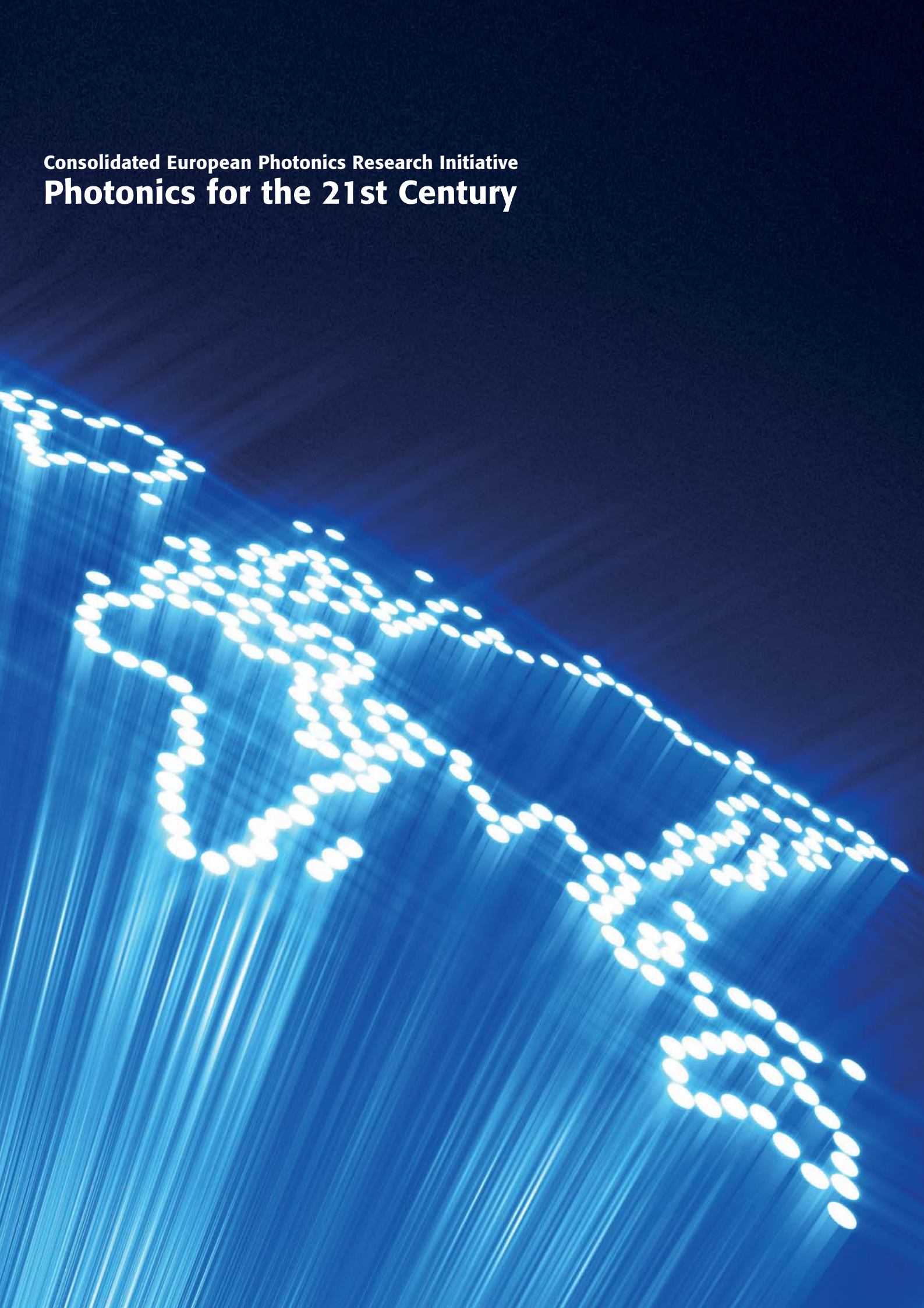
Consolidated European Photonics Research Initiative

Photonics for the 21st Century



Executive Summary

Photonics is one of the most important key technologies for markets in the 21st century. It influences all aspects of our lives and is essential to Europe's industrial competitiveness. The photonics industry plays a vital role in securing leadership in areas such as information and communication, lighting, manufacturing, security or life science and health. Photonics is a driver for technological innovation and has tremendous leverage for creating products that multiply the value of initial photonics components and technologies many times over. Photonic technologies have already revolutionised the worldwide exchange of information and data flow by forming the technological backbone of the World Wide Web. Because photonics technologies are at work, we are now benefiting from the convergence of an industrial society with the information society and dynamic growth due to their synergies.

Our entry into the “photon century” requires a shared European initiative that enables industry and research to uphold their outstanding initiatives to explore the nearly limitless future applications of light and to reap the expected benefits in terms of creating both jobs and wealth. Many important European industries, from chip manufacturing and lighting, health care and life-sciences, to space, defence and the transport and automotive sector rely on the same fundamental mastery of light. Without strong European leadership in photonics technologies, these industries will be left vulnerable to strong competition from the USA and Asia.

To achieve this leadership for the benefit of Europe and our citizens, an ambitious programme is required to:

- Supply the necessary research environment capable of supporting the visionary and industrially relevant R&D activities for photonics components, systems and their application over a broad range of industry sectors;
- Establish strategic links between mainly SME based photonics industries and principal user industries to share their long term vision and to mobilise a critical mass of resources;
- Foster co-operation and smooth out the current fragmentation of national and European R&D activities.

