATE PARTNERSHIP

Photonics PPP

Photonics21 Innovation topics (IA)

for the Horizon2020 PPP Work Programme 2018-2020

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Content

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Photonics21 Innovation Actions – Summaries

Work Group proposed action 2018-2020, extract

Work Group: 1

Title: Photonic networking for the cloud intensive solutions

The massive rise of the cloud requires optical transport to be 1000x more dynamic. An ultra-fluid network would pave the way to an optical capacity marketplace, where anybody could buy capacity or even a new (virtualized) network to set up new service on-demand in a fraction of a second. Today's optical networks are still highly static (reconfiguration times typ. range by weeks). Photonic components are a limiting factor.

1. **What should be achieved by the funded projects under this proposed action?**
   Projects will build upon proof-of-concept photonic technologies from previous FP7/H2020 calls to dramatically improve response time of photonic devices and subsystems, while complementing them with adequate control interfaces and monitoring functionalities to integrate the most relevant mix into a testbed emulating an end-to-end optical backbone network. Projects will an include end-to-end demonstration showcasing the conditions for a capacity marketplace or for cloud-intensive solutions, at TRL 5-6.
   Enhanced photonic components and subsystems:
   - Ultra-fast (<1ms) reconfigurable elements: transponders, switching (MEMS/WSS)
   - Fully programmable elements - preferably modular (for network slicing)
   - Photonic integrated sub-systems (for scalability and footprint)

   Optical networking mechanisms and architectures:
   - Mechanisms to reconfigure a complete optical transmission line end-to-end
   - Innovative mix of photonics technologies allowing ultralow latency

2. **What are the relevance and expected impact of this proposed action?**
   End-to-end networks enabling a fluid photonic networking marketplace will enable:
   - Removal of barriers for new applications and foster innovation:
     - Enable the Akamai, Netflix or YouTube of tomorrow to emerge in Europe.
     - Example: Click to instantiate a complete content delivery network, end-to-end;
   - European operators can lead capacity marketplace through control of their networks
   - Equipment makers will provide key building blocks integrated in full solutions.

   Thus, the novel blocks and solutions can crystallize into improved business opportunities in Europe by reinforced cooperation along the value chain.

   Societal impact: Cloud-computing to influence advanced applications/services to the whole population and social entities, thereby influencing health, demographic change and wellbeing; Secure, clean and efficient energy; Smart, green and integrated transport.

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Work Group proposed action 2018-2020, extract

Work Group: 1 & 6

Title: Enabling automated mass manufacturing of datacom photonics in Europe

1. **What should be achieved by the funded projects under this proposed action?**
   The projects should demonstrate, at TRL level 5-7, the capability for automated mass manufacturing of datacom photonics in Europe. Key goals are:
   - Establish European manufacturing consortia covering the whole value from chip manufacturing to photonic/electronic integration chain through to packaging and testing, and involving end-users
   - Drastically reduce the manufacturing cost of Photonic Integrated Circuit (PIC)-based optical transceivers to enable a massive deployment in datacenter (DC) environments.
   - Demonstrate optical transceivers with transfer rates above 1Tb/s at competitive costs according to the interconnection distance (i.e. <1$/Gbps between racks and <0.1$/Gbps inside racks)
   - Support companies in shifting from photonics R&D and prototyping to low-cost mass manufacturing in Europe
   - Leverage the value chain set up for Datacom photonics to produce also other products, such as telecom and sensor components.
   - Strengthen the value chain by playing an active role in standardization bodies

2. **What are the relevance and expected impact of this proposed action?**
   Automated fabrication is mandatory to relocate optical interconnects components manufacturing from low labour costs countries to Europe. Europe is very well positioned with key assets such as excellent integrated photonics R&D labs and institutes, chip foundries, equipment manufacturers, optical packaging companies and end-users in the Datacom sector. Public authorities in other regions of the world are heavily investing in R&D to enable large scale manufacturing, like for example the US initiative AIM Photonics, supported by more than 610 M$ in public and private funds. EU investment is necessary to reach a critical mass at European level and to maintain European technology at the forefront of developments and applications.
   These projects will complement existing pilot lines, such as the PIC Assembly & Packaging one, by (i) covering the full value chain, including chip manufacturing, testing and system integration, (ii) having a product-oriented approach starting from end-users requirements and targeting primarily cost-sensitive markets.
   The complete value chain, from chip manufacturing (Photonic IC and Electronic IC) to integration of optical transceivers in Datacom products is available in Europe, and ready to exploit the results of the action.

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Work Group proposed action 2018-2020, extract

Work Group: 3

Title: Photonics enabled, more accurate quantified diagnosis during interventions and treatment – Innovation actions

1. **What should be achieved by the funded projects under this proposed action?**
   The projects should advance therapies towards stratified medicine by enabling or further developing:

   - Therapy and diagnostics driven therapy (including, e.g., image guidance during surgical interventions, medical laser systems etc.)
   - point-of-care diagnostic tools and instruments for minimally invasive as well as non-invasive longitudinal monitoring and/or companion diagnostics

   The corresponding devices should be more reliable and precise than current 'gold standard' methods allow, without substantially increasing the examination costs or duration. The focus is on diseases where photonics can make a difference like cancer (with the exception of skin cancer), infectious diseases and cardiovascular diseases.

   In contrast to the corresponding research action, for the innovation projects it is expected that TRL 5 has already been reached before the project starts and that the instrument to be further developed will have a completed TRL 7 after the corresponding project. Also, for the innovation projects it is mandatory that at least one medtech company must be involved.

2. **What are the relevance and expected impact of this proposed action?**
   Most European countries will see a strong demographic change in the near future with drastic consequences for the health and well-being of the European citizens and for their healthcare systems. Early detection and precise diagnostics is key to an appropriate and successful treatment. However, also treatment can be improved in several ways. On the one hand, we need gentler and stronger focused therapeutic methods. In particular, we are looking for advanced photonic methods which support surgical procedures e.g. by helping to delineate tumor borders or areas with a perfusion deficit, to guide navigation of devices, to develop new surgical tools for navigation and treatment, or to locally apply drugs. On the other hand, the challenge is to improve therapy by longitudinally monitoring the therapeutic progress while administering a drug and/or by working towards stratified medicine, i.e. to include and measure individual dispositions, including genetic dispositions, with regard to the effectiveness of drugs using photonics. Another important issue for many diseases is the aftercare phase in order to prevent a relapse. Here, it would be of advantage to detect first signs of changes in the health condition well before the symptomatic manifestation of a relapse. Detection of the health status could be facilitated by minimally or non-invasive longitudinal monitoring of biomarker panels in a decentralized manner employing photonic technologies.

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Work Group proposed action 2018-2020, extract

Work Group: 3

Title: Pilot lines for advanced optical medical devices – *in-vivo* diagnostics

1. **What should be achieved by the funded projects under this proposed action?**
   Activities will focus on one of the most promising photonics health technologies, on which Europe has heavily invested R&D wise these last decades, advanced optical technologies for ***in-vivo* diagnostics**.
   The main objective will be to create interface and acceleration conditions to transform low TRL technologies to robust medical devices answering to clinician needs. The European photonics industry must pool investments for enabling the rapid development of new products and minimizing times to market. This speed to market approach needs to include the entire value chain, from advanced research through to technology take up, pilot lines, and manufacturing platforms, in close relation to end-users. Standardization must be addressed, in particular to answer to calibration and control issues, both at component and system level.
   The pilot cases will serve as models for the specifications of future optical based medical devices, with a focus on new components (laser sources, sensors) and system integration, answering to industrial requirements in reliability, robustness and replicability.
   Activities are expected to focus on Technology Readiness Levels 4 to 5, and target Technology Readiness Level 6 to 7.

2. **What are the relevance and expected impact of this proposed action?**
   Europe's photonics industry is facing fierce global market competition and has to cope with a very high speed of technological developments in the field. In particular, advanced optical photonic technologies for health applications is a very promising field, where Europe has produced during the past decades excellent R&D results. However, industrialization is still lagging behind. Europe is experiencing the existence of many fragmented and rather uncoordinated developments between many different national and regional players. Europe suffers also from a slow innovation process for turning many good R&D results into innovative products ('Valley of Death'). This requires a joined-up approach, covering missing links in the value chain, such as assembly and packaging of photonics components.
   Expected Impact:
   - Strengthened industrial deployment of research results by promoting wide-scale cooperation and greater integration across the whole research and innovation value chain.
   - New capacity to offer to the medical community industrial quality solutions answering to their needs
   - Early adoption of standards and specifications at research level allowing smooth technology transfer to the whole industrial value chain.

   Biophotonic technologies present real competitive advantages in fields such as oncology, hematology etc. Their success rely on the integration of multiple key enabling technologies, namely, photonics, micro-nanotechnologies and system integration and advanced materials.

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Work Group proposed action 2018-2020, extract

Work Group: 3

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Work Group proposed action 2018-2020, extract

Work Group: 4 – Displays

Title: **Innovation in Ubiquitous Wearable Visualization for Citizens in a Digitized Society**

1. **What should be achieved by the funded projects under this proposed action?**

Objective is to enable **wider adoption of personal connected near-eye/in-eye augmented-reality (AR)** systems and **related business models**, from **professionals towards citizens**. This proposal is in the continuation of ICT-29-2016-IA activity that put emphasis on niche markets like industry or medical, where we expect that by 2018 wearable AR will have started to be productively used. Main goals are:

- **Establish innovation consortia** including industry and research along the **entire value chain**, from components and subsystems to end product and service providers.
- **Development of components and systems** featuring various **photonics technologies** to **enable large deployment of wearable AR**, namely: (i) compact see-through **optics** including **natural depth-of-field** view (multiple/ variable focus planes) and ophthalmic correction (ii) high-speed/ high-resolution **microdisplays** for light-field or holographic imaging, (iii) **embedded SW and HW** solutions for in-/outdoor localization, scene recognition, secure and ubiquitous connectivity, privacy protection as well as intuitive user-interaction, including human feature recognition, haptic perception and feedback, or recognition of situation awareness.
- Creation of **application scenarios** for open yet safe public environments and communities and **verification in Living Labs** including end-users.
- Development of service focused **business cases,** e.g. for lifestyle, health, sports, or social networks for safe and secure society (telecom providers, public authorities), education, autonomous driving, Smart Home, entertainment, manufacturing industry, etc.)

2. **What are the relevance and expected impact of this proposed action?**

Providing anytime secure use, non-obtrusive look-and-feel, wearable visual information including AR, and intuitive user-interaction will have a huge impact on several social challenges, namely for **security and privacy awareness for citizens** (Open yet safe and inclusive society), **personal health** (remote doctor, support of sensory impaired (visual, audio), emergency assistance), or for **mobility** (Smart transportation, personal travel advice e.g. based on crowd-sourced concepts). In a more general manner, it will **move social interaction in real world space**s enhanced by virtual information presentation (education, gaming), without getting lost in purely virtual spaces.

Large European companies are already on the **forefront of application** of wearable AR in production, training, maintenance, or logistics, and **many key components** like see-through optics, microdisplays, low power chipsets, sensors, and specific software, as well as related materials like e.g. for OLEDs, are currently developed and manufactured by highly specialized **European companies, SME's and start-up's.**

We expect the outcome of the innovation actions to enable **European system manufacturers** to bring to market **highly competitive products** by integrating wearable visualization for **systems and user-centric services** in the business cases listed above, and to build a **Europe-centered value chain** by strengthen domestic manufacturing of **optical & semiconductor components, and software** up to the already strong system integrators and end users, e.g. from **telecom, medical, sports, or eyewear** industry. The expected **market potential** is high, as shown by different studies, e.g. AR hardware revenues are expected to reach **$40B in 2020** (Digi-Capital Jul/'15). EU-level funding will ensure European companies **to compete** with US and Asia in the emerging **wearables and IoT markets**, create **high-end jobs** and cultivate a skill base in Europe. This will contribute to further foster Europe's world-wide credibility to set **high level standards** for **communication networks and data security** and to gain a leading position on that matter.

