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Plataforma Tecnológica Española de Fotónica

Photonics21
Strategic Research and Innovation Agenda

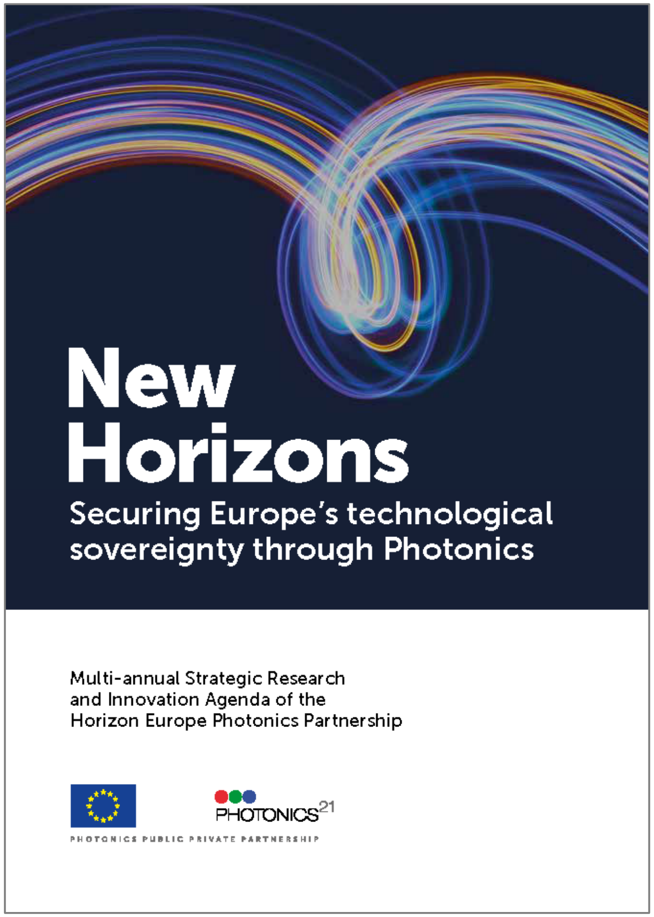
GOBIERNO DE ESPAÑA
MINISTERIO DE CIENCIA E INNOVACIÓN
AGENCIA ESTATAL DE INVESTIGACIÓN