The members of the representative group of industrial and research organisations are committed to joining in and anticipate contributing actively to such an initiative. As a first step, all stakeholders must endeavour to implement a technology platform for photonics to ensure that Europe strives to be a leader at the forefront of the photonics century.

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The Century of the Photon has Just Begun

The progress and development of mankind are driven by dreams. One of these dreams is the mastery of light, starting many millennia ago with the control of fire. Since then, huge achievements have been made in both the understanding of light and applying this understanding for the improvement of our lives.

In the last part of the 20th century, a new field of study and enterprise was created: photonics. Photonics has emerged from a number of disciplines altogether involved in the mastery of the photon: optics, material science, electrical engineering, nanotechnology, physics and chemistry. Meanwhile, the sophisticated combination of light and electricity has created synergies that no one could dream of when the term "photonics" was coined in 1967 by Pierre Aigrain, a French scientist.

- Photonics is the science of the harnessing of light.
- Photonics encompasses the generation of light, the detection of light, the management of light through guidance, manipulation, and amplification, and most importantly, the utilisation of light as a tool for the benefit of mankind.

Today, at the beginning of the 21st century European scientists and engineers are prepared to take the mastery of light to a new dimension, bringing a quantum leap in growth and competitiveness in economic areas of the highest importance.

History teaches us that a major technology principle can trigger the creation of new and revolutionary industries for decades following its discovery. The transistor was immediately appreciated as a new kind of electronic amplifier when it was invented in 1948, but no one could conceive of the revolutionary change that this device would create in all walks of life. The transistor paved the way for the microelectronics industry, and the computer age, both of which are now major drivers of the worldwide economy. The laser was invented only a few years later, but there was no idea at the time that this would lead to a revolution in recorded music, communications, life sciences and manufacturing, to name but a few important examples.

We have just crossed the threshold of the age of photonics with the knowledge and the technologies in hand to benefit from the photonic revolution: achieving a new level of mastery in the generation, control and use of light, harnessed for many and varied applications.

The 20th century is often called the century of the electron because of the technological breakthroughs enabled by the mastery of the electron. In a similar way the 21st century will likely be known as the century of the photon.

Phenomenal Photons

Light is made up of photons. The photon, like the electron, is a fundamental building block of the universe. Photons have properties that set them apart from anything else that we encounter in our lives:

- Nothing can travel faster than the speed of light.
- Photons, unlike electrons have no weight and create no resistance.
- Focussed light generated by lasers constitutes the highest concentration of energy known on earth.
- A pulse of photons can be as short as one-millionth of a billionth of a second, the dimension of time in which molecular and atomic reactions take place.
- Light beams are well-suited not only to help us see, but also to hold and manipulate atoms.
- As light acts virtually contact-free; it can be used as a tool even under extreme conditions.

Due to the ground-breaking progress in photonics and the related disciplines, a new generation of photonic tools is within reach. Now we have the means and the insight to create photonic systems that will fully exploit the unique powers and potentials inherent to light.

Boundless Possibilities

Several technological achievements of the present could not have been realised without significant contributions from photonics. At this stage, photons are found at work all around us in obvious as well as subtle ways. Moreover, photonics has an extraordinary potential for the benefit of the European citizen. Here are some examples from the present and the future:

- Photonics technology enables the processing, storage, transport and visualisation of huge masses of data; information flow and data streams are rapidly increasing; in the future optical systems will provide a bandwidth 1000 times greater than today's offering and enable broadband for all.
- In manufacturing, (laser) light is used as a fast and precise tool for many purposes, materials and objects, from huge ocean-going tankers and car manufacturing to tiny nanostructures. Light is the medium that ensures flawless production processes, as machines start to see with "digital eyes". What is more, photonics will pave the way for maintaining and developing cost-effective manufacturing in Europe in the future.
- Innovative lighting systems create convenient surroundings and save energy; if light-emitting diodes are introduced aggressively, it will be possible to save at least 2 billion barrels of oil per year by 2010.
- Modern health care has been revolutionised by the use of optical applications in examination, diagnosis, therapy and surgery; further innovations and breakthroughs seem to be within reach, for example micro-probes and remote diagnosis.
- Finally, light is the key to the microcosmos of life in biotechnology, pharmaceutics and genetics. For example, photonic tools are capable of not only manipulating molecules but also living cells without causing harm to them. Photonics will significantly contribute to make life-saving drug development faster, more effective and affordable.

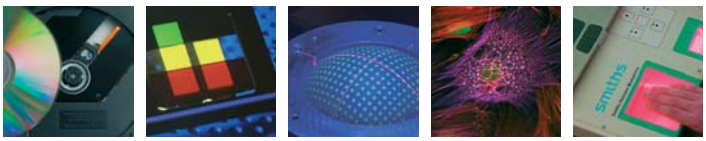
However, this is just the beginning. Present-day tools, sources, systems and applications allow us to realise only a small fraction of the ultimate performance of photonic systems. There can be no doubt that photonics and optical technologies will be among the most influential drivers of innovation in the 21st century:

- Photonics offers new and unique solutions where today's conventional technologies increasingly reach their limits in terms of velocity, capacity and accuracy.
- Future progress in key areas of industry and technology, such as life science and health, information and communication, energy and production, will literally depend on photonics.
- Photonics offers vital contributions to a number of fundamental societal challenges with regard to the information society, public health care, sustainable growth, etc.
- Photonics is a growth sector capable of strengthening and advancing the competitiveness of European industry and economy to a considerable extent.

