PROJECT FINAL REPORT

Grant Agreement number: 226604

Project acronym: OPTICON

Project title: Optical Infrared Co-ordination Network for Astronomy

Funding Scheme: Combination of CP & CSA

Period covered: from 1 January 2009 to 31 December 2012

Name of the scientific representative of the project's co-ordinator, Title and Organisation:

Professor Gerard Gilmore,

Professor of Experimental Philosophy,

Institute of Astronomy, Cambridge University, Cambridge CB3 0HA UK

Tel: +44 (0)1223 337506

Fax: 44(0)1223 339910/7523

E-mail: gil@ast.cam.ac.uk

Project website address: www.astro-opticon.org

4.1 Final publishable summary report

4.1.1 Executive summary

The OPTICON consortium set out to deliver a simple yet challenging set of strategic objectives:

1. To structure the European astronomical community by ensuring astronomers are able to carry out state of the art research on state of the art facilities.
2. To develop European astronomy by allowing astronomical communities to develop scientific and implementation plans for their own future facilities.
3. To strengthen European astronomy by delivering technology research and development to help ensure extant and future astronomical research facilities are state of the art.

These technological ambitions are met through a complementary set of technology development RTD activities, combining University-based, national agency based, international agency based, and industrial partners. The community strengthening activities are met through a focused set of networking activities, concentrating on developing the community to develop and implement next-generation world-leading facilities and infrastructures. The structuring activities have been met through a unique common-operation peer-review based programme to deliver access to Europe's premier national infrastructures to all scientists irrespective of nationality or local funding support.

Globally OPTICON has made, in conjunction with other national and European astronomical organisations, considerable positive impact in all of the following areas:

i) Maintained European leadership in the key technologies and techniques of Adaptive Optics (WP1, 2);
ii) Developed synergies between European technology players and the astronomical community, making the industrial concerns aware of expertise in the scientific community and vice versa. (WP3, 5, 6, 9.1);
iii) Enhanced co-ordination of the European Interferometry Community (WP4, 11.2);
iv) Opened a range of European observatories to new user communities (WP7) and made significant efforts to engage with these new communities so they can take advantage of these opportunities, by offering a single proposal process (WP12) and training schools (WP11.1);
v) Supported Technology Development for European Solar telescopes (WP1), enabled access to existing solar facilities (WP7) and enabled strategic planning for future new facilities (WP12);
vi) Provided a communications pathway between the general user community and the future European ELT project teams (WP 10);
vii) Published its RTD development results widely for wide benefit, through over 175 published scientific/technical articles.

The beneficiaries of the project include individual research astronomers, astronomers interested in specific subjects or facilities, scientists involved in technical RTD activities, industry, and funding agencies.

4.1.2 Project context and objectives

The OPTICON consortium set out to deliver a simple yet challenging set of strategic objectives:

4. To structure the European astronomical community by ensuring astronomers are able to carry out state of the art research on state of the art facilities.
5. To develop European astronomy by allowing astronomical communities to develop scientific and implementation plans for their own future facilities.
6. To strengthen European astronomy by delivering technology research and development to help ensure extant and future astronomical research facilities are state of the art.

The programme had started to gather pace on all its activities by late 2009 and continued until the end of the contract in 2012. A new grant agreement, approved for the period 2013-2016, will carry forward many of the key achievements of this now completed contract.

WP1: Adaptive Optics Systems

The main objective of this work package was to design and develop Laser Guide Star Adaptive Optics systems for existing large telescopes (e.g. the Large Binocular Telescope (LBT), Very Large Telescope (VLT), the William Herschel Telescope (WHT)), to upgrade extent Adaptive Optics systems for a solar telescope (GREGOR) and to upgrade the Very Large Telescope Planet Finder instrument (SPHERE) to maintain its competitiveness. On-sky tests of prototype systems are a key goal in this, and have been achieved at the William Herschel Telescope as part of the CANARY project.