19 Mayo 2021

New Horizons

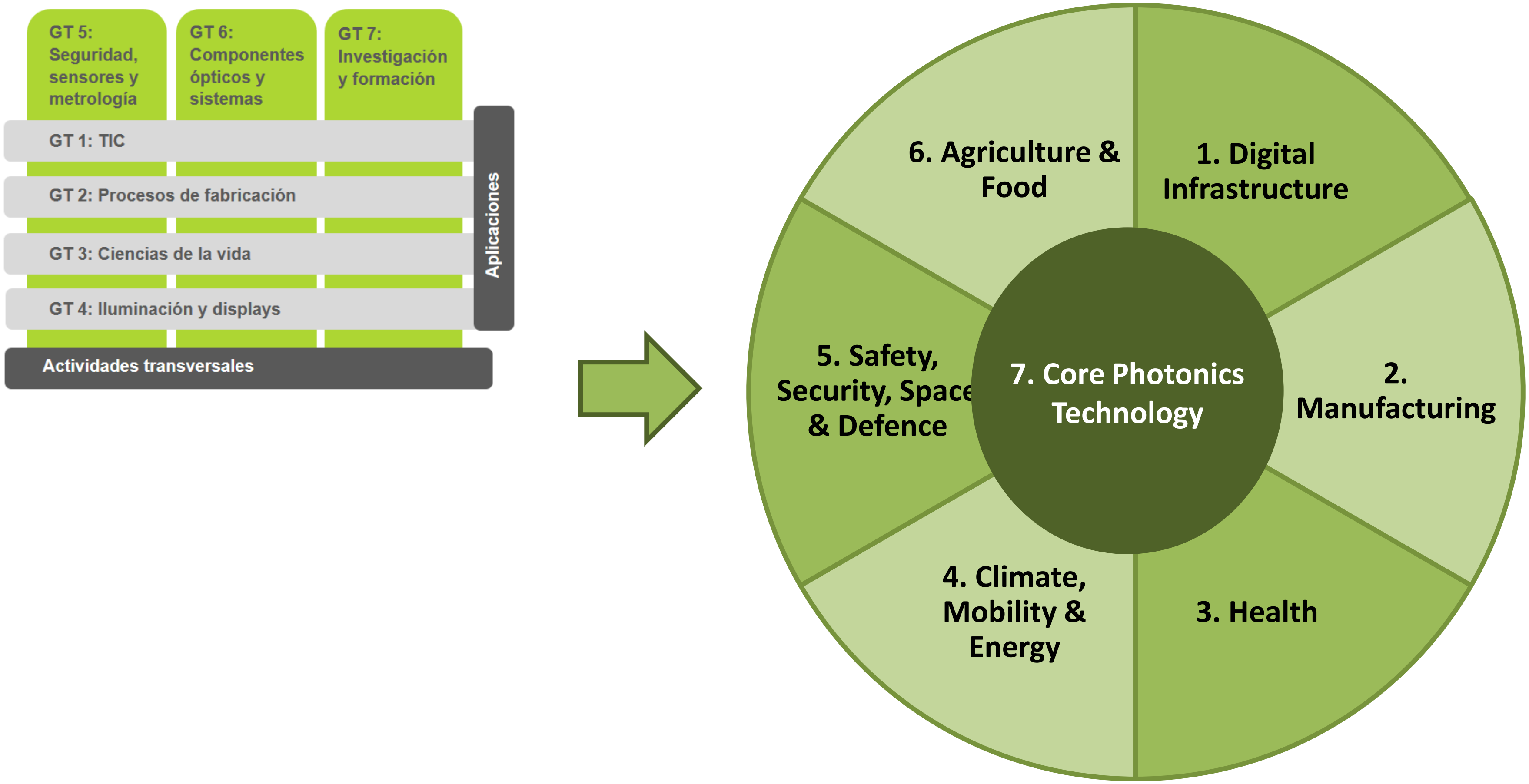
- November 2020 – Photonics21 Partnership releases a **new Strategic Research and Innovation Agenda**, that proposes a vision and path forward, a long-term strategy for the next seven years **2021-2027**.

- The **socio-economic challenges** that must be addressed to achieve European ambitions in key strategic sectors of the European economy are highlighted. The **major research and innovation Challenges for the European Photonics community in each sector** are detailed.



https://www.flipsnack.com/Photonics21/photonics-strategic-research-and-innovation-agenda.html

Key strategic sectors



1. Digital Infrastructure

Major challenges:

- **Zero-touch operation:** Photonic networks augmented by AI/machine learning
- **Instantaneous response:** Low and deterministic latency in the optical network connections
- **Access anywhere:** Fibre-to-the-Home, FttRadio-Antenna, ‘Fibre-in-the-sky’ optical satellite comms, LiFi
- **Intrinsic security:** The resiliency of optical network infrastructure, secure transmission of data, complemented by quantum communications infrastructure covered by quantum flagship and other projects (cybersecurity, Sendate)
- **Sustainable capacity growth:** In a 5G and datacentre centric network, capacity in fibre networks has to ‘keep-up’ – hyper-scalability, power consumption, network cost, operational efficiency, green network.

Research and innovation challenges

1. Digital Infrastructure

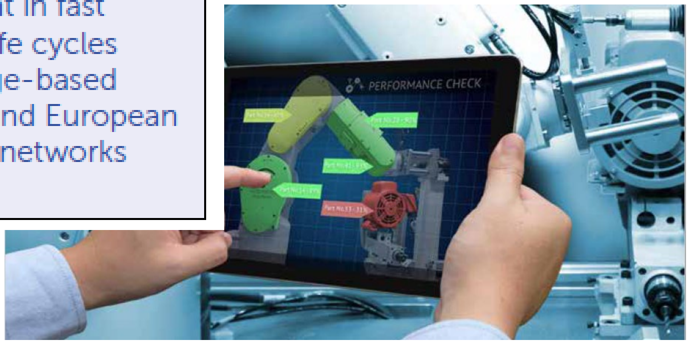
Roadmap:

	2021	2022/2023
Overview **Technology Challenges *(user view)***	Zero-touch operation	Instantaneous response
Critical milestones to move from Science to Market	Open platforms, open interfaces & APIs	The growth of latency critical applications
Photonics **Research (R) & Innovation (I) Challenges**	**AI-enabled optical networks:** • Interoperable optical network nodes based on open HW and SW (white boxes) • Dynamically self-configuring optical network technologies based on AI/ML for control, optimisation, and fault detection • Optical devices enabling energy-efficient telemetry and analytics in optical networks	**Deterministic latency comms:** • Time-sensitive optical networking technologies • Latency-optimised optical interconnects • Optical precision timing solutions • Integrated optical comms for demanding sensor/actuator systems (e.g. 3D machine vision) • Optical robot and sensor networks **Ultra-dynamic networks** • Optical solutions for industrial internet applications • Optical spectrum and Ethernet services with hard service guarantees • Large scale, fast optical and hybrid e/o switches • Ultra-dynamic photonic devices (laser, cross-connects)
Joint actions required with other disciplines (e.g. Artificial Intelligence) or fields (e.g. robotics)	Artificial Intelligence	Factories of the Future, robotics

2. Manufacturing

Major challenges:

Digital	Green	Sustainable
• Fast and multi parallel high power laser beam handling • High-speed digital controlled materials processing • Simulation-based digital process chain development and optimisation • Rapid manufacturing of complex individualised products • Big data and AI-based production and process development • First time right production by high resolution and high-speed metrology and machine technology	• CO_2 emission reduction within the process chain by highly efficient and material-specific laser processing tools • Lightweight and bio-based components and their manufacturing • Substitution of carbon-based production and hazardous materials • Resource optimisation by material-specific usage and processing • Implementation of biological transformation elements in production and end products	• Future proof ecosystem by technological unique selling proposition for flexible and eco-friendly manufacturing • Comprehensive integration of process chain and materials and product life cycle • Manufacturing of affordable individualised complex products • Long-lasting flexible re-use of production equipment in fast product life cycles • Knowledge-based regional and European technical networks



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2. Manufacturing

Major challenges:

- **Laser beam sources:** due to the increasing demands on process speed and quality, it will be essential to increase system performance – and at the same time increase the quality of optical fibres and elements – in coatings and laser components.
- **Beam guidance and beam shaping:** for the integration of the new beam sources, powerful optical fibres and beam guidance will be required, especially for the extended wavelength and pulse duration ranges that are expected.
- **Industry 4.0:** the key challenge is that laser systems become perfectly embedded in the digital process chain.
- **From bits to photons:** close connection between processes, devices and systems could be achieved by methods like digital twins.
- **Quality control and NDT:** the major challenge is to ensure high product yield while simultaneously maintaining high quality.
- **Laser specific materials development**: short interaction times and high cooling rates involved in laser material processing require materials and alloys specially designed for optimum part performance.
- **Skilled people and flexible infrastructure**.

Research and innovation challenges

2. Manufacturing

Roadmap:

	2021	2022/2023	2024/2025	2026/2027
Overview **Technology Challenges**	**High speed processing** **Weight reduction** **Digitalisation of production** **Agile manufacturing and connected production** **Individualisation and personalisation of products and production equipment**		**CO_2 emission reduction** **Material savings** **Simulation supported production**	
Critical milestones to move from Science to Market	High-speed scanners / tailored beam developments and applications	Simulation and digitalisation	Connected production	Global environmental goals
Photonics **Research (R) & Innovation (I) Challenges**	**Efficient lasers and components** • Material, coatings and components for high power/high-intensity beams • High energy and highly agile ultra-short pulse lasers • High brilliance diode lasers (CW and pulsed) with different wavelengths • Lasers for the generation of coherent X-rays • High power mid-infrared lasers with wavelengths greater than 1 µm • Multibeam lasers **Beam delivery, shaping and deflection systems** • Novel optical fibres for use at wavelengths greater than the UV (and beyond 2µm) • Non-mechanical high-speed beam scanning systems • Re-configurable and programmable beam shaping systems (tailored light) • Rapid monitoring and quantitative feedback systems • Focusing and imaging optics facing the Abbe limit for highest spatial resolution of energy • Multibeam guiding and switching • Miniaturised interchangeable optical processing systems **Industry 4.0** • Connectivity of laser systems for integration in manufacturing platforms (also intelligent fibre connectors with integrated functionality e.g. back reflection or temperature) • Integration of sensors throughout the laser processing system • Parallel processing for high throughput • Data and knowledge management for laser materials processing "standardised" CAM-modules for materials processing • Development and integration of simulation tools into production chains			

2. Manufacturing

Roadmap:

	2021	2022/2023	2024/2025	2026/2027
	Quality control and NDT • Real-time process control • On-line non-destructive testing of laser manufactured parts • Process optimisation based on novel in-line / at-line photonic measurement and multi-modal metrology • Big Data correlation, meta modelling and quality prediction • Data analytical techniques / mathematical methods to optimise information gathered from available measurements (e.g. compressive sensing, super-resolution imaging) **Laser specific materials development** • Alloys and materials for additive manufacturing • Photonic specific materials for electronics • High-performance materials for laser processes			
Joint actions required	EFFRA; Robotics; SPIRE			

3. Health

Major challenges:

- **Advanced Photonic tools for life science industry as well as endusers** (for example, medical doctors or research)**:**
  - ✓ Photonic tools for real-time proteomics, genomics, metabolomics;
  - ✓ Accelerating and enabling photonic tools for the pharmaceutical industry, understanding, regenerative medicine, personalised medicine, high throughput, high-content screening;
  - ✓ Photonic tools for understanding the origin of diseases beyond risk factors, finding pathways for treatment, photonics for health (nutrition, lifestyle, environmental influences, toxicity).
- **Affordable photonics-based real-time diagnostics:** to stratify and classify disease status monitor and assess treatment response for the practical implementation of precision medicine; optogenetics for the treatment of brain or heart diseases; photonics for interventional guidance (augmented reality); multiscale access to the body (depth of penetration/optical resolution)
- **Mobile photonics devices and advanced biosensors** for instant point-of-care (-use) detection/diagnostics and treatment, that measure the patient’s medical condition, transportable photonic devices for monitoring environmental parameters

Research and innovation challenges

3. Health

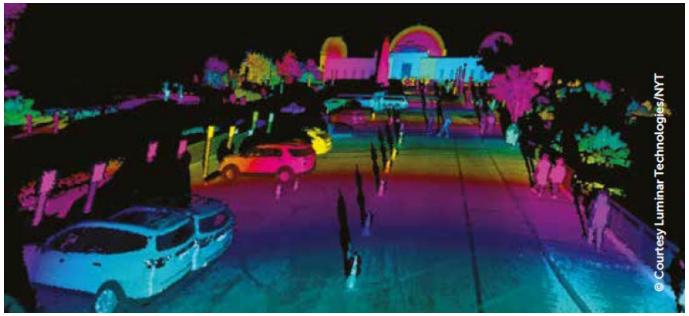
Roadmap:

	2021/2022	2023/2024
Overview **Technology Challenges**	Mobile Biosensors	Photonic diagnostics and intervention
Critical milestones to move from Science to Market	Biocompatible materials need to be found/investigated. Further convergence and integration of photonics, electronics and microfluidics: • Miniaturisation of optical components to enable smaller on-chip solutions (in-body devices with volume < 1cm3) • Low cost miniaturised broadband sources and detectors • Demonstration of higher effectiveness for state of the art reliability and specificity in in-vivo conditions	Miniaturisation and integration of optical components to build a • 3D label-free histopathology and treatment modality • Imaging platform to measure cell/brain oxygenation mountable on a cart • Integration of optical, electronic and microfluidic components for POC systems for advanced analysis of body liquids to fit in a shoebox
Photonics **Research (R) & Innovation (I) Challenges**	Improve optical contact for on-body/in-body biosensors (stable, reproducible and continuous) (R) Biomarkers research (R) Develop mobile biosensors to the next level (body liquids, but also portable image systems) (R & I)	3D label-free histopathology and treatment modality relying on augmented reality – • photonic components (R) • system (I) Advanced POC Device for fast analysis of body liquids (I) Imaging platform to measure cell/ brain oxygenation (10x more precise than current gold standard) (R)
Joint actions required with other disciplines (Artificial Intelligence) or fields (robotics)	ETP: EuMaT for biocompatible materials ETP 4 HPC for the development of data handling and evaluation ETP Nanomedicine (biomarkers)	ETP Nanomedicine (biomarkers); European Technology Platform on Smart Systems Integration EPoSS, ETP 4 HPC for the development of data handling and evaluation

4. Climate, Mobility & Energy

Major challenges and technological needs:

- **Photonics sensing:** Improved and robust sensing capabilities at affordable costs are required (i.e. point-cloud image). A considerable gap to be covered is to get an improved, fully performant lidar sensor, with the required spatial resolution and range that allow motorway to travel at normal traffic flow.
- **Battery health monitoring:** Technology for measuring the battery state of charge, state of health, and inside temperature should be safe in case of vehicle collisions or other damages to the battery pack. A beneficial approach appears to be based on fibre optics which are not electrically conducting.
- **Photonic Integration for Sensors:** Photonic integration is a key enabler to overcome these and to create embedded sensing systems suitable for compact, robust and cost-effective multi-physical sensing
- **Affordable and efficient Adaptive Driving Beam (ADB) for mainstream vehicles**.



4. Climate, Mobility & Energy

Major challenges and technological needs:

- **Communication with Light:** low-cost, reliable and small components for light-based communication (LiFi) communications, together with the implementation of V2V and V2I communications will enable new capabilities of interaction between various IT devices, machines, vehicles, other road users, and the infrastructure through high-speed, short-range communication.
- **Immersive Interaction and Occupant Monitoring**
- **Micro displays**

4. Climate, Mobility & Energy

Roadmap: *Mobility*

	2021	2022/2023	2024/2025	2026/2027	2028
Overview Technology Challenges	• Photonic sensing • Battery health monitoring • Affordable and efficient Adaptive Driving Beam	• Photonic sensing • Battery health monitoring • Affordable and efficient Adaptive Driving Beam • Information projection • Communication with Light (LiFi)	• Photonic Integration for Sensors • Battery health monitoring • Information projection • Communication with Light (LiFi) • Immersive Interaction with displays having new properties • Micro Displays	• Photonic Integration for Sensors • Information projection • Communication with Light (LiFi) • Immersive Interaction with displays having new properties • Micro Displays	• Photonic Integration for Sensors • Communication with Light (LiFi) • Immersive Interaction with displays having new properties • Micro Displays
Critical milestones to move from Science to Market	Sensing sufficient for automated highway driving High-beam always on, except where glare	Sensing and Adaptive Driving Beam adverse weather performance	Daylight vs night-time information projection requirements Distraction and drowsiness monitoring	LiFi range, bandwidth and immunity requirements	Distraction measures
Photonics Research (R) & Innovation (I) Challenges, Education (E) & Training (T) Challenges	Sensing range and resolution for highway speed under all relevant weather conditions	Affordable high-resolution matrix headlights and related control abilities Efficient light sources and optical systems with appropriate colour temperature and colour change abilities.		Wavelength selection Communication protocols and interference handling	Virtual displays Augmented reality Congruent displays