It will take inspiration, brilliance, diligence and a lot of hard work to turn the ideas into design prototypes and then into useful products. Above all it will require a shared vision between industry, R&D, and the users of these technology innovations.

Advancing Growth and Competitiveness

The photonics industry in Europe has already become complex and multidisciplinary after only a few decades of existence. The industry relies on a unique set of talents, markets and circumstances in Europe and is bound together by its academic network, suppliers, markets and challenges in the global market. Moreover, about two-thirds of the photonics workforce are employed by SMEs. Optics and photonics products mainly drive five major market areas:



Information, Communication and Imaging
Lighting and Displays
Manufacturing and Quality
Life Science and Health Care
Safety and Security

Europe is a major player in all of these areas, with world-leading industry and academic institutions. Many of the key inventions and technologies which have underpinned the photonics revolution have stemmed from Europe, including pioneering work in optical fibres, optical amplifiers, transmitters, receivers, displays, instrumentation, metrology, lasers for material processing and imaging systems.

The overall economic impact of photonics results not only from photonics products and systems constituting markets in their own right. Much more significant is the huge secondary impact, resulting from the use and application of photonic and optical components, tools and techniques in several sectors. This emphasises the fact that photonic technologies are regarded as highly important enabling technologies and drivers for innovation.

With regard to the primary sectors, there are at least two areas where European industry leads the world: solid-state lighting, where European companies now account for more than 30% of the world lighting market and are innovation leaders in the development of LEDs for lighting, and laser-assisted manufacturing, where Europe dominates global manufacturing and sales with about 50% of the total worldwide market.

Moreover, the economic growth rates for optics and photonics industries far exceed those of the economy. For example, the laser sector, where European industry holds the majority share, had enjoyed an annual growth rate of more than 18% for the past 10 years and has now reached a volume of 2.5 billion. The European machine vision sector has experienced annual growth rates of between 10% and 30% in the last decade and will continue growing dynamically, as only 15-20% of all possible applications have been realised. For optics and photonics in life sciences the annual growth rate exceeds 38%; and for the market for organic light-emitting diodes (OLED) an annual growth rate of about 40% is expected over the next 5 years.

Intellectual property is one of the pillars of economic growth, and is the most important for ensuring that new businesses can get started and grow, replacing mature industries that may be outsourced to lower labour-cost regions. There are three domains where Europe is a leader in intellectual property: communications, imaging and manufacturing.

When subsumed in three key figures, the relevance and the potential of photonics for European industry and economy become more than obvious:

Estimation for 2003:
500,000 jobs in the EU
60 billon worth of products
15,000 patents

Prediction for 2010:
1.5 million jobs in the EU
250 billion worth of products
45,000 patents

In the knowledge society of the 21st century, the availability of highly qualified staff with a scientific-technical background is an indispensable prerequisite for prosperity and growth. This issue must be addressed in a coherent approach, starting well before university, by making photonics and optics part of the curricula at all educational levels. We need to fascinate pupils at school in the very early stages. The triggering of enthusiasm and interest for the field of photonics is relatively easy, as the fruits of this technology are ubiquitous: lighting, displays, CDs, DVDs and lasers.

Photonics – a Common Challenge for Europe

Although involving a number of disciplines, photonics is clearly a stand-alone scientific and technological field. Its common denominator is the mastery of the photon. In Europe, this factor has not yet been sufficiently taken into account. Until now, photonics research is fragmented among various fields of application. Consequently, we are lacking a concerted effort to develop the fundamental sciences, technologies, components and systems that together drive all applications. The division of research into different application areas prevents us from fully exploiting the tremendous synergy that is a reward of more multidisciplinary organisation of the research. Only a coordinated approach can make use of the economies of scale that are necessary to sustain economic production in Europe and to reach the critical mass of investment to address the big markets of the 21st century.

To rise to this challenge, a partnership has been formed between the actors in the important sectors of the optics and photonics R&D infrastructure: industry, research and academia. The paper in hand provides the rationale and the justification for the important political process that is needed to implement a coordinated action plan among all the stakeholders.

At the political level, support is required with respect to the strengthening and to the structuring of photonics research within the scope of the forthcoming Framework Programmes. Such political backing will be crucial in order to foster cohesion and co-ordination between the fragmented endeavours and lay the foundations for the implementation of joint strategies and concerted plans for action among all stakeholders:

- Establishing public-private partnerships;
- Combining top-down and bottom-up approaches;
- Broadening pre-competitive collaboration and standardisation;
- Providing for protection and exploitation of European intellectual property;
- Adapting and improving the educational and scientific basis;
- Raising public awareness and communicating research results to the wide public.

It will take prompt and forceful coordinated European efforts in order to address the challenges, stay competitive and tap the full potential of photonics for the benefit of our citizens. The absence of co-ordination and of jointly developed and implemented strategies is a brake that impedes the progress and competitiveness of the optics and photonics industries in Europe. Many important European industries, from chip manufacturing and lighting, health care and life-sciences, to space, defence and the transport and automotive sector rely on the same fundamental mastery of light. Without strong European leadership in photonics technologies, these industries will be left vulnerable to strong competition from the USA and Asia.