Work Group: 4 – Electronics

Title: Large volume OPV application

1. **What should be achieved by the funded projects under this proposed action?**
   Organic Photovoltaics (OPV) has been developed over the last decade with significant funding from private and public sources. OPV is now at the edge of market entry, facing the valley-of-death problem when upscaling a new technology, which has to compete with existing solutions. Thus, to make OPV a success, some more funding will be required – else most of the investments of the last decade would be wasted.

   OPV has all properties of a game-changing technology: Once upscaled, it has the chance to create huge markets up to the Gigawatt scale, combined with the fact that OPV is the "greenest" PV technology, with the smallest environmental footprint. OPV is complementary to existing PV and can be used in fields where conventional (Si based) PV has drawbacks, e.g. in weight, flexibility, or visual impression.

   The projects should develop OPV based solutions with potential for large scale deployment. The most relevant market for OPV is building integrated photovoltaics. Thus, developing scalable solutions for building materials to be used in energy efficient houses, can be the best way to overcome the valley-of-death issue of OPV. It must be taken care to fund preferably projects which focus on good scalability and potential access to high volume markets.

   To back-up these developments, further research and innovation on OPV materials will ensure that the basic technology will be kept up-to-date. As a side-effect, such developments can cross-fertilize also other technologies, such as the organic photodetector technology.

2. **What are the relevance and expected impact of this proposed action?**
   Securing the energy supply of Europe during and after the transition to a decarbonized, decentralized energy system will require significant efforts for durable, low-cost energy sources, which further must be accepted by the society. Organic photovoltaics has all the properties that are needed in this respect: Besides good progress in power conversion efficiency (now in the range of 12..13%) it has some unique properties like superior low light behavior and positive temperature coefficient, which make OPV the potential best PV technology to be used in buildings, especially in façades and light industry roofs. At the same time, OPV is a very green technology as it 1) avoids the use of rare earths or toxic heavy metals, and 2) has the shortest energy payback time (3-6 months) of all PV technologies. Large volume deployment of OPV in façades can generate huge chances for Europe's re-industrialization, as the full value chain from organic electronics, building materials suppliers and integrators is available in Europe, distributed over the whole continent. In contrast to conventional PV, OPV is still a European domain, with excellent business perspective: Large volume manufacturing in automated processes requires low workforce, but high skills – which is an ideal case for production in Europe. Thus, the projects will both help achieving EU's climate targets, as well as keeping Europe's industrial leadership.

Work Group: 5

Title: myCloudSense – Hyperspectral VIS-NMIR Sensing and Deep Learning

1. **What should be achieved by the funded projects under this proposed action?**
   For the past decade, data has been produced twice as fast as the expansion of communication bandwidth. The conclusion is obvious: Our sensors must become smart – data must already be processed at the edge! This is particularly true for photonic sensors in the VIS-NMIR spectral range ("diagnostic wavelength range"), where hyperspectral image sensors are producing huge amounts of data that need to be analyzed. The proposed innovation action focusses on pressing societal problems in environmental sensing (pollution of air, water and soil), with the aim of
   - Developing and demonstrating a portable hyperspectral VIS-NMIR sensing system connected to the cloud for data analysis, resulting in a comprehensive chemometric analysis. The resulting demonstrators are expected to exhibit TRL 6-8
   - Combining the development of cost-effective photonic systems with the practical use of advanced deep-learning algorithms, leading to "smart" sensor systems.
   - Generating insight into the "chemometric meaning" of particular VIS-NMIR measurements, paving the way to photonic IoT solutions with embedded data pre-processing and analysis
   - Exploiting the results of several European initiatives (MIRIFISENS, CHEQUERS, MIRPHAB, GRAPHENE, EMPHASIS, HYPERION, etc.) for the realization of commercially viable smart sensor systems

2. **What are the relevance and expected impact of this proposed action?**
   Smart sensing micro-systems are a key component for the forthcoming IoT revolution, for which a global market size of $400b is predicted for 2024, and $46b is the size of the device market. Particular emphasis is placed on the close collaboration between photonic system developers and big data analysts. Understanding the meaning of large amounts of photonic data through analysis in the cloud is a prerequisite for the future development of autonomous smart sensing solutions in the hands of our citizens. Our aims, therefore, include
   - Providing compelling examples of affordable, portable hyperspectral photonic measurement systems for a broad class of pollutants and personal health-impairment indicators
   - Empowering our citizens by providing them with easy-to-use instruments with which they can obtain first-hand information about the safety of their environment and potential risks for their health. This will encourage public participation of "community-based monitoring" for the creation of inventories of emitted pollutants and pollution hotspots
   - Creating strategic alliances between the European photonics and ICT sector, by providing showcase examples of how consortia with key players from both industrial sectors can work together efficiently and successfully.

Work Group: 5

Title: SensOPro – Sensor-Based Optimization of Production Processes

1. **What should be achieved by the funded projects under this proposed action?**
   Europe is the largest manufacturer of machine tools and the industry's technology leader. The proposed innovation action shall contribute key elements to maintaining Europe's leading position also in the forthcoming Industry 4.0 framework by
   - Providing integrated photonic solutions (TRL 6-8) for the factory of the future
   - Making intelligent use of all data from a production process, from the product/work-piece stream, the production facility, as well as the worker and its working conditions
   - Employing photonic and photonic-enabled smart sensors (for physical, chemical, imaging, geometrical and environmental measurements) for the exact monitoring of process and product parameters
   - Exploiting the properties and advantages of broadband/multi-modal sensing photonic approaches, to increase the measurement speed, the measurement accuracy and the user convenience, while reducing the laser-safety requirements and the system cost
   - Treating the factory floor for the first time as a whole, by a holistic data analysis from process modeling to quality assurance, where the human worker is a central element and not an after-thought
   - Gathering exact sensory data of resources (raw materials, energy, time, human involvement), of process and production parameters, environmental conditions, as well as the quality of the finished product will lead to uncompromised quality and production efficiency at minimum cost.

2. **What are the relevance and expected impact of this proposed action?**
   The EC has stated that "The industrialization of Europe is a strong pillar on which the development of new calls shall be built". SensOPro will provide the combined sensing and holistic data analysis instruments to address the four main target fields in Industry 4.0: Resources, quality, safety and costs. This will lead to
   - Retention of European industry's position by providing the essential sensor solutions required for the realization of the factory-floor of the future,
   - Supporting the European manufacturing industry with novel photonic sensing solutions – including holistic simulation and data analysis tools – to profit from the predicted CAGR of the global machine monitoring market of 7.2% (2014-2020)
   - Contributing to the creation of better and safer workplaces in integrated production processes, by suitable exposure monitoring against dangerous by-products, by increasing ergonomics, mental and physical health, as well as by reducing work-related stress levels.
   - Treating the human worker as a central part for the Industry 4.0 paradigm, enabling efficient lot-size-one production, lower-cost and higher quality manufacture, while reducing resources/raw-material requirements and production waste

Work Group: 6

Title: Photonic Integrated Circuit Pilot Line

1. **What should be achieved by the funded projects under this proposed action?**
   The project(s) should bring
   - InP integrated photonics and Silicon Photonics Generic Foundry Pilot Lines for providing open access to MPW runs and volume manufacturing of PICs that include lasers and optical amplifiers (to TRL7).
   - Process Design Kits for enabling rapid and reliable design.
   - Test-facilities for low-cost testing of yield and performance of basic and advanced components.
   - An educational infrastructure for training designers.
   - Wide adoption of the generic foundry model through easy access for companies and universities.
   - A technology and business development roadmap

2. **What are the relevance and expected impact of this proposed action?**
   Initiated by the FP6 ePIXnet Network of Excellence, Europe has taken the lead in developing a Foundry Model for design and manufacturing of Photonic ICs in InP, Silicon Photonics and dielectric waveguide technology. Through a number of large projects, e.g. EuroPIC, PARADIGM, HELIOS and PLAT4M, this approach has been carried through to the point that Europe is offering competitive foundry services in Silicon Photonics and exclusive foundry service in InP integrated photonics.

   Recently the US has launched a large project (AIM-Photonics) in order to catch up with Europe. US investments are motivated by the expectation that the foundry approach will prove important for fields like data center communications, 5G wireless networks, Internet of things, the sensor market and health applications, as well as for security and defence. Because Europe made already significant investments in this field it can keep playing an important role with more moderate investments. Although a pilot line for dielectric waveguide technology has recently been granted EC support, no support is presently in place for the higher functionality photonic integration technologies, silicon photonics and InP PICs. In order to maintain an important European role in this field it is important such a pilot line is put in place as soon as possible.

Work Group: Cross Cutting Task Force

Title: Open access to Photonics Innovation Hubs

1. **What should be achieved by the funded projects under this proposed action?**

   The Photonics Innovation Hubs provide European industry easy, open, one-stop-shop access, supported through competence centres, to services and capabilities such as expertise, training, prototyping, design, engineering or pilot manufacturing services for first users and early adopters enabling the wider adoption and deployment of photonic technologies in innovative products.

   The purpose of this action is to:-
   - Provide the photonics industry, in particular SMEs, with access to complementary expertise and capabilities which allow them to be more innovative and competitive.
   - Provide non-photonics industry with access to photonics technology in order to innovate their products, processes and business models.

   Access to Photonics Innovation Hubs must be provided in a way that:-
   - is driven by the business needs of industry that are the users of the Innovation Hubs
   - builds on technology platforms and capabilities that have previously been matured
   - includes a proactive outreach to end user sectors to increase the uptake of photonics
   - provides other complementary support such as facilitating access to other sources of financing as well as business support (e.g. market intelligence, business plan development)

   The Photonics Innovation Hubs should provide access on both a subsidized basis as well as a commercial basis depending on the scale and closeness of the activity to the market. It will build further on previous actions and give access to an ever wider and more mature photonics technologies basis that is developed in Europe (through H2020 as well as outside of H2020).

2. **What are the relevance and expected impact of this proposed action?**

   The expected impact is
   1/ to strengthen the innovation capability and competitiveness of the photonics industry by providing access to complementary expertise and capabilities
   2/ to strengthen the broader industry by accelerating the deployment of photonics in other sectors, making European industry more competitive and increasing the demand for photonics components and systems.

   This action needs to be supported atEuropean level because Photonics Innovation Hubs across Europe need to be linked together and must be made accessible by any company in any region in Europe.

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Annex – Full Proposals

WG 1 – Photonic networking for the cloud intensive solutions

I. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed

- Application domain: optical telecommunication networks
- Targeted application: highly dynamic, programmable , automated optical network

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?**

EU research is at top level on this topic and a number, if not most, of network elements and control plane bricks were developed in past or current projects, yet networks still lack programmability and automation, for the following 3 key reasons:

- A few major photonic building blocks are still missing (enablers);
- A number of building blocks that could improve network programmability and automation are missing (improvers);
- The bricks developed in past projects were not assembled within real networks, such that operators were not given the opportunity to assess the true benefits of what was developed. At-scale deployment is lacking.