WP2: Laser Guide Star Adaptive Optics Detectors

The main objective was the development of a scaled-down demonstrator detector CCD for Laser Guide Star wavefront sensing, leading to a version suitable for large scale production and eventual deployment for the European Extremely Large Telescope.

WP3: Astrophotonics

This activity carried out and co-ordinated research in the new field of Astrophotonics to bring to astronomy the benefit of photonic devices developed over many years by the telecommunications industry and to use photonic principles to deal with key challenges in the construction of astronomical instruments required for future generations of observatories.

WP4: High Angular Resolution by Interferometry

The main objective of this activity was to build on the co-ordination of European activities in the demanding area of astronomical interferometry, both to enhance the existing infrastructures and to develop plans for the future.

WP5: Smart Instrument Technologies

This was an effort to develop smart instrument technologies which can be used to meet astronomers' needs for instruments with ever increasing fields of view, higher spectral and spatial resolutions and multi-object observations within demanding size, mass and engineering limits.

WP6: New Materials and Processes for Astronomical Instrumentation

The main objective was to identify and characterise new types of optically-active materials with possible astronomical applications, moving beyond glass and steel to organic, photosensitive and polymer materials. A specific challenge was the retention of industrial production capability in this technically challenging field following the bankruptcy of the only European based producer of Volume Phase Holographic Gratings (VPHG) substrates.

WP7: Transnational Access

The Transnational Access programme was a key part of the OTICON I3. It made it possible for European astronomers from any region to access the state of the art telescopes and instruments owned and operated by just a few European countries. This was achieved by opening access to a network of telescopes via single, international peer review process which treated all applications equally, giving priority to the best scientific projects irrespective of their origin.

WP8: Management

The Management Board was responsible for making strategic decisions. Meetings were held roughly annually so that the work package leaders could provide overview presentations of their activities, status, and progress to the whole consortium. An Executive committee oversaw the day-to-day implementation of the OPTICON programme and ensured feedback to the key national funding agencies. Both groups met regularly during the contract.

WP9.1: Key Technology Network

This group focussed on specific areas where value could be added by bringing together scientists and engineers from across Europe and from different industrial sectors to exchange ideas and plans, and to generate impact and value. A key role is publicising the future technology opportunities to industry.

WP9.2: Software Standards

This activity has developed detailed software standards for an open, modular system for processing and analysis of astronomical data by end users.

WP10.1: Science Case for the European ELT

The main objective of this working group was to continue to develop and monitor the scientific case for the building of the European Extremely Large Telescope and to maximise community involvement in, and support for, this critical future infrastructure.

WP10.2: European Network for High Time Resolution Astrophysics (HTRA)

This network developed science cases and concepts for telescope and instrument designs for the E-ELT in this specific area. In particular, it concentrated on the science foundations of HTRA, and included considering the implications of suitable detectors and the data acquisition and handling aspects of HTRA on the E-ELT.

WP11.1: Community Development

The main objective was to organise activities transferring knowledge from experienced astronomers familiar with forefront observatories to new users (young scientists, or scientists from the new member states). This was achieved via training schools and conferences.

WP11.2: The European Interferometry Initiative

This activity set out to maximise community-wide involvement in the world's first common-user large telescope interferometer, ESO's VLTI, strengthening both scientific and technical involvement (see for example http://www.european-inteferometry.eu).

WP12.1: Telescope Directors Forum

The telescope directors forum, which included the managers of all the observatories in the TNA programme, met regularly to develop actions of common interest to medium sized telescopes, both those in the Transnational Access network, and those currently of lesser international competitiveness.

WP12.2: Planning for a Viable Future

This multi-pronged activity was set up to optimise and, where possible, integrate the operation of Europe's main 2-4m night time telescopes and Europe's 4 major solar telescopes.