To achieve this leadership for the benefit of Europe and our citizens, an ambitious programme is required to:

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Taking into account the fierce global competition with talented and well-educated scientists in Asia and the US, it is crucial for the optics and photonics community in Europe to build on its leadership position. A powerful and concerted European approach is the way to ensure our continued success and to ensure that we benefit from the thrilling innovations that lie ahead.

Annex 1:
Information, Communication and Imaging

Evolution of communications: The electronics intermezzo
In ancient times, the fastest method of long distance data transport was provided by smoke signals. This "optical" approach was polished over several centuries to a complex network of relay stations, where arms of semaphores were lifted and lowered, visible over long distances.

The speed of data transport was acceptable, but capacity was low. During the last century this problem was solved by switching to electronic data transport, which connected people around the world. This approach revolutionised our lives, but about twenty years ago this technology had reached its limits, while our need for an even higher capacity of communications had not. The paradigm shift back to optical solutions for communication heralded the birth of our modern information society. Optical networks have opened the door to almost unlimited digital communication, building the very foundations of our modern life, for business as well as personal needs.

Photonics – booster for information and communication
Perhaps unnoticed by the public, photonics has become the driving force for information and communications in all their facets. The extremely small nano-structures of computer chips are fabricated by means of optical lithography. The next generation of optical lithography equipment capable of reducing the size even further arrives just at the time when the international roadmap tells us that industry will need these new chips. In other words, the progress toward a higher quality of information and data processing has become a question of the driving force of photonics.

The highways of communication and information flow are optical, as stated above. The data rates of the Internet are scaling with advances in lasers, optical fibres and optical coding technologies.

Bringing the benefits of broadband communications to European citizens presents both the challenges and the rewards for the next generation of photonic systems. We need components and architectures that support bandwidth growth to 100-1000 times that of today's "broadband" services. Through a leadership position we can drive standards rather than react to them and leverage European solutions into the global market.

Less than five years ago, connector technology for optical fibres had become so mature that it could withstand the rough environment of a car and was easy to use for any mechanic. Since then most manufacturers are implementing optical data buses in their cars. The era of interactive communication of the different intelligent components in cars began.

Third in league with information and communication is data storage. The change from records to CDs and video tapes to DVDs, again, is a hint of a major paradigm shift. Abstracting away the obvious advantages of this scalable technology, it is important to point out what made it happen:

The CD displaced the record when infrared laser diodes became a one-euro article, the DVD replaced the video cassette recorder (VCR) when visible red diodes also reached this price level, and the current arrival of the blue-ray disc is exactly correlated with the affordability of blue laser diodes – made possible only by the development of laser diodes with shorter and shorter wavelengths. Further developments are underway, ranging from non-spinning optical discs and optical near-field discs to holographic media. Whether future optical TeraByte discs come from Europe or abroad is just a question of who is first.

Similar arguments hold true for data displays, the last component necessary for an I&C infrastructure, besides data processing, transportation and storage. The LCD replaced the cathode ray tube and novel concepts based on inorganic or organic light-emitting diodes are just around the corner. Beamer technology, in contrast, is not a replacement technology but rather one that created a completely new market.

The markets for photonics in I&C are sound with steady growth, as demonstrated by the exemplary figures below:

	2002	2003	growth
DVD drives	17 m. pcs.	22 m. pcs.	29%
Digital cameras	20 m. pcs	27 m. pcs.	35%
Data transport Internet	33 Mio. Tbyte	57 Mio. Tbyte	73%
Flat-panel displays	20 m. pcs.	29 m. pcs.	45%

Annex 2:
Lighting and Displays

From fire to physics
Since the age of the caveman, mankind has essentially used burning or heated materials as a light source. The invention of the incandescent light bulb in the 19th century, based on heating a wire, together with the introduction of the electric power grid, paved the way for the first mass-produced light source that offered clean and reasonable bright illumination for the homes and factories of the industrial world. However these light bulbs are very inefficient and wasted energy is a major component of today's energy crisis.

Europe is leading the way to the future: solid-state lighting
European R&D has been leading the way to the development of new principles of more efficient lighting, such as gas discharge lamps, invented in the middle of the 20th century, and more recently solid-state lighting, which offers the most elegant method for direct conversion of electrical energy into visible light. As a result the major players in the lighting industry are in Europe and have a European R&D base: Philips and Osram. Together they hold a worldwide market share of more than 50%. This excellent position for Europe must be secured by constant innovation.

Solid-state lighting (SSL), consisting of inorganic and organic light-emitting diodes, is a true revolution in the lighting industry and has the potential of replacing conventional light sources the way integrated circuits replaced electron tubes fifty years ago. SSL combines high conversion efficiencies that will surpass today's most efficient sources in general lighting applications, as early as 2007 with freedom in shape and full tunability of brightness and colour. This paves the way for tuning the light spectrum with respect to visual and in the future biological perception. "Healthy light" will improve workplace safety, human mood and wellbeing and enable light therapy.