3. What needs to be done?

Projects encompassing the highly dynamic, programmable optical backbone network should be set up; in particular, each project should develop the missing building blocks, reaching at least the proof-of-concept status and proving that there can be an ecosystem for such blocks, both in terms of possibility to industrialize the blocks, and in terms of exploitation by the (telecom and service) operators, and demonstrate them in a highly realistic transmission line.

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

In which year should the area be called: as part of WP 2018, WP 2019 or WP 2020?
(e.g.:
a. WP2018
b. WP2019

Photonic networking for the cloud intensive solutions

Innovation Action (IA)

Topic/context:
With the rise of cloud computing, data is increasingly created and consumed by machines rather than humans. This increasing amount of machine-to-machine traffic requires adaptation of the backbone networks at machine speed, rather than human speed. The possibility to reconfigure network resources quickly, on-demand (whether by humans or machines) will create a capacity marketplace, where network resources can be bought and instantiated on-demand. Eventually, the whole network substrate should be sliceable into independently operated network subparts with varying contours, so as to create a network market, in which not only capacity but also full networks can be instantiated and operated on demand. It should be possible to allocate capacity or even networks between data centers, data centers and access points, and between access points, with arbitrary granularity on demand on an open marketplace (pay as you consume) with bandwidth guarantees across domains and operators.

However, current backbone networks are still very rigid, with reconfiguration speed well above the second time scale, and are essentially never reconfigured except in case of upgrades or protection/restoration. In essence, optical networks are used in a “set and forget” mode. The limitations are essentially due to the speed of the photonic components used in the transmission lines, and to the restricted monitoring/feedback capability of the photonic network elements, especially when accounting for unavoidable fast changes of the propagation conditions. .

Hence, a fully programmable, proactive, human intervention-free, secure, highly dynamic automated optical network, based on novel photonic components and subsystems. Mechanisms to leverage those subsystems and achieve the vision outlined above, specifically, in terms of automation and programmability, should also be provided.
Research projects will leverage progress made during past projects to propose and implement novel photonic components and subsystems that are fast, monitored, integrated, programmable, and software-controlled (e.g., via an SDN-enabled control plane).Each project must combine **photonic components and subsystems together with operation mechanisms to emulate an end-to-end optical backbone network over a realistic (ideally, production/dark fiber) transmission lines.**

In particular, the following building blocks should be designed and developed:
- Photonic components and subsystems:
    - **Ultra-fast reconfigurable** elements (millisecond time scale or below) in particular, transponders and switching elements such as MEMS/WSS).
    - F**ully programmable** elements, preferably modular to allow for dynamic network slicing;
    - **Photonically integrated** sub-systems to overcome scalability and footprint issues (compatible with super-channels, very large port count) network;
- Optical networking mechanisms and architectures:
    - Mechanisms to reconfigure a complete transmission line from end-to-end including e.g. amplifier lines;

- End-to-end long-term security techniques designed and implemented to inherently integrate into reconfigurable networks.
- Innovative mix of photonics technologies allowing ultralow latency for improved end-user experience

Target TRL: 6.

1. **Relevant Research & Innovation present in Europe?**
   What is the positioning of EU research of this topic? With regard to the current EU industrial landscape, are the results likely to be exploited in the EU?

EU research is at top level on this topic and a number of network elements and control plane bricks were developed in past or current projects. Precisely, there is a strong research and development dealing with the virtualization and control/management of telecommunication networks, as well as with the programmability of network elements towards a software-defined transmission and networking. Also, Europe has shown important results in the development of novel and innovative photonic devices. However, progress is still needed in terms of speed of reconfigurability of the various network elements, and integration of various research efforts into a compelling end-to-end network scenario is missing. In fact, further major S&T progress and R&I investments are required to sustain Europe's industrial competitiveness and leadership in this market sector.

2. **Impact on European economy, employment**; *What is/are the concrete business case(s)? Why/how will it improve the competitiveness of the EU industry? Direct market potential [market fig.]/ impact on End user markets [market fig.];Which value/supply chain(s) does the product(s) address, which parts of the value/supply chain(s) are likely to be located in Europe? Creation of jobs in Europe;*

A fluid networking capacity marketplace will drive innovation by removing barriers for new applications such as content delivery-based services, which will simply have to click on a button to instantiate a full CDN (content delivery network). Research should enable the Akamai, Netflix or YouTube of tomorrow to emerge.
The supply chain in Europe is there (leading equipment makers and operators). Leading European operators should lead the control plane effort so as to create a capacity marketplace. Leading equipment makers should lead the data plane effort, and leverage or exert leadership on their suppliers to provide the key building blocks to be integrated in full network solutions. Thus, the novel blocks and solutions can crystallize into improved business opportunities in Europe by reinforced cooperation along the value chain.

3. **Impact on societal challenges**

Societal challenges will come from the novel applications made possible by an ultra-fluid network substrate. A widespread adoption of the programmable network and (the development of) the related key enabling technologies entails the development of a cloud-computing ecosystem capable of delivering novel advanced applications/services to the whole population and social entities. This fact implies a radical departure in the organizational models for work and social relations, becoming the seed of a transformation process that facilitates societal inclusion, involving private/public entities. The consequent strengthening of ICT as transversal technology would consolidate it as the main driver of change in key European economic sectors.

4. **EU added value**: *Need for EU investment rather than national or local investment? Why should it be funded at EU level?*

For scale and efficiency, a European capacity market should be the target, not a national capacity market. Hence collaboration between operators across national borders is needed. In addition, to target the proposed objectives, there are many technical challenges that require knowledge in the fields of photonic devices, optical communications/networks, information security and techno-economic analysis. This results in a relatively large and complex scenario to be addressed. Thus, no single country has the full eco-system from operator to equipment maker to basic photonic building block, able to reach the required level of expertise and knowledge (at least not fast and efficiently enough) for developing a solution.

5. **Funding**: *What could be the share of financing requested under Horizon 2020 compared to the overall investment required (only for innovation actions)?*

Funding of around 30 M€ starting in 2017-2018, comprising 2-3 large scale projects (6-8 M€) involving a multiplicity of operators and 3-4 small scale projects (3-5 M€); All projects should include end-to-end demonstrations.

Full Proposal: WG 1 & 6 – Enabling automated mass manufacturing of datacom photonics in Europe

I. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed

- Application domains[1] Communication (results can be later applied also in sensing, computing etc.)
- targeted application : Automated low-cost manufacturing of optical interconnect components for data communications

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?**

Europe has been very successful in establishing photonics companies including SMEs, creating scientific results in photonics and in setting up cost-sharing multi-project wafer (MPW) run services with related brokering and design services. These results support companies around the world to develop product prototypes, to do long-term research towards future products and to even get small-volume production done. However, these results have been much less suitable for taking the important step from product prototypes and small-volume production into mass production that is crucial for the commercial exploitation of the European R&D efforts in the large scale. There is presently a gap between photonics prototyping and low-cost mass manufacturing – also globally. To ensure that the benefits from the long-term investments into European photonics R&D occur in Europe it is important that this gap is filled first in Europe. Small and large companies are now looking for possibilities to launch large volume photonics manufacturing and we should ensure that solutions for this can be found Europe. Presently there are two barriers for this. Firstly, the fabrication facilities that offer R&D, prototyping and small-series services in Europe are not presently able to expand their offering to low-cost mass production. Secondly, the volume manufacturing companies in Europe (and elsewhere) are not interested in investing into photonics manufacturing until the volumes reach a critical mass.

3. What needs to be done?

New innovation actions are needed to support companies in shifting from photonics R&D and prototyping to low-cost mass manufacturing in Europe. This is most critical for those cost-sensitive products that cannot be first manufactured in low volumes and with high costs. Optical interconnects in data centers or between data centers are the most important example of such a market where one needs to jump directly to large volumes and automated low-cost manufacturing methods in order to be successful. Therefore Europe should invest into such innovation actions that allow companies to start producing photonic components and systems for data center interconnects in large volumes and at low costs. For this purpose wafer processing, testing and packaging needs to be automated so well that Europe remains competitive with respect to countries with lower labour costs. Once this is achieved for this first application area the same manufacturing lines can be used to produce also other products, such as telecom and sensor components.

The concrete innovation actions to reach this aim at supporting the existing fabrication facilities to expand their activities from R&D, prototyping and small-volume production into automated mass manufacturing, and supporting the existing mass manufacturing companies to expand their services to photonic integrated circuit (PIC) manufacturing, for example via technology transfer from smaller fabrication facilities..

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

[1] For horizontal work groups focus can be on generic technology domains

. WP2019 : 20M€

II. Proposal for Innovation Topic (2 page max) in Horizon2020 WP 2018-2020

The objective is to achieve major advances in chip manufacturing, photonic/electronic integration and packaging, enabling a cost-effective, automated mass manufacturing of photonic transceivers that could be massively deployed in datacenters. Action should cover all stages of manufacturing through to packaging and testing. Action should demonstrate drastic cost reduction of transceivers, and may also include process and equipment optimisation and qualification. Action should also include standardization activities. It should demonstrate strong industrial commitment, be driven by user needs and concrete business cases supported by strong exploitation strategies, and cover the whole value/supply chain and the end-users.

Innovation Topic: Enabling automated mass manufacturing of datacom photonics in Europe

1. **Description of the topic, objective:**

The direct objective is to build capabilities for automated mass manufacturing of datacom photonics in Europe. This should be done in such a way that companies around the world would choose Europe as the place for getting their photonic products manufactured in large volumes. Also, there should be an easy path, especially for European SMEs, to get their photonic products developed, prototyped and finally mass produced in Europe without the need for heavy NRE investments in the ramp-up phase.
The indirect objective is to drastically reduce the manufacturing cost of PIC-based optical transceivers to enable a massive deployment in datacenter (DC) environments. The main focus is on optical transceivers for intra-DC interconnection, on edge mounted and mid-board mounted transceivers, and Active Optical Cables. s. The IA will address validation and demonstration of new PIC-based transceivers and will be driven by user needs and concrete business cases.
The technology and the supply chain developed in the IA must be compatible with mass production of optical modules with a significant reduction of manufacturing cost. The IA will demonstrate optical transceivers with transfer rates above 1Tb/s at competitive costs according to the interconnection distance (i.e. <1$/Gbps between racks and <0.1$/Gbps inside racks). The main challenges to tackle are manifold: chip manufacturing, testing, system integration and optimization (thermal, RF, optical), high throughput automated fiber alignment and attachment. The PIC-based transceivers should also exhibit superior performances in terms of bandwidth density, size and power consumption compared to competing electrical and optical technologies.
The IA will build a sustainable ecosystem that will remain attractive for users beyond the duration of the project. Even if the primary market is Datacom, other application fields such as telecom, sensing or consumer could benefit from the outcomes of the Innovation Action. In particular, in view of the transformation of DC into Mega/Hyper DC, interconnections between DC are likely to become a high volume cost-sensitive market and go into the same revolution as it appears in short reach interconnects.

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

Flagship projects such as ePIXnet, HELIOS, PLAT4M, PhoxTrot, Firefly, COSMICC, have strengthened the positioning of European players in the field of photonic integration and optical interconnects over the past decade. Europe has pioneered with ePIXfab the concept of integrated photonics multi-project wafer (MPW) programmes - which allow organisations to cut the cost of prototyping optical chips by sharing semiconductor wafers. This has allowed an ecosystem of coordinating bodies, optical and CMOS foundries, optical chip design and simulation services, and photonic testing and packaging companies to develop and flourish. On the end-user side, industrial leaders in DC equipment are based in Europe. Thus, the complete supply chain, from chip manufacturing (Photonic IC and Electronic IC) to integration of optical transceivers in Datacom products is available in Europe, and ready to exploit the results of the IA.

