KETmaritime Case Study 4 – Photonic Marine Applications

A pioneering scientific centre in northern Portugal has led a major two-year project studying advanced manufacturing technologies with the potential to revolutionise the Atlantic maritime sector. The International Iberian Nanotechnology Laboratory (INL) located in Braga is the lead partner in the €1million 'KETmaritime' project backed by the European Regional Development Fund. Project coordinator Ana Vila said the INL is now releasing details of a fourth case study focusing on 'Photonic Marine Applications'. She said the pan-European project identifies how advances in this field will benefit shipbuilding, Structural Health Monitoring (SHM) of marine assets and the development of 'blue-light' lasers for underwater ranging, imaging and communication.

Key findings from the KETmaritime project are now being revealed following two years of intensive international work involving a world-class consortium of partners across Spain, Portugal, France, Ireland and the UK. Its mission is focused on identifying KET (Key Enabling Technologies) to meet the future needs and demands of the Atlantic maritime industry.

Project partners include French multidisciplinary research laboratory CIMAP (CEA group), Portuguese maritime economy association Fórum Oceano and Spanish technology centre IDONIAL. Ireland's national centre for marine and renewable energy MaREI, UK marine cluster organisation Marine South East and Spanish non-profit research association AIMEN.

A total of five detailed case studies have been produced under the €1million initiative funded by the Interreg Atlantic Area Program, via the European Regional Development Fund. Topics include 'Advanced Manufacturing Shipbuilding Applications', 'Nanotechnology Marine Applications', 'Marine Industrial Biotechnology', 'Photonic Marine Applications' and 'MEMS (Micro Electromechanical Systems) Marine Applications'.

AIMEN - World-renowned for laser technology applied to materials, processing, robotics and automation

The fourth case study led by AIMEN in collaboration with Marine South East and IDONIAL focuses on 'Photonic Marine Applications' (access http://ketmaritime.eu/media/ to view the full report). In addition, the International Iberian Nanotechnology Laboratory (INL) provided key input.

AIMEN is world-renowned for its expertise in laser technology applied to materials, processing, robotics and automation. It has delivered more than 650 R&D&I projects in the last ten years working with an annual average of 650 customers. The advanced tech centre employs more than 230 people and has produced more than 270,000 technical reports.

Its latest case study reveals new boundaries broken in marine laser development – enhancing the detection of underwater objects including submarines and archaeological sites.

Light – An essential element for life on earth

Light is an essential element for life on Earth. Not only does light provide illumination it also contributes to all processes in nature requiring energy. From a physical point of view, light is an energetic manifestation within the broad electromagnetic spectrum, with the photon considered its elementary particle which carries energy. Modulation in frequency and wave amplitude give rise to photons across all parts of the spectrum.

Photonics is a science which seeks to generate, control and detect photons, in search of applications for the energy they contain within. This ranges from the use of concentrated beams for cutting and welding to 3D scanning and surgical applications, through to more 'ordinary' applications, such as presence detection for door control, bar code scanning, printers and laser levels. Its potential applications are enormously broad and of major R&D interest across many fields of technology.

The century of the 'photonic revolution'

Photonics is one of the most important technologies for the 21st century and can be used to tackle some of the global society's greatest challenges. History shows that scientific and technological breakthroughs lead to new and revolutionary industrial activities continuing for decades after the invention. The 21st century is the century of the photon. Due to recently acquired knowledge and technological breakthroughs we are ready to profit from the 'photonic revolution' achieving greater advances and control in the application of light across many high-tech markets where industry and knowledge institutes play a prominent role.

The global photonics market is estimated to be worth €615billion by 2020. Between 2005 and 2015, it showed a real annual growth rate of 7pc, which is twice as fast as the global GDP growth and higher than many other sectors including Food 2pc and Automotive 3-5pc. By 2015, the global photonics market was worth an estimated €447billion - about 20pc of the size of the global electronics market at large. The European segment in the global photonics supply and demand equals 15pc. Meanwhile, global sales growth between 2012 and 2016 for photonic components production equalled a Compound Annual Growth Rate (CAGR) of 5.4pc, with worldwide job growth growing by 7pc.

Photonics – Key enabling technology for the maritime sector

Photonic science translates into a multitude of applications, many of which have derived into sensor technology that can provide information about the environment. In the marine field photonics can play an important role based on the development of detection and recognition systems. This is particularly applicable to areas including navigation, tracking of objects and masses at sea, and maritime rescue.

Photonics have been successful used for monitoring in fisheries where historic detection techniques (such as HPLC) were slow, required sampling and were not in real-time. New photonic tools are able to detect contaminants in the sea with a series of advantages including simplicity, small size, fast analysis, low cost, on-line detection and the ability to install in existing equipment.