Colossal energy savings
Solid-state light sources are already the most efficient sources of coloured light in almost the entire visible spectral range and are rapidly replacing alternative light sources in areas such as signage, signalling, advertising and emergency lighting. Considerably more energy savings can be realised in general lighting by replacing existing less efficient white light sources, such as incandescent lamps by solid-state light sources. That translates for Europe in 2015 into savings of 40,000 MW electrical peak power supply or an equivalent of 2 billion barrels of oil and 50 million tonnes CO2 per year. It is estimated that by 2025, SSL could reduce the global amount of electricity used for lighting by 50%! This would be an historic achievement for mankind.

More than a light bulb: revolutionary new displays
Our society is becoming increasingly dependent on the provision, processing and reception of information. The key technology at the end of this information chain is visualisation. The human brain spends most of its activity on seeing and interpreting images. Future displays based on SSL compo-

nents will offer exciting features in terms of resolution, colour, contrast, speed or compactness, far beyond today's possibilities. The display market will grow with double digit growth rates (17%) from 58 bn. in 2004 to 90 bn. in 2007 .

Slim, liquid crystal displays (LCD) are everywhere in our daily life: on our wrist watches, our mobile phones or in our electronic organisers. These displays get their light from the same solid-state light source, the light-emitting diode. An LCD screen backlit with a multitude of tiny red, green and blue LEDs can achieve colour quality in terms of brilliance and colour that has not been feasible up to now. Screens like this will claim their share in future large-area flat-screen televisions. Now we must make sure that Europe is participating in this huge marketplace.

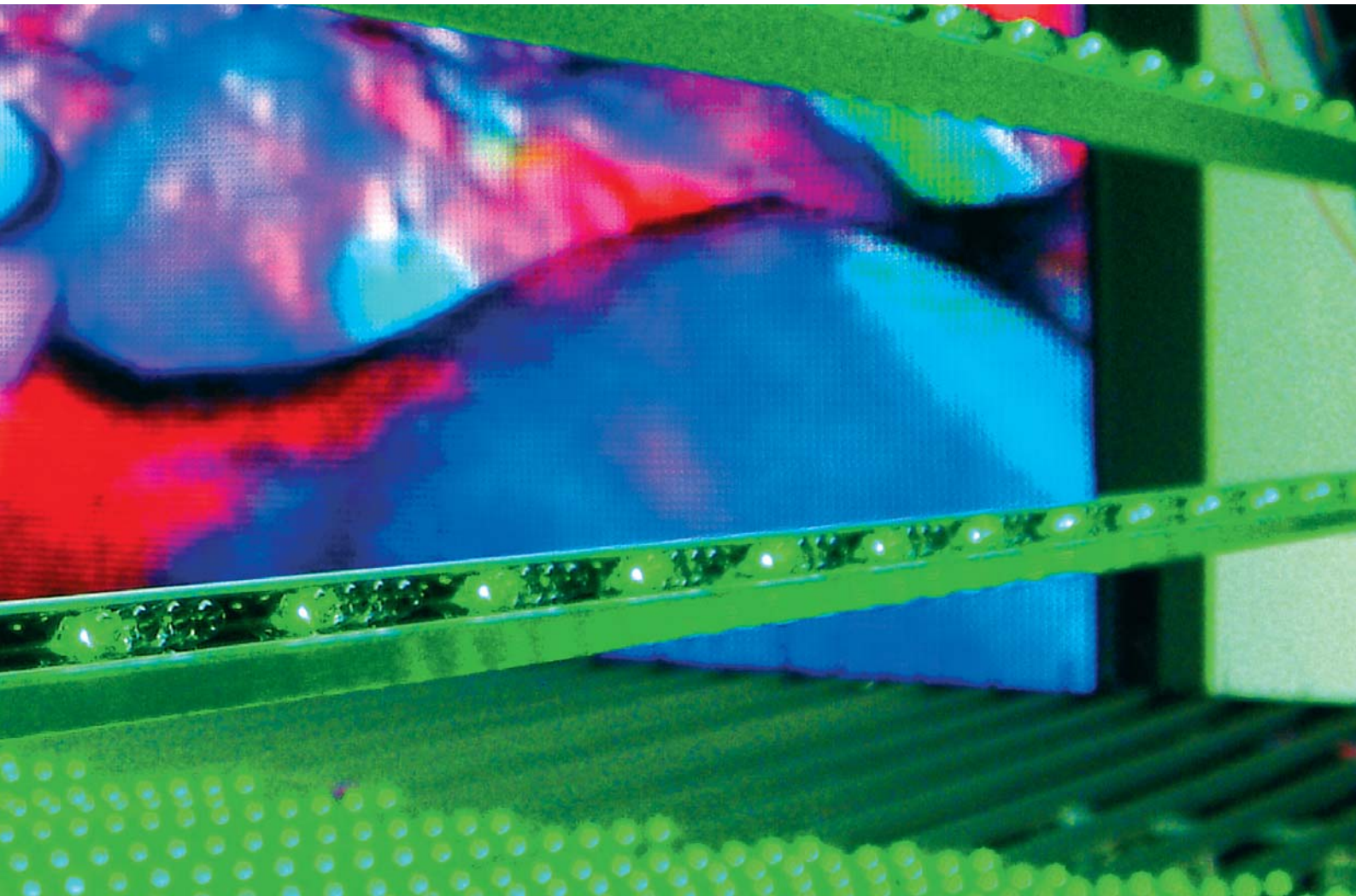
But LEDs can do even more than that. If space is available, they can be arranged as colour pixels in large-area display panels. We can find such panels of considerable size in train stations, airports, shopping malls or sports stadiums. In this very international market, Europe is playing an important role, both as supplier of panels as well as components.