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

The 21st Century is clearly characterized by the explosion of requests for computing, storage and communication capabilities. Annual global DC IP traffic will reach 10.4 zettabytes by the end of 2019, up from 3.4 zettabytes (ZB) per year in 2014 *(Source: Cisco Systems)*. Moreover, more than 80% of the traffic stays within the DC or flows from DC to DC.

Photonic integration enables a drastic level of miniaturization, while the costs of implementation and the energy consumption are remarkably cut. However, it has to be combined with cost-effective assembly and packaging processes, since packaging typically consumes a significant portion of manufacturing costs for most photonic modules.

Automated fabrication is mandatory to relocate optical interconnects components manufacturing from low labour costs countries to Europe. Europe is very well positioned with key assets such as excellent integrated photonics R&D labs and institutes, chip foundries, equipment manufacturers, optical packaging companies and end-users in the Datacom sector.

Small-volume and R&D -focused photonics fabrication facilities in Europe remain to be crucial for supporting scientific research and for enabling both small and large companies to develop new photonics products. At least some of these facilities should expand their scope into automated mass manufacturing, so that they could support companies in shifting smoothly from product development and prototyping into at least small and medium volume manufacturing, potentially even to large volumes in these facilities. For very large volumes technology transfer to dedicated mass production facilities could occur. The most critical applications are those, such as DC interconnects, where the manufacturing costs cannot be lower gradually as the volumes increase and a rapid step from small to large volume is needed.

Thanks to the ecosystem that the IA could establish in Europe, European companies should capture a significant share of this fast growing market.

4. **Impact on societal challenges**

DCs are the enablers for all types of digital goods and services driven by the digitization of European industry as well as the emergence of Internet of Things (IoT). From value-added services offered by the cloud to instant content delivery provided by edge computing, DC technologies offer unlimited opportunities affecting economic growth and access to knowledge. Mastering DC technologies is critical and essential for the European economy. Optical interconnects are also essential for scaling the performance of high-performance computing (HPC) systems, with significant impact in a broad variety of societal challenges, giving rise to breakthroughs in medicine, material design, climate modelling and more. Moreover, optical interconnects enable important energy savings to minimize the negative environmental impact of ICT, favouring the society sustainability.

5. **EU added value**:

The market targeted by the IA is worldwide, as well as the competition. The competencies requested for this action are by far too complex and too diverse to be carried out at local or national level. This is true on the technological level, for which expertise of different partners needs to be combined for reaching the goals set forward, as well as on the application level, for which the potential users are spread over Europe.

Public authorities in other regions of the world have recognised manufacturing of integrated photonic components as a key domain and are heavily investing in R&D to enable large scale manufacturing. For example, the US initiative AIM Photonics will be supported by more than 610 M$ in public and private funds. In Japan, the PETRA consortium will receive about 250M€ of total public funding until 2021.

EU investment is necessary to reach a critical mass at European level and to maintain European technology at the forefront of developments and applications

6. **Funding**:

Level of funding requested: 20M€

Most of the manufacturing infrastructure is existing (e.g. PIC foundries, CMOS foundries)

WG 3 – Photonics enabled, more accurate quantified diagnosis during interventions and treatment

WG 3 – Pilot Lines for advanced optical medical devices

I. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed

The application domain is the health and life science area. The targeted application areas are

1. Photonics enabled, more accurate quantified diagnosis during interventions and treatment; diagnostics driven therapy (including, e.g., image guidance, medical laser systems etc.) or point-of-care diagnostic tools and instruments for minimally invasive as well as non-invasive longitudinal monitoring and/or companion diagnostics towards stratified medicine.
2. Pilot lines for advanced optical medical devices
3. Next generation of biophotonic methods and tools to understand the origin of diseases.

Generally, it is expected that the resulting tools and methods are clearly superior to earlier approaches/Goldstandards.

Additionally, the following specifications are expected (for 1. and 2.):

- High sensitivity, specificity and accuracy, with high reliability (in particular a minimal number of false positives) and speed
- Robustness
- Compliant with regulations
- Safe to operate, minimally invasive
- Low cost or leading to an overall cost reduction

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?**

Photonics enabled therapy

While most of the projects in the area of biophotonics focus on either imaging or point-of-care equipment for the diagnosis of diseases, only very few projects concentrate on the advancement of therapy itself. Therapy can be improved in several ways. On the one hand, we need gentler and stronger focused therapeutic methods. In particular, we are looking for advanced photonic methods (from THz, visible light, X-ray to gamma frequencies) which support surgical procedures e.g. by helping to delineate tumor borders or areas with a perfusion deficit, to guide navigation of devices, to develop new surgical tools for navigation and treatment, or to locally apply drugs (note that further development of photodynamic therapy is generally excluded as it will usually be not possible to increase the TRL level substantially due to the need for FDA approval of the necessary drug except if approved photosensitizing agents are used and the development is focused on e.g. dosimetric planning and guidance tools). On the other hand, the challenge is to improve therapy by longitudinally monitoring the therapeutic progress while administering a drug and/or by working towards stratified medicine, i.e. to include and measure individual dispositions, including genetic dispositions, with regard to the effectiveness of drugs using photonics (this also includes, e.g., methods to determine the resistance of bacteria against antibiotics). Another important issue for many diseases is the aftercare phase in order to prevent a relapse.
The corresponding devices/methods should be more reliable and precise than current 'gold standard' methods allow, without substantially increasing the examination costs or duration.
Even better than improving therapy, would be to build on strategies to avoid diseases right from the start or to detect first signs of changes in the health condition well before the symptomatic manifestation of a disease. Detection of the health status is facilitated by minimally or non-invasive longitudinal monitoring of biomarker panels in a decentralized manner employing photonic technologies.

Pilot lines for advanced optical medical devices

Europe's photonics industry is facing fierce global market competition and has to cope with a very high speed of technological developments in the field. In particular, advanced optical photonic technologies for health applications is a very promising field, where Europe has produced during the past decades excellent R&D results. However, industrialization is still lagging behind. Europe is experiencing the existence of many fragmented and rather uncoordinated developments between many different national and regional players. Europe suffers also from a slow innovation process for turning many good R&D results into innovative products ('Valley of Death'). This requires a joined-up approach, covering missing links in the value chain, such as assembly and packaging of photonics components.

Next generation of biophotonic methods and tools to understand the origin of diseases

A third topic that is in the focus consists of advanced instruments and methods to understand the cellular reasons for the origin of diseases to stop diseases even before their onset. This is a long-term challenge, which can be solved only by sustained effort.

3. What needs to be done?

Necessary steps to overcome the problem described, including the type of activity (research, innovation, other)?
(e.g.:

1. In case of the photonics enabled, more accurate quantified diagnosis during interventions and treatment; diagnostics driven therapy, therapy monitoring, and decentralized health status monitoring we suggest both, a call for research projects to promote solutions to a TRL level where product development can pick up (1a) and a call for innovation projects to further develop prototypes close to the system level (1b).
2. The main objective will be to create interface and acceleration conditions to transform low TRL technologies to robust medical devices answering to clinician needs. Accordingly two calls for innovation projects are planned, one pilot line for *in-vitro* diagnostics (2a) and a second pilot line for *in-vivo* imaging (2b).
3. The further development for instruments to investigate further the origin of diseases should be supported by a call for research projects.

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

In which year should the area be called: as part of WP 2018/19 or 2020?

1a): WP2018, 20 million €
1b, 2a): WP2019, 20 million € each
2b), 3): WP2020, 20 million € each

II. Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2018-2020

For the topics described in the following we assume that a clear medical need stood in the beginning of the basic research and that already at that stage a clinician/physician or another end-user was directly involved.

Photonics enabled therapy

The objective concerning therapy is to further develop methods that provide the clinicians with photonics enabled tools to improve or to assess the successes of therapies, be it a surgery or the administration of a drug or a less traditional therapeutic approach (e.g. as in case of wearables/mobile health, tele-medicine etc.). In surgery it is often the case that e.g. the border of a tumor is not well-defined and/or not easily visible with the tools the surgeon has at hand. Usually tissue is therefore removed radically (i.e. generous). Another example is the administration of antibiotics, where it is often not known or yet not quickly determinable if the bacteria are resistant against the antibiotic. A third example is the radiation dose or the dose of a drug, e.g. a chemotherapeutic. Genetics may lead to the situation where a dose is already dangerous for one patient while the drug is dosed too low for another patient to be effective. For this topic we suggest both a call for research and a call for innovation projects. The research projects should start after TRL 3, which means that an experimental proof of concept had already been completed beforehand, and bring the instrument or tool to TRL 5 or 6 with a validation or demonstration in a clinical environment. For the innovation projects it is expected that TRL 5 has already been reached and that the instrument will have a completed TRL 7 after the corresponding project. The targeted diseases are restricted to the following major diseases: cancer, infectious diseases, cardiovascular diseases (skin cancer is explicitly excluded as a result of the market and portfolio analysis!) for both (research and innovation actions) since for these diseases the use of photonics methods and tools can make the biggest difference in comparison with conventional methods.
Accordingly, the difference between the research and innovation projects lies in the different technology readiness levels (TRL). Therefore, a corresponding research project must be carried out by teams that include, in addition to the physicians/clinicians, academic teams and companies that provide components, systems and methodologies and/or carry out further development activities on these. While the clinicians have defined the need earlier, they provide samples and finally carry out the evaluation concerning the usefulness of the instrument; the research and development is carried out by a team of academic institutions, research institutions and companies. There are various levels of company involvement possible. In one scenario, companies will mainly provide sub-systems and components, whereas academic institutions carry out assembling of the system and method development as well as e.g. the development of software and solutions for sample preparation. In another scenario, companies focus on system integration and method development in close collaboration with academic partners. In this context both system integration companies (mostly large OEMs) and SMEs collaborate with System and method development will need to include steps necessary to enabling clinical studies. For the innovation projects the project lead is expected to be conveyed to a company, but the evaluation of the instrument must still be carried out by the end-user. Also, for the innovation projects at least one medtech company (which is able to bring the product to the market proved by its market share or by an elaborated business case, which needs to show how to bring the product to the market) must be involved. Furthermore, a potential project proposal must include a part where the benefit of the outcome is demonstrated in a real environment – (preclinical studies, including pilot clinical studies when necessary) within the study. This demonstration needs also to assess the usability of the device and the ability to manufacture it.

Pilot lines for advanced optical medical devices

With regard to the pilot lines, the objective will be to create interface and acceleration conditions to transform low TRL technologies to robust medical devices answering to clinician needs. Activities will focus on the most promising photonics health technologies, on which Europe has heavily invested R&D wise these last decades, advanced optical technologies like, e.g. photoacoustic imaging or Raman spectroscopy etc. Such label free technologies present real competitive advantages in fields such as oncology, hematology, microbiology, endoscopy and dermatology, and show promising features in cellular therapy (characterization of tissues, biological fluids at cellular level, microbiological tests, label free *in-vivo* imaging, etc) The European photonics industry must pool investments for enabling the rapid development of new products and minimizing times to market. This speed to market approach needs to include the entire value chain, from advanced research through to technology take up, pilot lines, and manufacturing platforms, in close relation to end-users. Standardization must be addressed, in particular to answer to calibration and control issues, both at component and system level. The pilot cases will serve as models for the specifications of future optical based medical devices, with a focus on new components (laser sources, sensors) and system integration, answering to industrial requirements in reliability, robustness and replicability.
Activities are expected to focus on Technology Readiness Levels 4 to 5, and target Technology Readiness Level 6 to 7. Potential projects could, e.g., be continuations of former, also EU, research projects with highly positive outcome.