Research and innovation challenges

4. Climate, Mobility & Energy

Roadmap: *Lightning and Organic photovoltaic*

	2021	2022/2023
Overview **Technology Challenges**	• Cost-effective VHF and embedding • High-efficiency luminaires and light sources for energy saving • Semiconductor-integration and System in a Package to save resources • Sensing and energy harvesting/ wireless power • Deep UV-LEDs for Corona prevention • IR based sensors • OPV efficiency + stability increase • Next-generation freeform optics for energy-efficient luminaires • LED in X (in cars, textiles,...)	• Multicolour high pixel density dice • New materials for light emitters, detectors, OPV,... for energy saving • Transparent displays, OPV, luminaires • Visible wavelength VCSEL + optics • System in Package for higher power LEDs (resource-saving) • 3D printed optics for resource-saving • Horticultural lighting • Validation and verification of HCL
Critical milestones to move from Science to Market	• Complex ecosystem • Proof of manufacturability • Proof of business case - Cost for manufacturing low enough - Consumer persuaded of a new concept - Understand the real demand of consumer (as part of HCL) - Seamless product integration	• Scientific and business community able to judge the market/technology • Open source vs. alternative implementations decided • Standardization
Photonics **Research (R) & Innovation (I) Challenges**	• Extension of VHF to SELV, higher power, wide output-range • Cost-effective supply for IoT-devices, most probably also based on VHF • Closed-loop solutions for colour-temperature • Sensor fusion • Process improvements • Realistic lifetime models	• Sensorics/camera with hyper-spectrum analysis (IR, UV) => cheap system-approach • Wireless power (electromagnetic-resonance and radio) for sensors and small luminaires

5. Safety, Security, Space & Defence

Major challenges for **photonics-empowered, autonomous and resilient dual-use IoT microsystems** include:

- **Systems, not components:** integration of the photonic parts into full products.
- **Miniaturisation:** of utmost importance for its integration into IoT microsystem products.
- **Cost-effectiveness:** to achieve the lowest fabrication cost of photonic sub-systems, maximum use of manufacturing techniques related to semiconductor production should be made.
- **Platforms, not individual solutions:** for utmost cost-efficiency, minimum NRE (Non-Recurring Engineering, a onetime cost to research, design, develop and test a new product) is mandatory.
- **AI-empowerment:** only insights and not raw data should be communicated, analysis and interpretation of the acquired data must occur within the photonic subsystem to reduce external bandwidth requirements.
- **Multi-parameter sensing:** Future IoT solutions will lie in the simultaneous acquisition of data, in the form of massively parallel multi-parameter/multi-analyse sensor systems.
- **Maintenance-free:** during long periods or even during full life-time of the system.
- Resilience/robustness; Low power; Eco-Friendliness;
- Focus on high-growth/high-value markets

5. Safety, Security, Space & Defence

Roadmap:

	2021	2022/2023	2024/2025	2026/2027
Overview **Technology Challenges**	• AI empower ment of photonic IoT solutions • New materials and fabrication processes for NIR/MIR/FIR IoT components and sub-systems	Integration of cost-effective, low-power, miniaturized multi-sensor IoT platforms. Demonstration with cloud-based AI/ML engines	Novel concepts for "smart" multi-sensor photonic IoT systems with built-in AI data interpretation: Data at the edge, i.e. cloud-free autonomous IoT solutions	Successful demonstrations of maintenance-free, self-calibrating, fault-tolerant, self-diagnosing, "smart" multi-sensor photonic dual-use IoT solutions
Critical milestones to move from Science to Market	Alliances created between partners in Photonics, AI/ ML, security/ safety and defence	PoC studies and demonstrations in selected high-potential dual-use applications and markets	Field tests in selected high-potential dual-use applications and markets	International market penetration with first dual-use IoT components and systems
Photonics **Research (R) & Innovation (I) Challenges**	• Lower costs of NIR/MIR/FIR IoT components and sub-systems. • Value creation through AI/ML empowerment of photonic IoT solutions • Identification: High-value dual-use applications	• Miniaturize multi-sensor PIC-based photonic sensing platforms • Select most promising applications for cloud-based dual-use proof-of-concept demonstrations	• Make IoT devices "smart" by embedding AI/ML engines • Fabricate/ demonstrate cost-effective, autonomous high-value IoT solutions without cloud-computing	• Optimize user value through robust, self-calibrating "smart" IoT solutions • Focus on "green" products, including recyclable or biodegradable consumables