These same light-emitting diodes are now being used in light projection displays. If we look a bit further into the future, it will be possible to replace the LEDs with coloured laser diodes, which will further enhance the performance of such projectors. The European industry has a strong position because of their expertise in optical design, optics fabrication and solid-state light sources. This can be exploited with great economic returns.

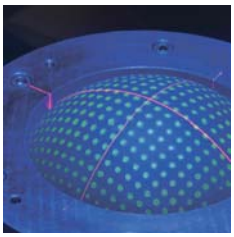
Displays based on organic light-emitting diodes (OLEDs) are used to generate light of any colour with remarkable efficiencies. The processes for depositing these speciality organic materials have the potential to produce large light-emitting areas on flexible substrates at very low cost. Ultimately, OLEDs appearing transparent or mirror-like will enable the convergence of illumination and visualisation. Windows and walls will be converted into the carriers for lighting and visualisation with applications beyond our imagination. Significant inventions and basic developments have already been made in Europe, which puts Europe in a promising position in this field. Today, the market for OLEDs is 260 million. With an expected annual growth rate of 40%, it will grow to a 2.5 billion market by 2010.

Securing Europe's leading position in a key industrial area

Inorganic and organic LEDs will become the next generation of light sources, replacing in about 10 years' time the currently used incandescent and fluorescent lights. The possibilities in the field of displays are enormous, and so are the challenges. The strategic challenge is to develop these opportunities into an economic success for Europe. It will require the well-coordinated, focussed effort of many players in various fields, from materials science to manufacturing. We can ensure that the leading position of Europe in the lighting market of the 20th century will extend into the 21st century. Now is the time to build the basis for sustainable growth business with an historic positive impact on the environment.



Annex 3:
Manufacturing and Quality



A revolution in manufacturing technology
In a few short years, lasers have progressed from "a solution in search of a problem" to the most versatile, economical, and ecological tool in manufacturing. Nowhere is this more apparent than in the printing industry, where laser technology predominates from homes to the largest industrial installations. Lasers are the tools of choice for welding and cutting in automotive assembly, but also for fabric-cutting in the textile and apparel industry. Far from replacing scissors, the laser is the only tool capable of drilling the spray hole in high-efficiency fuel injection nozzles for automotive engines.

Opportunities for laser-assisted manufacturing
European companies and research dominate every aspect of this field, from basic research to manufacturing systems. It is a clear example that high technology development, manufacture and marketing can thrive in the European economic environment.

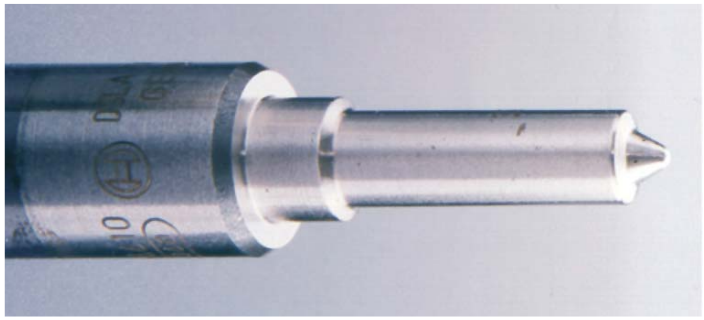
The key to the growth of this market is understanding the interactions between lasers and matter, and then using this knowledge to optimise the laser beam characteristics in order to control this interaction between light and matter. For example, in laser ablation the laser is pulsed with a low repetition rate but with a very high peak power. The electric field of the photons is strong enough to literally rip atoms apart. There is very little heating. On the other hand, for laser welding you want to heat up the material. The laser is operated in near continuous mode, and the total absorbed optical power promotes welding between two surfaces.

The major applications areas are:
- Printing
- Welding
- Cutting
- Marking
- Drilling
- Maskless lithography

Lasers are now being adapted to perform maskless lithography by laser ablation. This technique replaces a 30-minute cycle with a 5-minute cycle and therefore increases the throughput of a display line by a factor of 6. The laser scans across the surface of the screen, blowing off the metal where it is not needed and creating the entire network of contacts to millions of pixels. The process takes less than five minutes for a 1-metre screen. No polluting chemicals are used. This process replaces a 30-minute cycle using photo resist, a mask stepper and photo mask, followed by etching and chemical dissolution.

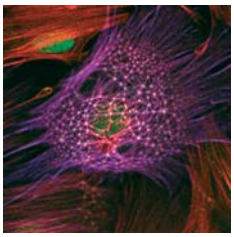
Important challenges
Research, innovation and the exploitation of intellectual property are the keys to the strong competitive position of European industry. To make the market grow, it is necessary to educate the manufacturing sector about the potential that laser-assisted fabrication can offer in a particular application. Through exchanges and discussions, the desired processing features can be understood, and a laser process devised. This can be a slow design cycle, or it can be accelerated through the implementation of an applications development centre. Europe's laser industry may consider creating such a centre where new manufacturing processes can be tried out on the latest available equipment. It is an ideal setting for a public-private partnership.