Next generation of biophotonic methods and tools to understand the origin of diseases

With the third topic we want to further develop photonic tools to investigate the origin of diseases (i.e. the understanding of processes within the cell which lead to outbreak of diseases) from TRL 2 (technology concept formulated) to TRL 5 (technology validated in relevant environment). The goal is to provide the biochemical end-user and the medical doctors engaged in research with new tools towards a better understanding of the origin of diseases (DNA sequencing or other genomics, leading e.g. to personalized (or stratified) medicine is not included, as the final goal is the development of photonic tools and not the research on the cellular processes itself).

For all three topics above, it is of less importance what kinds of photonic technologies and methods will be employed, what photonic component, subsystem or method will be combined or further developed as long as the final device is clearly superior to already available and established devices and has a definite added value for the physician/clinician and the patient in case of the first and second topic and for the biochemical end-user for the third topic. If photonic methods are combined with non-photonic methods, the further development of the latter is explicitly out of scope as long as it is not necessary for integration. The benefit of these newly to develop tools compared to existing one needs in any case to be obvious and proved in a final evaluation by the end-user in a realistic environment corresponding to the individual TRL level.

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

Point-of-care testing for the purpose of health status monitoring will play a pivotal role in the health care system and, thus, offers much room for photonics based solutions. There is a large number of European key players from academic and applied research institution as well companies, which can advance and exploit photonics technology in this field. The branches of photonics based diagnostics driven therapy (not always is therapy diagnostics driven; sometimes diagnostics is still not fast enough, like e.g. in case of sepsis) and in particular therapy monitoring is comparably new. Even in newer studies like the Yole report on Biophotonics (2013) these branches do not yet get special attention. However, the methods and instruments are comparable to those necessary for diagnostics in the first place like e.g. point-of-care equipment. Accordingly, European companies are able to supply the whole food chain from components over systems to complete solutions.

In the life science related market Europe is also well-positioned with larger companies like Zeiss, Leica and Tecan but also with a multitude of different SMEs. For medical imaging systems industries providing both hardware and software are e.g. Philips and Siemens Healthcare. Besides, there also exist several smaller companies who can be worldwide or European leaders on a particular specific domain related to equipment and/or components, as for example Thales for X-ray detectors and imaging solutions in cooperation with Trixell (a joint venture of Thales-Philips-Siemens). To fully exploit the potential of new photonics innovations it is also essential to optimize integration into the medical workflow and into existing hardware and software products and solutions.

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

The concrete business cases are the sales of systems and related components of

1) Biophotonics devices for health status monitoring, diagnostics guided therapy / therapy monitoring
2) Photonics enabled point-of-care and imaging tools.
3) Photonics based tools and instruments for Life Science applications.

Any decisive technological advantage will obviously improve competiveness of the European companies and directly translate into higher sales. The explicit market figures for 1) is hard to determine as these markets are still developing and 1) is usually not detailed separately from the market for biophotonics imaging and point-of-care devices. For 2) we expect in particular:

- Strengthened industrial deployment of research results by promoting wide-scale cooperation and greater integration across the whole research and innovation value chain.
- New capacity to offer to the medical community industrial quality solutions answering to their needs
- Early adoption of standards and specifications at research level allowing smooth technology transfer to the whole industrial value chain

Europe's share of the biophotonics market currently amounts to about one third of which is predicted to be 85.5 billion € in 2020. The market for optical microscopes amounts to about 6.2 billion € in 2020 according a study of AT Kearney (2013). The market for optical in-vitro

diagnostics amounts to 55.9 billion € according to the same study. This market study shows that Europe is (mainly thanks to Germany) in a leading position in these segments, which may, however, be threatened by the lack of innovation among the related products. If this does not change in the future, Asia is, according to the market study, in a strong position to take over the lead. Since the supply chains are comparably complex or highly diverse, statements about the parts of the value chains that are likely to be located in Europe and the number of potentially created jobs, would be impossible to make.

3. **Impact on societal challenges**

Most European countries will see a strong demographic change in the near future with drastic consequences for the health and well-being of the European citizens and for their healthcare systems. E.g. the number of new cancer cases and corresponding incidences will rise steeply every year as a consequence. The same is true for other age-related diseases such as cardiovascular, osteoarticular and cerebrovascular diseases and many others. Early detection, precise diagnostics is key to an appropriate and successful treatment. Of particular concern are the falling birth rates and the increasingly aged population. The latter is causing an increase of the number of people with degenerative diseases (Alzheimer's, Parkinson's etc) and the former decreases the ability of the working population to support retirees.

4. **EU added value**:

On the one hand, the addressed societal challenges are European wide, since disease knows no borders as would the impact in case of success. Therefore, combining the expertise across the EU to address these problems would generate a lot of synergies. In particular, since highly specialized knowledge is necessary in a number of different fields which is not available to a single country. This approach will exploit the EU's substantial knowledge base in photonics and biomedical technologies and their clinical application. It will provide added value by investing in projects which allow complementary cross disciplinary skill sets to be combined from a number of different research groups.

5. **Funding**:

There are lots of barriers to the market entry of SMEs as medical device manufacturers due to regulations and other barriers as well as further risks. Also large companies face such issues. In order to ease these problems and accelerate the speed and effectiveness of R&D&I in Europe, higher levels of H2020 investments for both the academia and the industry would be useful. A concrete number/percentage is hard to provide. For applications in the area of the Life Sciences, environment and food quality the regulations are less serious, therefore the market barriers and the related risks are much lower, but, again, concrete figures are hard to provide.

WG 4 – Innovation in Ubiquitous Wearable Visualization for Citizens in a Digitized Society

I. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed

Initial deployment of wearable and non-aided augmented-reality (AR) in professional and semi-professional applications is expected around 2018, e.g. in domains like production, logistics, maintenance, training and sports. Goal here is to go beyond this, to move wearable AR and light field visualization systems from "professionals to citizens" by focusing on personal privacy protection (user's and others) and enabling networked, everywhere augmented-reality (in-/outdoor localisation, scene recognition, cloud access,…) which is non-intrusive, exhibits intuitive user-interaction, as well as anytime safe and secure use.

Technical aspects include in particular:

- Optics & Ergonomics: Compact and cool look&feel see-through optics, natural light field visualization providing wide field-of-view, high resolution, large field-of-depth (3D), while avoiding eye and brain-strain, or any discomfort even on longer use, good visibility under outdoor conditions.
- Seamless wireless connectivity, with very low power consumption
- Natural user interaction
- Embedded intelligence, e.g. for localization, scene or human feature recognition, security & privacy protection

2. What is the challenge (in Europe) in the respective area today?

Wearable AR has already started to be used productively mainly in production industry and logistics, and some larger European companies are on the forefront of these developments. On the component side, many key components for these systems (including optics, electronics, and software) are today developed and manufactured by highly specialized European companies, large companies, SME's and start-up's. We expect that after 2018-2020, wearable AR and light field visualization will be widely used in professional domains and will start to spread into high volume applications like healthcare, lifestyle & sports, smart cities, entertainment, and general connectivity. There are strong EU industrial end-users and integrators in all the cited application domains.

The **Challenge** we want to address here is to strengthen the links from component suppliers to system integrators and end-users in order to build a Europe-centered value chain in order to accelerate innovation and to enable Europe to take a relevant share into the large projected growth connected to the expansion of the market from professionals to citizens, both in regional and worldwide markets.

3. What needs to be done?

A. Innovation Action (IA) for Wearable Augmented Reality,
B. Research and Innovation Action (RIA) on realizing 3D Light field and Holographic systems for natural visualization,

The actions will focus on fostering innovation both at the component and sub-system level (optics, microdisplays, electronics components) as well as on system integration (natural visualization, connectivity, user interaction, application specific software) in order to establish an ecosystem on EU supply chain for system level & complete system solutions towards the end-users.

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

1. Innovation Action on “Ubiquitous Wearable Visualization for Citizens in a Digitized Society”, called in 2018, total funding 20M€
2. Research and Innovation Action on “3D Light Field and Holographic Displays for Natural Visualization ” called 2018, total funding 18M€

PHOTONICS PUBLIC PRIVATE PARTNERSHIP

Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2018-2020

A. Innovation in Ubiquitous Wearable Visualization for Citizens in a Digitized Society" (IA)

Objective is to enable **wider adoption of personal connected near-eye/in-eye augmented-reality (AR)** systems and **related business models**, from professionals towards citizens. This proposal is in the continuation of ICT-29-2016-IA activity that put emphasis on niche markets like industry or medical, where we expect that by 2018 wearable AR will have started to be productively used. Main goals are:

- **Establish innovation consortia** including industry and research along the **entire value chain**, from components and subsystems to end product and service providers.
- **Development of components and systems** featuring various photonics technologies and components to **enable large deployment of wearable AR**, namely: (i) compact see-through optics including natural depth-of-field view (multiple focus planes) and ophthalmic correction (ii) high-speed/ high-resolution microdisplays for light-field or holographic imaging, (iii) embedded SW and HW solutions for in-/outdoor localization, scene recognition, secure and ubiquitous connectivity, privacy protection as well as intuitive user-interaction, including human feature recognition, haptic perception and feedback, or recognition of situation awareness.
- Creation of **application scenarios** for open yet safe public environments and communities and **verification in Living Labs** including end-users.
- Development of service focused **business cases,** e.g. for lifestyle, health, sports, or social networks for safe and secure society (telecom providers, public authorities), education, autonomous driving, Smart Home, entertainment, manufacturing industry, etc.)

Relevant Research & Innovation present in Europe

Wearable AR is today mainly driven by industrial applications **and European industrial companies** like Volkswagen, BMW, DHL, or EADS **are at the forefront on testing and already using AR based systems** e.g. in production, for training and maintenance, or logistics. Other current applications are in the car and avionics industry (based on head-up systems), in the medical domain as developed currently by companies like Essilor or Zeiss, e.g. for surgery or ophthalmology, but also e.g. for vision aids for visually impaired people.

Although probably not so widely known, many **key components** for wearable AR systems are currently developed and made in Europe, namely:

- **Optics for wearable AR and smartglasses:** companies like Zeiss, LUMUS(IL), WaveOptics, or Savimex, Microoled have realised highly innovative optical components for see-through systems, and companies like EverySight(IL), Optinvent, Headapp, Trivisio, Laster, GlassUP, or Composytlabs(CH) are developing or selling already smartglass products.
- **Microdisplays:** MICROOLED is already selling OLED microdisplays for smartglasses and is focusing its current developments on this market, other suppliers are Forth Dimension, Holoeye, or MLED.
- **Microelectronic components:** companies like Infineon, ST Microelectronics, NXP, XFAB, EM-Marin (CH), Bosch, Nordic, Dialog and others are developing and providing key components for wearable systems like low power Bluetooth chipsets, microcontrollers, image sensors, other sensors e.g. for proximity, intertial, pressure, environmental, MEMs microphones, etc.
- **Specific application software** for AR is developed by companies like Ubimax, a-Sis, Xmreality, Augmented Automation, Lusovu, Visionsmarts, Evolar, Expert-Teleportation, Tobii, and others.
- **Materials,** like e.g. Novaled, Merck, or Cynora for OLED

On the **Research** side, Europe is traditionally strong in the field of optics, visualization, sensors, low power circuits, and software, and many renowned research institutions are on the forefront of research in these field, with recent breakthroughs e.g. in OLEDs or MEMS. Institutions are e.g. IMEC, Fraunhofer (e.g. video coding, ultra-low power microdisplays, micro-scanning mirrors), CEA-LETI, Dresden University (5G), Tampere University, Mittunivesitetet . Just recently the ZEISS International Symposium "Optics in the Digital World" concluded to focus research in AR (see White Paper June 2016).