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6. Agriculture & Food

Major challenges:

- **Image-based systems: innovation drivers in agriculture and food.** Demands for robust photonic imaging systems under outdoor conditions are high. imaging systems strongly support process automation: the evaluation of the sensor interpretation is crucial for the admission of autonomy (field robotics).
- **Integrated Photonics Technologies for Agrofood:** Fibre Optic sensing, sensors for forestry, hybrid lasers, etc.
- **Lasers and lighting devices; tailored light for agrifood applications:** LED lightning in greenhouses, optical sensors, light sources and laser technology.

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Research and innovation challenges

6. Agriculture & Food

Roadmap:

	2021	2022/2023	2024/2025
Overview **Technology Challenges**	Mapping and gapping: • AI & photonic solutions • Identify powerful applications	Mapping & gapping: • Continuous alignment of crossover research agendas • Powerful applications identified	• Fingerprinting of plants/food products with novel concepts for "smart" multi-analytic photonic systems with built-in AI/ML data interpretation
Critical milestones to move from Science to Market	• Report & new alliances / projects launched in crossover Photonics & AgTech	• Report & prototype demonstrations in projects	• A clear increase in photonic industry sales in AgTech
Photonics **Research (R) & Innovation (I) Challenges**	• Precision agriculture and novel sensors: User benefits • Vertical Farms & autonomous systems through AI/ML empowerment of photonics solutions: User benefits	• Miniaturisation/ featherweight sensor developments • Select most promising applications for cloud-based proof-of-concept demonstrations	• Make sensor systems "smart" by embedding AI/ ML engines • Fabricate/ demonstrate cost-effective sensors aimed for a large number of sales (> 1000)

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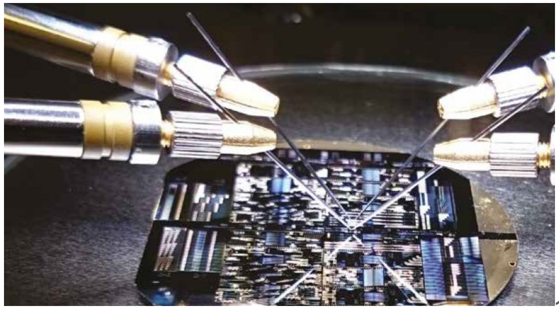
7. Core Photonics Technology Platforms

Major challenges:

- **Systems, not just components:** we must provide effective means for the combination of technologies to achieve overall systems goals
- **Miniaturisation:** Many applications require subsystems that are very small so that they can be integrated into other devices such as sensor elements and smartphones
- **Cost-effectiveness:** The power of photonic integration to achieve high performance at minimum cost will continue to provide major opportunities for innovative products
- **Platforms, rather than individual solutions:** This is the key to achieving maximum return on investment and reach the largest number of market sectors in the shortest possible time
- **Robustness and reliability:** Many photonic systems will be embedded in safety-critical systems where reliability and resilience are mandatory
- **Power efficiency,** to mitigate the environmental impact of large-scale electronic systems deployment and allow new applications which are self- or battery-powered
- **Eco-friendliness**
- **Accessibility**



7. Core Photonics Technology Platforms

Roadmap:

	2021	2022/2023	2024/2025	2026/2027
Overview **(Technology) Challenges**	Photonic Components and Systems Enhanced functionality, spectral coverage, performance to enable new applications New organizational frameworks to facilitate route to market			
Critical milestones to move from Science to Market	Horizon 2020 pilot lines successful and sustained	Innovation Factory established	Enhanced production technologies	>50 products in market through Innovation Factory
Photonics **Research (R) & Innovation (I) Challenges, Education (E) & Training (T) Challenges**	Photonic Systems Integration → PICs for sensing; PICs for communications → Pervasive Photonics in Next-Generation Electronic Systems → Enabling component technologies →			
Joint actions required with other disciplines (e.g. Artificial Intelligence) or fields (e.g. robotics)	Microelectronics, microfluidics, imaging sensors, MEMS → Production equipment, techniques, materials → Roadmapping, international liaison →			