Machine vision – the enabling technology for competitive manufacturing
Machine vision technology gives production systems the capacity of visual perception. These "seeing machines" drive manufacturing to a preciseness and quality level never before seen – and at a falling cost level. More than 600 small and medium-sized machine vision companies in Europe currently employ an estimated 20,000 employees. This number is forecasted to increase to approximately 30,000 by 2010 – mostly highly skilled engineering and academic jobs. The turnover of the European machine vision industry is currently growing at a rate of 20% p.a. Solutions from Europe have a leading position in many fields, e.g. the inspection of optical media or flat panel displays predominantly applied in Asia. The real potential of the machine vision industry, however, is found in the "leverage effect" it has on virtually all manufacturing sectors – such as the automotive, pharmaceutical, electronics, food, paper or glass industry. It is the key technology for increasing productivity and competitiveness and decreasing costs, and the driving force for innovations on the factory floor. In a current survey, 82.3% of the companies reported an increasing demand for machine vision to keep their manufacturing operations competitive.



This is a fuel-injection nozzle. The exit nozzle is a hole only 50 microns in diameter and 1 millimetre in length and strict requirements on the roughness of the side-walls. This can only be achieved by the lasers machining with exceptionally high beam quality. The results are impressive: There is a 25% reduction in soot particle emission, and a 35% reduction in unwanted hydrocarbon emission.

Annex 4:
Life Sciences and Health Care



Optical technologies, new tools for life sciences and health care
Today our understanding of life is based on technologies that can show us only single pictures of the different stages in a living cell, so we do not know why things go wrong in the lifetime of a cell, e.g. developing cancer. Therefore our knowledge in life sciences and health care is limited, i.e. 2/3 of the available medication today is not effective. Additionally, early diagnostics of cancer or other major diseases are not possible.

Optical technologies have the exclusive potential to show us a live movie of the metabolism in a living cell without changing it, and build a new base for new effective treatment and diagnostics of major diseases making health care effective and affordable for our society. This way we will be able to see not only the structure but also the biological function of molecules in the entire cycle of life.

Imaging technologies: the first priority for medicine
The microscope helped Alexander Fleming discover penicillin and made the development of antibiotics possible. It has been established that optical technologies have always played a decisive role in life sciences and health care. The most important and unique feature of optical methods is, however, the possibility of interacting with and manipulating living tissue, in vivo, with a minimum trauma to the patient. Endoscopy enables minimally invasive surgery, making many operations simpler for the doctor and safer and more effective for the patient, while dramatically shortening the necessary stay in hospital. The latest advance in this respect is the "pill cam". This pill replaces the current colonoscopy procedure. The pill cam travels though the entire alimentary canal, recording pictures and transmitting them to a receiver worn by the user. No hospital stay is required at all.

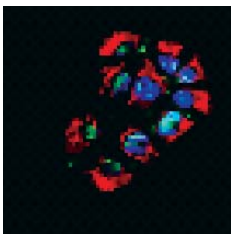
Laser surgery opened up new possibilities in vision care for treating ametropia, glaucoma, detachment of the retina or even macula degeneration, which invariably led to blindness just a few years ago. These examples, however, are just some milestones on the way to a real revolution, which is just ahead of us. We are now entering a new age of diagnosis and therapy on the molecular level, paving the way for cause-related therapy and early stage diagnosis.

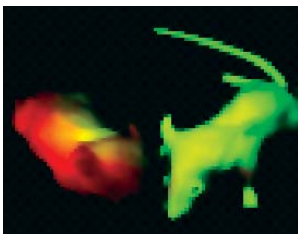
Understanding life on the nano-scale
To treat the root causes of a disease and to provide early stage diagnosis, it is necessary to understand the complex courses of action in living cells. The observation of metabolism inside living cells, however, only becomes feasible with the development of new bio-photonic materials: So-called photonic markers are molecules that are both optically active and can stain the organ or a pertinent process, finally bonding to a single molecule or protein that has to be identified. Currently, great efforts are being made to combine exquisite photonic functionality with total bioactive, but non-toxic materials.

Relief for social systems
Today, the drug libraries of the major pharmaceutical companies contain up to 1 million substances. The potential efficiency must be tested in the laboratory. In the last few years the cost for such an examination of substances as a potential drug was reduced from approx. € 7.5 m. to € 0.25 m. by introducing an optical readout to the biochip technology. Thanks to the optical analysis the automatic examination of up to 200,000 substances a day with up to 10 measurements per substance has become state-of-the-art. Further progress is underway. This technology makes European industry more competitive and contributes to a significant cost reduction in health care.

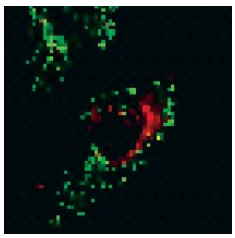
There is plenty of room at the bottom
Photonics is generating countless new possibilities in modern life sciences and health care just showing up on the horizon. Some examples: the smallest cavities can be detected effectively, even if hidden, by fluorescence or spectroscopy. Different precursors of cancer can be recognised by optical methods, ranging from holography and spectroscopy to coherence tomography. Photodynamic therapy is becoming an alternative to chemotherapy: Photosensitive substances can selectively be accumulated in tumours. They become a poison only if irradiated with light. The possibility of precise light delivery to cancerous areas by means of optical fibres is the guarantor for a therapy free of side effects. The latest major breakthrough in early stage detection of arthritis, which is crucial for an effective therapy, was achieved by photonics: Scattering infrared light in the joints is an effective indicator for an oncoming disease but neither as harmful as x-rays nor as expensive as magnetic resonance tomography.