Impact on European economy, employment

In the same way as the projected widespread use in the professional domains cited above, the targeted wider adoption of personal connected near-eye/in-eye augmented-reality (AR) systems and related business models will impact a large number of higher volume application domains where Europe is already strong, e.g.:

- **Personal Health Care:** Typical applications are eyewear and vision aids for visually impaired as developed e.g. by Zeiss or Essilor
- **Lifestyle, Sports & Health:** typical applications are cycling, running, ski where companies like Polar, Suunto, Garmin (CH), Adidas (DE), Salomon (FR), Garmin (CH), Polar (FI), Suunto have a strong market position
- **Smart Cities, Smart Home**, **entertainment,** with companies like Siemens, Schneider, Barco, Greenpeak
- **Connectivity:** Telefonica, Vodafone, Telekom, 5G Lab Germany, etc.

We expect the outcome of the innovation actions to enable **European system manufacturers** to bring to market **highly competitive products** by integrating wearable visualization for **systems and user-centric services** in the business cases listed above, and to build a **Europe-centered value chain** by strengthen domestic manufacturing of **optical & semiconductor components, and software** up to the already strong system integrators and end users, e.g. from **telecom, medical, sports, or eyewear** industry. The expected **market potential** is high, as shown by different studies, e.g. AR hardware revenues are expected to reach **$40B in 2020** (Digi-Capital Jul/'15), or "Smart Augmented Reality Glasses Shipments to Surpass 12 Million Units between 2015 and 2020" (Tractica, May 28'2015). Total AR revenues are estimated to $120B in 2020 (much larger growth than VR: $30B in 2020), and Europe could target a market share of 20 to 25% of that value. EU-level funding will ensure European companies **to compete** with US and Asia in the emerging **wearables and IoT markets**, create **high-end jobs** and cultivate a skill base in Europe. This will contribute to further foster Europe's world-wide credibility to set **high level standards** for **communication networks and data security** and to gain a leading position on that matter

Impact on societal challenges

Providing anytime secure use, non-obtrusive look-and-feel, wearable visual information including AR, and intuitive user-interaction will have a huge impact on several social challenges, namely for **security and privacy awareness for citizens** (Open yet safe and inclusive society), **personal health** (remote doctor, support of sensory impaired (visual, audio), emergency assistance), or for **mobility** (Smart transportation, personal travel advice e.g. based on crowd-sourced concepts). In a more general manner, it will **move social interaction in real world space**s enhanced by virtual information presentation (education, gaming), without getting lost in purely virtual spaces.

EU added value : As can be seen from the list of activities and actors above, the relevant knowledge and bits and pieces are all spread over Europe and some associated countries (e.g. IL, CH), especially for the components often in highly specialized SMEs. The idea is therefore to leverage the combined knowledge available in the different countries, SMEs and large companies, in order to build a Europe-centered value chain by strengthen domestic manufacturing of components, software, systems and services.

Funding
Innovation Action (IA) 2018: 20M€

WG 4 – Large volume OPV application

I. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed

Organic photovoltaics (OPV) and organic photodetectors (OPD) for large-volume applications

- Application domains[2]
  - Building-integration of OPV
  - OPV for automotive
  - OPD for flat panel X-ray detectors
  - OPV and OPD for portable electronics and wearables
- Targeted applications
  - Semitransparent OPV glass façades and shadings
  - Standardized building elements with OPV
  - Energy harvesting in car glass and car interior (e.g. dashboard)
  - Self-powered electronic devices and wearables containing OPV or OPDs
  - (curved) X-ray detectors for medical imaging using OPD
  - OPDs for industrial security and safety systems Biometric imaging and gesture recognition

We suggest joining forces between OPV and OPD to use synergies between both topics regarding materials and processing technology, although both are at different TRL and aim for different markets.

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?**

- Europe holds the leading position for OPV manufacturing in terms of technology and production facilities at SMEs like Belectric, Heliatek, and InfinityPV. In the long run, labor costs will not be the cost-limiting factor for OPV production. Thus, Europe needs to maintain and strengthen its world-leading position in the module development and commercialization of OPV. The full OPV value chain is available in Europe and should be kept here.
- Very good results have been obtained in lab-scale OPV research and OPV test installations. Next, this must be translated into reliable products and production technologies. Selection is required to only support technical solutions with very good potential for upscaling at preferably low losses in efficiency and lifetime as compared to lab samples.
- Products must be developed that exploit the unique properties of OPV: semitransparency, low weight, on flexible or shaped substrates. OPV is non-toxic, has a low energy payback time of only a few months, and is free of rare earth or heavy metal materials. Thus, it is the greenest PV technology at all. However, its large-scale deployment requires significant investments in production technology and production tools, as well as further development of materials.
- In the field of OPD, European companies together with research institutes have demonstrated world-first product prototypes. European companies are at the forefront of imaging technology and application. Players are e.g. Philips, Siemens and Teledyne Dalsa, medium companies like Trixell and start-ups as Jenetric and Isorg. Organic photodetectors promise to become a game-changer in this application field. They promise cost reduction of flat panel detectors and enable new products such as curved light detectors, interactive displays or advanced industrial security and safety systems. In particular the geometrical form factor (free definable photoactive area with

[2] For horizontal work groups focus can be on generic technology domains

only structuration of one electrode) and the large photoactive areas (e.g. lens free) play an important role for the industrial sensing applications.

3. What needs to be done?

- Funding is needed to set up pan-European collaboration in the field of OPV and OPD, to surpass the notorious valley-of-death. For OPD it is important to find integrators which make use of the unique benefits such as low cost processing on large area and flexible substrates in order to generate unique product features. Development of dedicated OPD materials will boost the performance of the devices to benchmark or surpass a-Si which is mandatory to replace the solid state detectors used today.
- Funding is needed to develop and showcase large area pilot installations that prove the market-readiness of OPV in end products, in order to convince early-adaptor customers (opinion leaders in building industry and automotive). Joint developments with these customer industries should be fostered
- Ongoing research for OPV materials is required to improve the triangle of efficiency, stability and cost. To stay a truly green technology, only manufacturing processes which use abundant, and non-toxic materials (non-halogenated solvents, no heavy metals, no rare earths) should be developed. OPD materials are presently by-products of the OPV research (which is mostly tailored for broad spectral response and stability). Dedicated OPD materials are needed in order to minimize leakage current for high sensitivity, maximize speed for fast sensors or tailor spectral sensitivity in order to create a differentiator to Silicon (e.g. vis-blind sensors, RGB sensors without color filters) . The involvement of European chemical companies is important.
- A number of pilot lines for organic electronic (OE) products like OPV and OPD exist at several places in the EU, both owned by public institutions and by private companies. Upgrading such existing pilot lines will be required to stay at the forefront of technology, and to prepare volume production of OPV
- Integrations with 2D or 3D substrates need to be improved based on high throughput processes in order to reduce the cost of final products that will be available for different type of applications.

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

a) WP 2018: (IA) Large volume OPV applications like Building Elements; 30M€ (maybe jointly with EEB)
b) WP 2019: (RIA) Robust materials for OPV and OPD performance; 25M€ (maybe jointly with NMPB)
c) WP 2020: (RIA) OPD integration into large area imagers for medical and non-medical imaging applications; 15M€

II. Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2018-2020

TOPIC

"OPV integration into large volume applications like Building Elements"

Description of the topic, objective:

OPV is at the entry to market relevant products. To harvest the fruits of the last decade of development, a few steps are needed to do achieve market-relevant product parameters, such as

competitive product stability (both in visual impression and technical functionality), suitable efficiency, high production yield, and scalable production methods with clear cost-down potential upon large volume production. The call should focus on the integration of OPV into value-added building elements for energy efficient buildings and building infrastructure. Projects should include field tests regarding installation, practical issues in construction (such as fire safety, mechanical integration, or building regulations), as well as lifetime issues. The work requires close cooperation between OPV experts, building components suppliers and building industry. A decent power conversion efficiency of 5..10%, (depending on application) on module level should be aimed for in order to ensure relevant energy harvest. Moreover, functional lifetimes of 25 years must be targeted to coincide with the timeframe of typical use of building components. Consortia should comprise research and industry partners, as well as dynamic SMEs. Their expertise should cover the critical parts in the value chain from OPV to building materials, which are 1) scalable and robust OPV production and 2) integration of high-tech OPV products in building material components. Verification of the products in field tests is required. It must be ensured that the proposed solutions meet existing or eminent building standards and codes.

Relevant Research & Innovation present in Europe?

As for the number of leading OPV research groups and manufacturers worldwide, Europe is at the forefront and holds a market-leading position compared to the USA and Asian countries. Thus, Europe has the potential to play the leading role in future markets. It is worth noting that a large number of Tier-1 building component suppliers come from Europe, offering highly innovative solutions, such as high-tech glass, concrete, or light-weight construction materials. First small steps in this direction are under way, such as the pan-European PVme consortium which unites Heliatek as a OPV producer with key players from the steel and glass façade industry (ThyssenKrupp Steel, AGC, Sapa), however with very limited budget (1.4 M€ public funding in total), so follow-up developments will be urgently needed.

Impact on European economy, employment

The EU is still leading in energy efficiency of buildings, while with the rise of Asian nations, the main market for building components for new buildings has moved to the Far East. In contrast, EU has a tremendous request for improved energy efficiency of existing buildings. This leads to new chances and risks, and a number of adaptive European players are changing their businesses already right now. This opens markets, e.g. for high-tech building technology and components to be exported, as well as used inside the EU for reducing the energy demand of its existing and new buildings.

According to a study of n-tech Research, the forecast of OPV revenues may crack $500 million in revenues by 2022.[3] Building integrated photovoltaics (BIPV) is a niche market which is seen as one of the most promising OPV applications. BIPV will see a significant growth over the next couple of years from just over USD 1 billion in 2015 to $6.3 billion by 2022, with a potential OPV market share between 5 and 10%.[4]

Impact on societal challenges

Reaching the European 2020 goals will require tremendous efforts in energy saving and energy scavenging. Building integrated photovoltaics – especially when implemented in facades and windows – adds another option to the possible technical solutions for the building codes valid beyond 2020, when near-zero energy buildings will become the standard. OPV-BIPV building elements offer a

[3] http://ntechresearch.com/market_reports/organic-photovoltaics-markets-2015-2022

[4] n-tech Research: BIPV Glass Markets: 2015-2022 Nano-859, Issued November 2015

solution to generate electricity at the point of consumption. This reduces the need for investment in grid extensions.

EU added value
Strengths and competences in OPV and building technology are distributed all over Europe, therefore coordinated research and innovation will require close cooperation between the European leading research and industry players.