WP12.3: The European Association for Solar Telescopes (EAST)

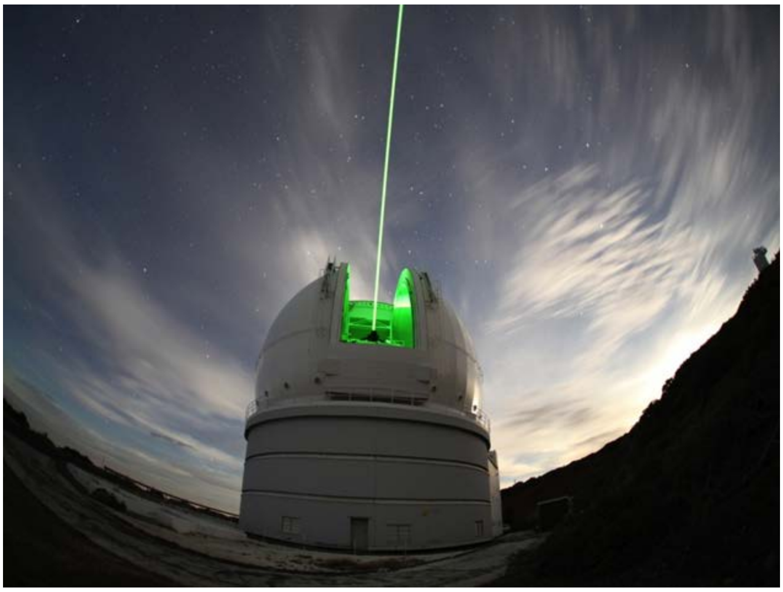
The main objective was to establish groups which will address key objectives towards plans for a large solar telescope to be included in the ASTRONET Science Vision Roadmap. This led to the creation of a stand alone I3 called Solarnet which began operations in 2013.

4.1.3 Description of the main S&T results/foreground

WP1: Adaptive Optics Systems

Adaptive optics systems (AO) are complex opto-mechanical systems using either natural starlight or laser light to correct for atmospheric turbulence and thus allow ground based telescopes to take images of heretofore unachievable sharpness. Already providing greatly enhanced capabilities at ESO's VLT telescope and at other large facilities, this technology will be essential for the European ELT. CANARY, a specially developed AO test bench which is unique in the world as being a dedicated experimental facility, is operated at the William Herschel Telescope in the Canary Islands.

After very successful Phase A for the Natural Guide Star (NGS) element of CANARY which was achieved by the end of 2010 and the successful completion of the Phase B Conceptual Design Review in early 2011, the system was built and laboratory-tested over the following year (with separate on-sky testing of the Laser Guide Star system). The combined Phase A/B system was then tested on-sky in July and August 2012, with high performance NGS and Laser Guide Star data being obtained.



Laser being fired from the WHT to generate an artificial guide star for AO tests.

SPHERE is an instrument for discovering planets around other stars and will be fitted to the European Very Large Telescope in Chile. The activities performed in this work package allowed optimizing, fully calibrating and mastering the overall stability of the SPHERE system in the laboratory. New concepts for optical aberrations measurements were proposed, fully validated in simulation and experimentally applied to SPHERE data during the Assembly, Integration and Test process. The first results were extremely encouraging and efforts will be invested in the future to push the concepts towards a Technology Readiness Level compatible with their final use in the SPHERE instrument for its first light at the ESO Paranal observatory, now expected in 2014.