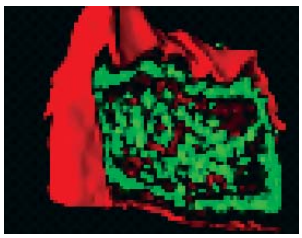
Europe is leading the race
Ernst & Young evaluated the impact of photonics in life sciences. The result was that we are just at the beginning of a tremendous technology boost. Annual growth of companies that deal with optics and photonics in life sciences is analysed to be 24% in Europe and 13% in the US for public companies that are quoted on the stock exchange, and 38% in Europe and 10% in the US for all companies including the public ones .





This picture illustrates some of the directions of research. The development of nontoxic markers allows to make living organisms photoactive. The skin proteins of a rat have been targeted with a green fluorescent protein (GFP), without causing any harm to the animal.





Novel photonic markers enable the analysis and tracking of living cell functions instead of merely identifying dead cell tissues, as was the case up to now. This change will represent a quantum leap in medical diagnostics and treatment.

Annex 5:
Safety and Security

Use photonics and absolute security becomes possible!
Although used for centuries, today a sealed envelope can be opened, read, and resealed secretly. More effort is necessary to crack a modern encryption code, but it can be accomplished with sufficiently powerful computers. Quantum cryptography, however, offers an absolutely secure alternative. It is based on entangled photons, a quantum-mechanical feature of light that has almost magical features. The features have now been measured experimentally, and European laboratories are leading the research to master this technology and its application to 100%-secure communications.

If there is an eavesdropper involved, the information destroys itself and the original recipient also notices the incident immediately. The mechanism of "self destruction" is in the laws of physics and can not be overcome by any means. Only photonics has the fraud resistant key! The impact can not be underestimated. It will influence our private lives, e.g. how bank transfers are made, but will also have grave consequences on the government level, e.g. how secret services and intelligence agencies work. Consequently it is an imperative to be at the forefront of this technology.

Photonics in safety and security has many facets
Photonics has a longstanding tradition in safety and security. In addition to traffic signals, signs, and lighting, innovations in photonics have enabled the transfer of high-technology innovations to commercial products for the benefit of the general population. The heads-up display, first used in fighter aircraft, are now being installed in automobiles, enabling the driver to keep his eyes on the road 100% of the time. Night vision systems, developed for military operations, are now being adapted to the automobile for safer driving after dark.

Machine vision is useful in critical situations where people tend to be overstrained or where human vision has its limits. Modern cars have optical pre-crash sensors that inflate airbags at the optimal moment or help with braking before the driver is able to react. Examples of the latest developments are automatic distance and lane detection or sounding a buzzer when the driver starts to fall asleep. This technology will evolve to driver assistant systems that can take over complete control in critical situations. The latest developments refer to an automatic distance and lane detection, sounding a buzzer when the driver falls into a micro-sleep. In the future this technology will evolve into driver assistant systems that can take over complete control in critical situations.

Machine vision also plays an important role in pattern recognition and identification. Prominent examples are the automatic search of patterns that need further control at the airport when x-raying, locating certain items when large amounts of aerial photos have to be inspected or an impartial additional diagnosis in critical cases of histology in medicine.

Photonics-based identification is just reaching a level of maturity that allows the first security-relevant installations. In airports, for example, the first biometric systems for fingerprint or iris identification can be found.

It is only a question of time until such systems are found at any given border. Further use will be made of it to control restricted access to areas in buildings or for authorisation of computer and bank accounts. Another safety-relevant optical method, holography, has already reached complete maturity. Holograms are found on the packages of expensive products, on bank cards, driving licences and money, helping to assure authenticity.

Unnoticed perhaps by the public, photonics plays an important role in food and drug safety. UV radiation is the only way to disinfect packages without using additives, and without modifying the contents. Quality control of food as well as contaminant control of top soil and air can be achieved with laser-spectroscopic methods. Photonics provides the way to assure that our food is healthy!

Terahertz technology is another photonic technology with an enormous impact on safety. This technology applies light with wavelengths in the mm range. THz technology is still in its infancy because it is still extremely hard to generate and detect THz radiation, but its potential to improve our lives is already quite clear. Like x-rays, THz radiation penetrates matter and reveals hidden objects, but unlike x-rays, THz radiation does not damage human tissue.

Additionally, THz radiation is able to deliver information about the chemical composition of a hidden or buried object. This opens up completely new possibilities for the detection of land mines, bombs, explosives and contraband. Certainly medical applications as well as food and drug safety will also reap major benefits from this emerging technology.

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Disclaimer
This document has been compiled from a very broad range of contributions from a large number of individuals from industry, academia and associations. We have tried our best to include all views and to verify the statements.

However, it is natural that not all opinions are in line with this paper. It summarises on a rather general level important statements on photonics in the 21st century. This paper might serve as a catalyst for a more intense discussion and hopefully provides the rationale and the justification for the important political process that is needed to implement a coordinated action plan among all the stakeholders.

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