Funding
70% funding as IA

WG 5 – myCloudSense – Hyperspectral VIS-NMIR Sensing and Deep Learning

I. Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2018-2020

myCloudSense – Hyperspectral VIS-NMIR Sensing + Deep Learning

1. **Description of the topic, objective:**
   Increased pollution of air, soil and water in the cities and their surroundings is raising new concerns regarding the safety of the environment and its potential risks for citizens' health. Distributed sensor networks could assist in creating inventories of emitted pollutants and pollution detection hotspots, also encouraging public participation in the process through the concept of community-based monitoring[5]. Furthermore the connection between pollutant exposure and personal health indicators may improve air pollution related diagnosis and medical treatment on an individual basis. Therefore, data quality is a key issue since it is crucial to make right decisions. Photonic based sensors can help to obtain the required quality level compared with conventional devices.
   The main objective will be to develop hyperspectral portable photonic sensors working in the visible/near/mid-infrared (VIS-NMIR) spectral range, connected to a cloud for data analysis for a comprehensive chemometric analysis. This combination of wide spectral information with a unique "learning from experience" data base (deep learning) will enhance the capabilities of photonic sensing in a wide range of already existing applications on the one hand and open up new opportunities and markets for these kind of sensors on the other hand.
   On the hardware side, this requires in particular NMIR detectors and imaging devices as well as light sources, such as tunable lasers, to be advanced further to be more compact, robust, power efficient and cost effective. Furthermore, resulting sensor modules and subsystems will have to be integrated into complex sensor networks. On the analysis side, chemometric algorithms have to be advanced and combined with a broad experience-based and learning data base. This data base will be shared between different sensors and sensor networks, and information will be provided from the web-based data sets to the individual sensing unit as well as uploaded as part of the learning-based architecture of the present approach.

2. **Relevant Research & Innovation present in Europe?**
   This initiative benefits from a whole range of past and ongoing R&D projects in Europe, focusing on the development and evaluation of NMIR core photonic components (such as the FP7 project MIRIFISENS and the Horizon 2020 project CHEQUERS) as well as the development and testing of whole sensor systems and the combination thereof, such as the FP 7 civilian security research projects EMPHASIS and HYPERION. Of particular importance is the European GRAPHENE Flagship, currently focusing on the development of new technologies with TRL levels ranging from 1 to 6, including the development of CMOS-compatible wafer-scale integration, in particular for the production of affordable NMIR image sensors[6]. Strong alignment and synergies of this flagship program with the photonics21 WG5 will enable

[5] J. Bruggers, "Looking for air pollution hot spots with micro-monitors", Courier Journal, 27 April 2014
[6] European Flagship GRAPHENE, URL: http://graphene-flagship.eu/

translation of technologies to fully integrated applications involving the photonics industries, photonics system integrators and end users. These European funded projects were and are backed also by national research initiatives further strengthening Europe´s position in this technology field. The Horizon 2020 pilot line initiative MIRPHAB, which started at the beginning of 2016 with a four years funding period, will provide innovative NMIR core photonic components as building blocks for the realization of complete sensing systems by all players active in the field of optical sensors. In this way, MIRPHAB could provide the basis in terms of dedicated photonic hardware for the proposed "myCloudSense" RIA.

3. **Impact on European economy, employment**;
   At present, the global market linked to earth observation is considered by many experts as the fastest-growing market for the next 10 years. Germany dominates the market of hyperspectral sensing in Europe, registering a 25.5% share in 2014, followed by France. Based on application, the military surveillance (defense) segment contributed the maximum share with 18.6% in 2014 to the overall hyperspectral imaging market, followed by the environment testing and mining & mineralogy segments. The military surveillance (defense) segment is expected to reach $13.87 million by 2020, at a CAGR of 9.7%. However, the fastest-growing application segment is life science and diagnostics, which is expected to grow at a CAGR of 13.7 % from 2014 to 2019

4. **Impact on societal challenges**
   Improvements in sensing capabilities will quite generally result in a safer and cleaner environment, a reduced consumption of raw materials and other resources, as well as providing for a higher quality of life via improved personalized health care. This is also true for the proposed "myCloudSense" initiative, as those advanced VIS-NMIR photonic sensor solutions will serve pressing needs in all the above mentioned application areas.
   The objective is to develop sensors or sensor arrays that are very inexpensive to produce (e.g. roll-to-roll processing and solution processing) and can be integrated into the environment, which requires compatibility with a large variety of substrates including flexible substrates, plastic, glass, silicon, etc. This will ensure low-cost and high-volume manufacturing making extensive use of CMOS electronics, e.g. using top-surface photodetectors without additional growth and lattice matching restrictions. In this way, myCloudSense can reach its goal of putting a smart sensor into the hands of all of our citizens.

5. **EU added value**:
   There exists an already well established European network of industrial companies, including many highly innovative start-ups and SMEs, and research institutes and universities in the field of NMIR photonic components and sensors, which has already led to the creation of the MIRPHAB pilot line initiative. This network enables the creation of advanced photonic sensing solutions which could not be realized on the basis of the research and supply chain infrastructure of any single member state alone. Building on and exploiting this European network, "myCloudSense" will further strengthen the interaction within Europe in this field, as well as further increase the European cohesiveness.

6. **Funding**:
   WP 2019: €30m

WG 5 – SensOPro – Sensor-Based Optimization of Production Processes

II. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed: Smart broadband sensing solutions where it matters for Europe: Agriculture, Smart Manufacturing and IoT

Sensing of the future will need to explore at once more than one single part of the photonic spectrum in order to achieve disrupting sensing solutions: from the UV range, where hidden deterioration in organic samples can be detected, to the visible spectrum in which fluorescence phenomena reside, over the broadband spectrum containing unique fingerprint absorption spectra, making use of recent developments in sensitivity-boosting laser-based spectroscopy, up to the THz frequencies where dielectrics become transparent and concealed objects can be revealed. In addition, the possibility to perform high-specificity Raman spectroscopy in the VISNIR spectral range is of high practical interest. For the past decade, the rate of data generation was twice as large compared to the expansion of communication bandwidth, and 90% of the created data was never analyzed[7]. It is obvious, therefore, what is urgently needed: Not only must better, cheaper broadband sensors be developed, acquired data must also be analyzed, and this analysis must eventually occur at the sensor site: Sensors must get smart! Also, for highest value creation we must not only develop smart sensors but also novel smart-sensor-based business models, i.e. smart broadband sensing solutions, which is perfectly in line with the upcoming developments in Industry 4.0.

We propose to accomplish and demonstrate this in three industrial areas of vital importance for Europe: Agriculture & Food, Smart Manufacturing, and the forthcoming Internet of Things (IoT).

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?**

Agriculture & Food: In 2013 Europe became the world's largest exporter of agricultural and food products[8]. However, a lot needs to be done to improve the world's food production industry. According to a widely cited report, getting food from the farm to our fork in the USA eats up 10% of their total energy budget, swallows 80% of their freshwater consumed, and nevertheless America is losing about 40% of its food to landfill[9]. Smart and flexible broadband sensor solutions will help to reduce this dreadful waste of food and resources.

Smart Manufacturing: Europe is the world's largest manufacturer of machine tools and the industry's technology leader[10]. As a key enabling capability for manufacturing, machine tooling is of vital importance for Europe, and "smarter" machine tools are at the basis of more efficient, lower cost, higher quality and more competitive production. Smart sensor solutions will help to

[7] IBM Research, "Global Technology Outlook 2015", January 2015

[8] EU Commission Monitoring Agri-trade Policy, "Agricultural trade in 2013: EU gains in commodity exports", MAP 2014-1, June 2014

[9] D. Gunders, "Wasted: How America is Losing Up to 40% of Its Food from Farm to Fork to Landfill", NRDC Issue Paper, August 2012

[10] M. Hauser (ed)., "CECIMO study on the competitiveness of the European machine tool industry", CECIMO, Brussels December 2011.

achieve this goal, by increasing the speed and accuracy of high-precision European machine tooling.

Internet of Things (IoT): The forthcoming Internet of Things (IoT) revolution promises ubiquitous sensing with huge business opportunities: A total IoT market size of about $400b is predicted for 2024, of which $46b is the size of the device market[11]. Such a huge market is of great interest to European industry, and it is of essential importance that European companies aim for complete smart sensor solutions right from the beginning.

3. What needs to be done?

Although all three considered relevant industrial domains make use of various parts of the wide photonic spectrum, the physical properties of the required components, subsystems and solutions vary widely and are complementary:

Agriculture & Food: The reasons for the occurrence of food waste are very different for the various types of food and the step in the supply chain from farm to fork. As an example, in fruits and vegetables, 20% of losses occur during production at the farm, and 28% are due to waste by consumers[3]. The challenge, therefore, is to create highly flexible yet affordable broadband sensing solutions that can be adapted to all the critical steps in the food production supply chain, providing information about the microbiological and chemical contamination along the entire chain. In particular, user-friendly and portable devices in the hands of the farmers up to the final users will enable them to obtain information about the quality of soil, used irrigation water and therefore of the final crop.

Smart Manufacturing: The primary reason for using a broad spectral range for novel metrology systems in machine tooling is the significantly reduced requirements of the eye-safety regulations, allowing the use of longer wavelengths and significantly increased light power levels. This leads to much faster and more precise sensor solutions, which can be employed in many more places in the complete manufacturing process.

IoT: The dominating factor of IoT sensing solutions is their price. For this reason, significant compromises in the selectivity of the employed sensors must be made, and this must be compensated by extensive data processing and multi-sensor data fusion of the various sensor modalities. Once it is known how to interpret sensor data "to make meaning" out of them, this processing will be carried out at the sensor site, i.e. "at the edge". Until then, sensor data has to be transmitted to the Cloud, where sufficient data processing and interpretation resources are available.

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

Innovation Actions (SensOPro, myCloudSense): WP2019

III. Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2018-2020

SensOPro – Sensor-Based Optimization of Production Processes

1. **Description of the topic, objective:**

[11] G. Girardin et al., "Technologies and Sensors for the Internet of Things", YOLE Development, June 2014

The European Industry (the sector of piecewise manufacturing as well as the continuous process industries) faces the continuous struggle to keep a leading role in the worldwide competition. There are four target fields to be addressed to be successful in that: resources, quality, safety and costs.
The intensified utilization of process-integrated sensor technologies can leverage all those target fields. Exact monitoring of process and product parameters can serve to optimize those processes, saving money and resources (raw material, energy, time) whilst guaranteeing optimum product quality without any rework or scrap, protection for the workers and preservation of the environment. Gathering sensory data on raw materials before entering the production can (when combined with perfect knowledge and modelling of the following process steps) be utilized to optimize production parameters in advance, allowing for uncompromised quality and efficiency still with changing parameters in the input raw materials, and possibly still for lot-size one production. Making intelligent use of all data from the process, from the product/workpiece/product stream/by-products, the facility, the surroundings and the worker/working conditions will lead to optimization of the process[12,13] and the product but also of the work/working conditions itself; optimization of the efficiency, quality and safety of process, work and product.
Sensors in this context are any means to collect data from all along the process chain and the surrounding environment (e.g. chemical, physical, imaging, movements or dimensions). In particular, intelligent broadband/multimodal sensing approaches (including nanophotonic, plasmonic, magneto-optic gas sensors, evanescent-wave fiber probes, cavity-enhanced laser spectrometers, optical fiber sensors (optical fiber Bragg gratings, optical fiber sensors based on light scattering and interferometry) are encouraged.

2. **Relevant Research & Innovation present in Europe?**
Similar challenges have been addressed in various projects, especially within other PPPs FoF and SPIRE. Nevertheless, in those cases the approach has either been focused on the process industry (e.g., SPIRE-01-2014) or on piecewise manufacturing (e.g., FoF.NMP.2011-5). None has been set up to span the whole field from process modeling and understanding, over the sensing/measurement itself to holistic data analysis, including also human workers and their needs. Dynamic development in the fields of photonic sensing and the capabilities for analyzing big amounts of data requires continuous efforts in ensuring the optimum utilization of those new possibilities.