Within aquaculture 'computer vision systems' provide automated, user-friendly research tools to assist the remote monitoring of fish activity. LEDs provide light of different wavelengths which can be adapted to stimulate and control the growth of marine products and analyse water quality. It also allows 'real-time' observation of fish populations, mapping of fish movement in confined environments, the detection of body posture in several developmental stages of fish and mapping of water indicators.

Photonic technology can also be used in the processing of fish and seafood. Applications enabling computer vision are found in automated systems for sorting, grading and processing fish and fish products. Computer vision technologies can objectively measure visual attributes related to seafood quality. This includes inspecting the appearance (size, shape, colour and texture), smell, category, bones and defects, presence of blemishes and textures on the surface of seafood products.

More broadly, within the oil and gas sector, photonics can enhance security by monitoring plants and hazardous environments. Oil and gas leaks are often invisible or difficult to detect, and such an event can sometimes last for several hours before being discovered. The risk of fire has serious implications making early detection essential for the industry. There is a large variety of sensing devices for the exploration of oil and gas. These sensors must operate in exceedingly challenging environments, such as high temperature and pressure. The majority of sensors are based on electronics because of the maturity of the technology. However, optical sensors have been used successfully for specific measurements where no replacement technology exists.

Seabed Mining (SBM) is an experimental industrial field involving the extraction of submerged minerals and deposits from the sea floor. This practice could benefit from photonics which offer 'sensing capabilities' for seabed resource management. In 'Blue technology' there is also a high demand for diverse sensor technology capable of operating in marine like environments. This provides critical information in multiple dimensions. For instance, understanding the evolution of water quality, evaluating the impact of biodiversity, assessing the integrity of operating vessels and infrastructures.

Photonics can also be used to great effect within the marine renewable energy sector, specifically managing performance within offshore wind energy through LIDAR systems. Within Marine & Maritime surveillance, photonics can inform new devices and systems for wider and more comprehensive monitoring of marine environments.

Meanwhile, additional benefits can be delivered to the shipbuilding sector, improving applications used in laser-welding, cutting, mapping and detection systems to improve navigability and to reduce risks. Ports, transport and logistics operations can use photonic technology to boost mapping and detection systems. Other maritime fields set to benefit from new devices providing comprehensive monitoring of marine environments include marine construction and dredging and marine environmental conservation.

'Virtual Reality' in shipbuilding – Supporting every stage of the vessel lifecycle

Virtual Reality (VR) use has extended to every industry, in every sector, at many levels. The technology has become much more accessible within vessel design and production in line with increased CAD use. Important improvements in both software and hardware have greatly impacted its use across the shipbuilding industry, where it is necessary to handle complex 3D ship models with huge amounts of data. There are three important factors that play a fundamental role in the successful implementation of VR. The first is having an appropriate CAD system with complete ship information in a single database. The second is a viewing tool which allows the management of a 3D model in VR environments. Finally, appropriate hardware is required to make VR navigation possible in different environments.

There are a broad variety of applications where advanced computer graphics technology can used to greatly benefit marine operations. These range from marketing and design to manufacturing support, training and maintenance assistance. There is no phase in the lifecycle of a ship or seaborne structure that cannot profit from 3D modelling, simulation, virtual/augmented reality or computer vision.

Shipbuiding and shiprepair is an industry where virtual reality is already widely used for all kinds of simulations. Vessels are expensive and complex platforms integrating multiple systems and equipment. In a very competitive environment with no room for error, both the design and production phases must be monitored and reviewed to avoid unnecessary costs. The availability of an advanced tool for the virtual navigation through the ship model, from the early design stages, enhances project control and speeds up decision making processes. This technology essentially allows the creation of a 3D ship model developed with a 3D CAD tool, integrating all design disciplines in one single environment. The development of a solution allowing the 3D navigation and interaction with the model in an immersive experience, opens a huge range of possibilities benefiting all stakeholders. Engineering and production departments which typically experience the costliest errors will find particular benefits with this process. These departments are not usually working with a VR solution. However, the benefit of checking the model in VR format is becoming clearer, not only to avoid errors and inconsistencies but also to improve production processes.

From a marketing perspective, the opportunity to present a 3D ship model in an immersive VR experience adds incalculable value to sales activity. Many shipyards are already taking advantage of this technology, not only in their facilities but also in fairs and exhibitions. Another promising application is the assistance in assembly, maintenance and repair of complex systems. Instructions, drawings, procedures and 3D virtual guides can be overlaid in real time and see-through images of equipment to help engineers complete work with greater speed and safety.

VR technology can also be used within bridge simulators to train maritime officers to use ship systems in a controlled real time environment. This important training tool prepares deck personnel for what to expect once they step onto a vessel navigating in and out of port. The simulator is usually integrated with the dynamic positioning, engine room and cargo handling simulators, which allows a broad range of realistic training scenarios.