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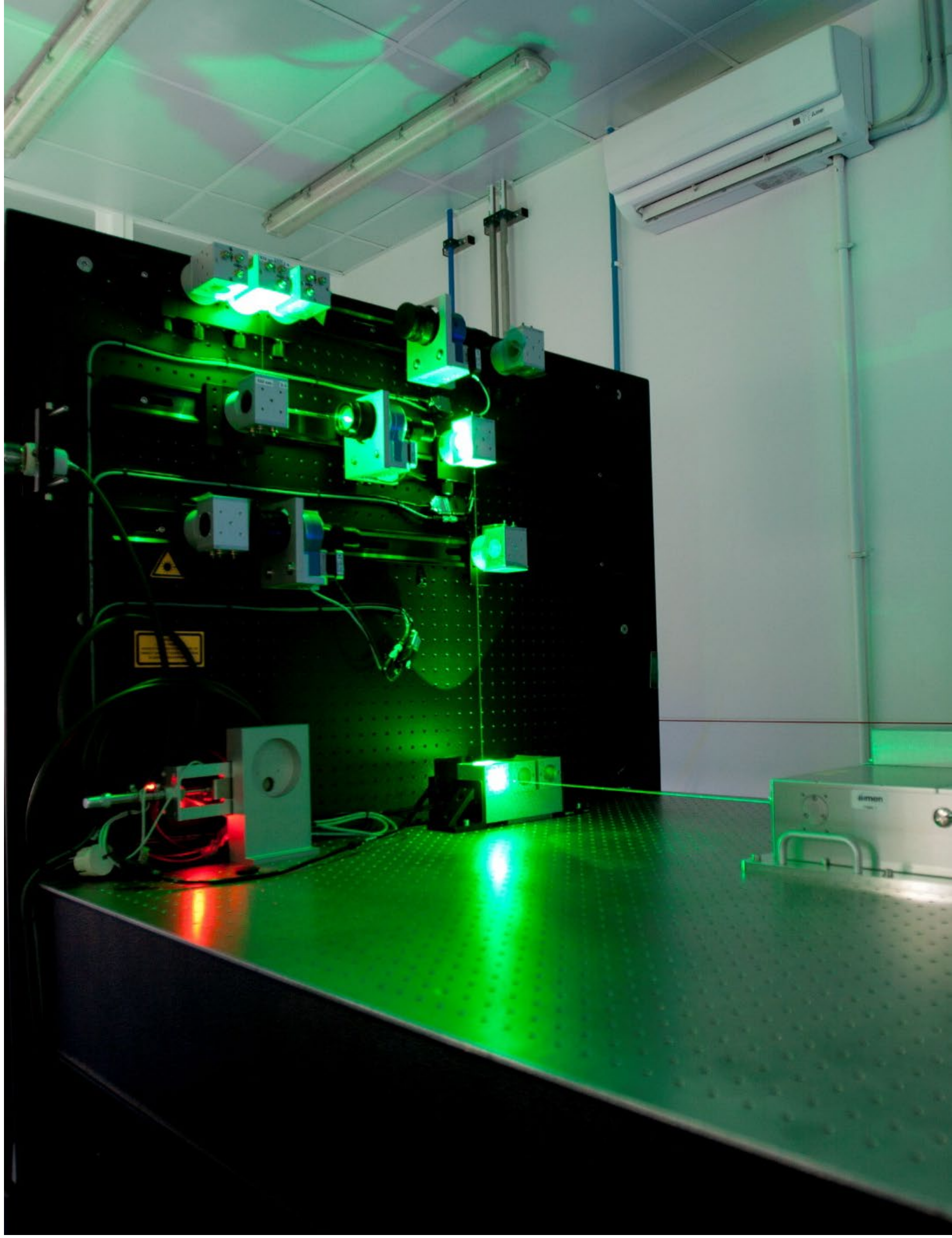

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