3. **Impact on European economy, employment**;
Possible economic benefits of sensor-based optimization of production processes include reduction of raw material consumption, energy consumption, process-/processing-time, rework efforts, scrap and emissions. At the same time product quality is optimized, (incl. cost/time effective 100% quality control where required). Lot-size-one production and efficient processing of variable raw materials are enabled. Implementation of novel manufacturing technologies should be sped up, e.g., introduction of efficient laser processing technologies into highly responsible industries (aviation, space…).

[12] Materials KTN, 2014: A landscape for the future of NDT in the UK economy
[13] ACHEMA, 2012: Trendbericht Nr. 8: Prozessanalysentechnik - Prozessanalytik: Der Weg zur wissensbasierten Produktion

According to market research[14] the global machine monitoring market is expected to grow at a CAGR of 7.16% from 2014 to 2020 and reach US$2.50b in 2020.

4. **Impact on societal challenges**
   Expected societal benefits of sensor-based optimization of production processes include the creation of a better and safer workplace (exposure monitoring against dangerous products/by-products, ergonomics, physical and mental health, reduction of stress due to sensor-based support.
   Thanks to optimized sensing systems it will be possible to meet European challenges of digitalization and safely connecting Europe to the IoT (Internet of Things). Strong support for coping with environmental and societal challenges is provided by fostering energy and resource efficiency and extended life of production systems. In addition, sensor-enhanced production systems will help in accident prevention, from which both people and our environment profit.

5. **EU added value**:
   "The re-industrialization of Europe is a strong pillar on which the development of new calls shall be built". This position has been stated by the European Commission[15,16,17,18] during the last years. The broad approach proposed in the SensOPro action is clearly oriented to serve this basic orientation. SensOPro represents a comprehensive approach, aiming at bundling various disciplines and fields of expertise and knowledge based on various former research results. This broad approach has to be addressed on European level in order to foster fruitful collaboration as intended. Success is crucial for Europe to maintain its position in the competition, e.g., with the United States, who are aiming at similar targets[19].

6. **Funding**:
   WP 2019: €30m

[14] "Machine Condition Monitoring Market by Monitoring Type (Vibration Monitoring, Ultrasound Monitoring, Thermography, & Others), Components, Monitoring Process (Portable & Online Condition Monitoring), Applications, and Geography - Global Trend & Forecast to 2020", MarketsAndMarkets, 2013
[15] European Commission, COM(2012) 582: A Stronger European Industry for Growth and Economic Recovery
[16] European Competitiveness Report 2013: Towards Knowledge-Driven Reindustrialisation
[17] European Commission, COM(2014) 14: For a European Industrial Renaissance
[18] European Commission, 2015: Digital Transformation of European Industry and Enterprises, Final report of the Strategic Policy Forum on Digital Entrepreneurship, 18.03.2015
[19] Euler Hermes Economic Qutlook, 2012, no. 1187: The Reindustrialization of the United States, Special Report

WG 6 – Photonic Integrated Circuit Pilot Line

I. Description of the area where Horizon2020 funding is requested (1 page max)

1. Area to be addressed

- **Application domains**[20]
- Photonic Components and Photonic Integrated Circuits, providing capabilities for products in a wide variety of application domains.

- **Targeted applications**
- Data communication and telecommunications from short reach to long reach; next generation supercomputers and data centres;
- Sensing, metrology and control, e.g. for medical applications, instrumentation and industrial 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. PICs are already widely deployed by European manufacturers in telecom and data networks and the generic foundry model developed in Europe is making this technology available to a wider applications community. There is however massive upside potential for PICs in industry, particularly in sensing, metrology, control and other applications. Furthermore it is vital that the performance and capability of European PIC manufacturers continues to be developed in order to meet competition from other countries. In particular:

- Some core optical functionalities not yet available in PICs
- Performance levels need to be continually enhanced in order to provide compatibility with next-generation telecom, data communications and sensor requirements, including systems based on quantum optical concepts
- Technologies for higher-density, lower-power components and circuits for next-generation PICs still have to be developed
- Techniques for combining photonic and electronic functionality in order to provide optimum performance and cost-efficiency are still at an early stage; advanced electronic/photonic integration schemes are not yet in production
- Packaging has a major impact on product performance and typically accounts for a large part of the costs. Action is required to develop high performance, lower cost solutions that are scalable in manufacture
- Photonic software design and simulation tools and Process Design Kits need significant improvement in order to support advanced PIC designs effectively
- European pilot-line activities for generic PIC technologies are presently limited to a single dielectric PIC technology. There is an urgent need for this capability to be available for other

[20] For horizontal work groups focus can be on generic technology domains

key PIC technologies (InP and silicon photonics incorporating lasers), as well as for packaged components using automated assembly approaches that are scalable to high volumes with low unit costs.

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. The emergence of the AIM Photonics programme in the USA, together with investments in China, Japan and other countries, underlines the need to consolidate and build on European strengths and bring these capabilities to market-readiness in a very timely manner.

The developments detailed in this document are fully in line with the strategic roadmap established by Photonics21 at the beginning of the Horizon 2020 programme.

3. What needs to be done?

a. Development of enhanced PIC building blocks in line with technology roadmap, e.g. high sensitivity, high density, lower power, higher speed; explore technology developments offering radical enhancement of performance and functionality, enabling existing and new applications, including quantum photonics (Research activity)
b. Integration of PICs with other technologies, including hybrid/heterogeneous electronic/photonic integration and electronic-photonic co-design, towards 'photonic systems in package' (Research activity)
c. New packaging technologies for scalable manufacturing, providing high performance and functionality (e.g. RF, EMC, thermal …), while providing a breakthrough in cost (Research activity)
d. Establish pilot production lines providing low entry barrier access to PICs based on InP and/or silicon photonics including lasers, supporting low to medium volumes and capable of being scaled up to high volumes, and including appropriate measures to stimulate demand and uptake (Innovation activity)
e. Support and develop pilot production capabilities for automated low cost packaging of PIC-based components (Innovation activity).

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

In which year should the area be called: as part of WP 2018, WP 2019 or WP 2020?

a. WP2020, 30M€ (supporting multiple research projects)
b. WP2019, 20M€ (supporting multiple research projects)
c. WP2018, 20M€ (supporting multiple research projects)
d. WP2018, 20M€ (supporting one or more innovation activities)
e. (in collaboration with WG1): WP2019, 20M€ (supporting one or more innovation activities).

II. Proposal for Research or Innovation Topic(s) (2 page max) in Horizon2020 WP 2018-2020

Photonic Integrated Circuit Pilot Line

1. **Description of the topic, objective:**
   This innovation topic addresses the need for photonic integrated circuit pilot lines based on InP integrated photonics and silicon photonics with lasers and amplifiers on board. Pilot lines should particularly address the development of high-throughput production processes, moving beyond prototyping and sampling. The chain should be in place to enable design, simulation, production, and test through to qualification, with methodologies for systematically enhancing yield and performance. Technology push and market pull should be linked through appropriate business development actions and roadmapping. Open access should be ensured through the development of stable and comprehensive process design kits. 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. A pilot line activity is now in place for dielectric waveguide circuits but not for InP integrated photonics or silicon photonic circuits. European businesses have a technological lead in the software tools, fabrication processes and circuit design required for open access PIC technologies. A coherent linkage throughout the supply chain is vital in order to provide the services required by users. All of the links are present in Europe but often in different countries and it is accordingly vital to take a European approach.

3. **Impact on European economy, employment**
   Photonic integration supports the further growth of the internet, which is of crucial importance for the sustainability of our modern information society. In particular, it will make a major contribution to the reduction of the power consumption of information systems, which is rapidly becoming a major limiting factor, as well as their cost. 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: for example, the opportunity to bring advanced medical technology much nearer to the patient, resulting in better, quicker and more cost-effective diagnostics. We envisage the widespread adoption of PIC technologies in a wide range of industries, including manufacturing systems, vehicles, avionics and consumer goods, all providing major opportunities for European companies.

   Establishing a European pilot line for PICs using the most advanced processes 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.

Europe has a high number of early-adopter businesses who are prototyping PIC technologies in new and emerging markets: Europe is accordingly very well placed to take a world-lead in the exploitation of PIC technology for business growth.

The data centre networking market alone will reach $21.85 billion by 2018 with a CAGR of 11.8% (Infonetics). This is driving growth in photonic interconnect sector, which represents an integral part of its ecosystem, with chip-level photonic interconnect expected to generate $990M by 2020 (CIR) and the market for Ethernet optical interconnects reaching $2.2 billion by 2018 (LightCounting). Target markets include also a significant share of the optical sensor market ($15B 2020 worldwide, CAGR 16.9%, Allied Market Research). The value of InP and Silicon Photonics PIC markets are anticipated to scale to multi-billion dollar levels over the coming five years (see *Integrated Optical Devices: Is Silicon Photonics a Disruptive Technology?* http://www.lightcounting.com/reports.cfm, January 2016).

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. Facilitating the availability of PIC technology at pilot production level 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 and manufacturing of photonic ICs, along with the diversity of applications, means 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.

PHOTONICS PUBLIC PRIVATE PARTNERSHIP

Cross Cutting Task Force – Open access to Photonics Innovation Hubs

This document contains a proposal for three actions that are all necessary to realise the vision of Digital Innovation Hubs in Europe:
1. **Access to photonics technologies for industry through Innovation hubs** (Innovation Action)
2. Linking innovation hubs (CSA)
3. Fostering new and reinforcing existing photonics innovation hubs (CSA)

Area to be addressed
Photonics Digital Innovation Hubs

1. **What shall be reached in concrete terms?**

What shall be reached?

- **Open access to Photonics Innovation Hubs:** Providing easy access to Photonics Innovation Hubs in order to reinforce the competitiveness of European industry. The aim is
  1/ to strengthen the photonics industry by providing access to capabilities and expertise which they do not have in-house and
  2/ to strengthen the boarder industry by accelerating the deployment of photonics in other sectors, making European industry more competitive and increasing the demand for photonics components and systems.

  Access to Photonics Innovation Hubs must be provided in a way that
  - Builds on technology platforms and capabilities that have previously been matured
  - Is driven by the business needs of industry which are the users of the Innovation Hubs
  - Facilitates the use by SMEs and non-photonics end-user industry all over Europe
  - Provides other complementary support such as facilitating access to other sources of financing as well as business support (e.g. market intelligence, business plan development)

  The Photonics Innovation Hubs should provide access on both a subsidized basis as well as a commercial basis depending on the scale and closeness of the activity to the market.

2. **Expected Impact on European economy, employment, societal challenges;**
   - Reinforcing the innovation capability and competitiveness of the photonics sector.
   - Significantly increasing the uptake of photonics by other industrial sectors, thereby increasing the demand for photonics and also reinforcing the competitiveness of European industry in general.

3. **EU added value: Why should it be funded at EU level rather than national or local level?**
   Photonics Innovation Hubs across Europe need to be linked together must be made accessible by any company in any region in Europe. This can only be done at EU level.

4. **Requested funding?**

   Open access to Photonics Innovation Hubs:
   Type of action: Innovation Action
   20 m€ as either a single consolidated action or a number of smaller well-coordinated actions supporting up to 400 subsidized access activities.