'Augmented Reality' in shipbuilding – Merging the real and digital worlds

Augmented Reality (AR) can help shipping companies accelerate and simplify processes providing new tools to execute tasks faster and more intelligently. It will also improve the performance of workers. For example, in the aviation industry it was reported that the use of an AR headset to help a GE technician wire a wind turbine control box improved performance by 34pc on first use. Devices using AR enhance surroundings by adding holograms into the field of vision. This makes it possible to merge the real and the digital world, creating a mixed reality. There are unlimited possibilities as the technology progresses. For example, a general arrangement drawing plan on screen could be transformed into an entire 3D ship model. This could be viewed from all angles and manipulated to highlight specific areas making interaction feel more natural.

The KETmaritime project team highlighted a number of 'promising' cases to drive efficiency improvements through the application of AR. They include the automation of 'quality control' processes through the use of computer vision techniques. Product modelling for instance could be carried out by using 3D cameras and reconstruction software. Once the actual model of the product is obtained, it would be possible to detect deviations from the CAD model.

AR could further assist the manufacturing process within workshops by visualizing 3D models on tangible interfaces located on the workbench. This involves introducing a visual marker on the working environment that acts as a spatial reference for the AR system. The marker can be printed on a fixed surface placed on the table of the manufacturing station or on a mobile support that allows for its manipulation by the operator.

With AR it is also possible to visualize the 2D-location of products and tools in portable devices such as tablets or AR glasses. This system would make use of sensor values and artificial tags distributed throughout the workshop that allow for determining the positioning of the user in the shipyard. It can further assist warehouse operators in the processes of storage, localization, relocation and collection of parts. The immediate advantage of displaying information on AR devices is that it decreases human errors and drives time savings.

Data from sensors in machines and throughout workshops can be further used to carry out predictive maintenance actions while informing quality control. The information generated from data mining can be analysed and shown through AR devices. In addition, AR can facilitate augmented communication between operators and controllers through portable AR devices. This improves 'trouble-shooting' sharing the 'point of view' of the operator regardless of location. It enables the superposition of information over the actual image seen by the operator, recording annotations and audio/video communications.

The use of AR can also greatly improve the visualization of hidden installations behind bulkheads, roofs or ceilings, by overlapping 3D virtual elements over the real environment. The ideal AR system would assist operators during the assembly processes, both during the pre-assembly and the block assembly, in order to reveal internal elements that would be difficult to see otherwise. In addition, such a system would ease maintenance or fault repairs.

Fibre optic sensors – 'Structural Health Monitoring' of marine and offshore assets

Well-maintained structures are essential for successful operation within the harsh marine environment. Increased durability has a direct impact on economic losses suffered due to repair, maintenance, reconstruction and structural malfunction. New materials, construction technologies and structural systems are increasingly being used in marine industry, while knowledge about 'on-site' asset condition and integrity has been boosted by advances in 'Structural Health Monitoring' (SHM).

SHM uses data obtained from a network of on-board strain sensors located at various sites of a structure. One of the most promising sensors, known as Fibre Bragg Grating (FBG), is created through fibre-optic technology. The length of the FBG sensor is in the range 1-25 mm depending on the application. These sensors have many advantages over conventional electric sensors, including high sensitivity, immunity to electromagnetic interference, and massive multiplexing capability. They are widely used in the aerospace, intelligent transportation, petrochemical, electric power industries. They are typically used for real-time online monitoring of the strain, temperature and other parameters of engineering structures.

Due to these advantages, FBG sensors work well in the harsh marine environment lasting for decades under duress. They are of particular interest in the application of SHM because they increase both human and environmental safety while reducing maintenance costs.

Marine structures like marine vessels and offshore structures, including wind turbines and offshore platforms, are exposed to long-term cyclic loadings from sea waves and short-term extreme loads such as severe storms, sea-quakes or collisions. The marine environment leads to fast corrosion, erosion and scour processes, and damage to marine structures can result in ecologic catastrophe in the case of oil spillage from offshore structures or fuel from marine vessels. The hugely important process of determining damage locations, degrees of injury and residual lifespan of marine and offshore structures can be greatly aided by SHM, before carrying out engineering maintenance.

Electrical sensors are restricted within offshore applications by the existence of thermal errors, large zero drifts, non-repeatable readings, difficult signal conditioning and high susceptibility to moisture and corrosion. FBG sensors however remain unaffected by these incidents. FBG sensors detect structural damage and uncertainty, nonlinearities, changes of mode shapes and frequencies and changes of structural damping characteristics. The continued search for new construction solutions and materials combining high levels of safety with ecologic requirements will ensure SHM systems, using FBG sensors, are widely implemented across many marine applications in the years to come.

Blue-light Lasers – Reaching record depths for underwater ranging, imaging and communications

Scientists have been developing blue-light lasers for use across the marine environment for a number of years. The technology can be used for a range of applications including underwater ranging, imaging, and communications.

The absorption of light in pure water is lowest in the 400-450 nm spectral range so that laser light can propagate in a specific direction over long distances with minimal attenuation. Therefore, these light sources can be used to determine distances, or by means of Lidar techniques record and image underwater objects, like submarines and archaeological sites. Airborne bathymetric laser scanners allow for high resolution hydrographic surveys in very shallow waters. This can be used for the documentation of submerged archaeological structures.

Conventional methods to detect underwater targets have employed acoustic waves. However, laser-based systems have clear advantages in high directionality and high range resolution. The combination of low attenuation in water and good reflectivity on desired surfaces allows for long-range applications. Blue laser-based systems also allow new methods of wide-band and interception-proofed communication. Practical applications are mainly undertaken in the USA by the Navy and in Asia.

France-based multidisciplinary research laboratory CIMAP is actively developing blue-light lasers in constant wave (CW) and pulsed regimes. It recently achieved a record 7.5W CW output at 452nm wavelength. Internal conversion efficiency of 55pc was achieved using a simple resonator including a LBO crystal cut for type I critical phase matching.

This is understood to be by far the highest CW 'pure blue' power generated from a frequency-doubled fibre laser. Further power scaling should be possible by using a polarization-maintaining Nd-doped fibre with a nearly single-mode core. In addition, due to the large tuning range of the NDF fibre laser, other blue wavelengths around 452 nm could be easily generated. Preliminary results show that wavelength tunability between 445 nm and 462 nm can be achieved using the same LBO crystal. On-going developments also involve the generation of blue laser pulses with high peak-power and nearly diffraction-limited focused beam.

Photonics – Technology with immense potential to broaden understanding of our oceans

The oceans and coastal zones of the world are vitally important resources for many aspects of human life. Their exploitation as sources of food dates back to the beginning of civilization. However, in relatively recent times our oceans have become valuable sources of energy. The oil and gas industries are obvious examples illustrating how the oceans have been exploited to satiate fossil fuel demand. More recently, wind, tidal and wave power have been harnessed as sources of renewable energy, alongside the extraction of vital mineral resources. However, the gathering and farming of food is still the most significant treasure that the oceans hold for us, and its control, management and sustainability are vital aspects of sea utilisation.

There are significant challenges ahead in our drive to understand this unique environment and sustainably manage the natural resources contained within it. New techniques and instruments are continually being developed to help us enhance our understanding of the sea. Photonics and optical techniques are front running technologies holding immense potential to broaden information about the nature of the oceans, its constituents and behaviour.

In the coming years, the maritime sector will greatly benefit from the broad variety of applications of photonic devices. It has become an increasingly accessible technology with particular relevance to Structural Health Monitoring of marine assets, as well as Virtual and Augmented Reality across shipbuilding. However, the increased use of photonic technology across the maritime sector is dependent on the alignment of 'Key Enabling Technologies'. For example, the integration of micro and nano electronic components is essential for the development of miniaturized sensors and systems for targeted applications such as lab-on-chip devices and implantable sensors. In addition, the biotechnology industry, which is one of the major innovative industries in Europe, will be a key end user of the products developed through the photonics ecosystem. Training is also an essential element to ensure successful implementation, showing how to integrate key enabling technologies into existing processes to add value to products or generate new products. Lastly, pilot programmes must be developed to demonstrate the feasibility and benefits of selected photonic applications.

For more information on the KETmaritime project visit the website www.ketmaritime.eu phone +351 253 140 112 email Ana Vila on Ana.Vila@inl.int

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Project Partners:

Notes to editors:

KETmaritime is a €1million project that aims to transfer Key Enabling Technologies (KETs) to the Maritime Industries of the Atlantic Area. Focused on building a cooperative network that stimulates innovation and competitiveness, the project embraces the challenge of increasing the capabilities, skills and knowledge on KETs in an integrated and cross-national approach. The consortium brings together seven partners from five countries that, under the framework of the project, work closely with industries and businesses. The ultimate goal is to bring to market new processes, products and services. Partners in the consortium include French multidisciplinary research laboratory CIMAP (CEA group), Portuguese maritime economy cluster Fórum Oceano and Spanish industrial design centre IDONIAL. Ireland's national centre for marine and renewable energy MaREI and UK marine cluster organisation Marine South East are delivering further support, alongside Spanish non-profit research association AIMEN. KETmaritime is a project funded by the Interreg Atlantic Area Program, supported by the European Regional Development Fund.