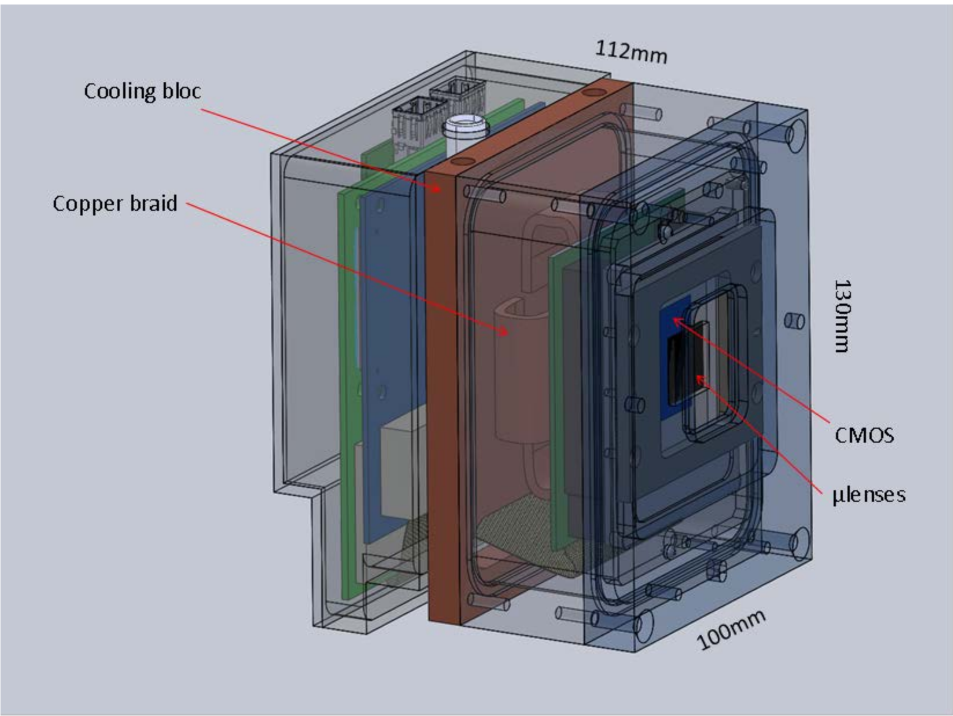
Another objective of this workpackage was to design the Laser Guide Star Facility for the international Large Binocular Telescope project in which German and Italian astronomers have a large investment. The project aims at an initial implementation of a Ground Layer Adaptive Optics system, which enables wide field seeing improvement for imaging and spectroscopy at the LBT with the LUCI instrument. All deliverables of this work package were completed. After the final design in spring 2010 the teams went on to build the ARGOS instrument. Currently, the overall project is in the integration phase and is close to shipment to the telescope. The laser system, which was built by MPE, is under intensive testing in Garching, Germany. In October 2012 the Preliminary Acceptance review was held successfully for this sub-system in Garching. The shipment is scheduled for 2013. The wavefront sensor is built by the Osservatorio Astrofisico di Arcetri and is undergoing assembly in Florence, Italy. Several parts of the instrument are already mounted on the telescope. This includes the laser launch system, the swing arms for the calibration unit and the instrument platform. The goal is to hand over the full commissioned instrument to the community by 2014. This system will be the first multi Rayleigh laser adaptive optics system on any large telescope. The Rayleigh laser technology is commercially available and therefore much cheaper than sodium lasers. This is crucial for future Extremely Large Telescopes, which plan on using large laser facilities.

Another activity was to procure a deformable mirror for high order Adaptive Optics to be fitted to the GREGOR solar telescope in Tenerife. This has been delivered and has enabled the Kiepenheuer-Institut to improve the performance of the GREGOR telescope AO system significantly.

WP2: Laser Guide Star Adaptive Optics Detectors

Adaptive Optics techniques require the availability of a suitably bright 'guide star' to be visible in the sky close to the astronomical object of interest. It is the light from this star which is used to calculate the distortions caused by the atmosphere and then to correct for them many times per second. This in turn requires detectors able to sense faint stars and to be read out with very great speed while producing as little extraneous noise as possible. This is a very challenging requirement, but the better such detectors can be made, the fainter and hence more numerous, are potential guide stars. The E-ELT must have an effective AO system in order to function properly, so high speed low noise detectors are critical for this flagship European facility.

In this workpackage a detailed technical specification was developed and detector fabrication was sub-contracted to e2v technologies, the well known UK visible light detector manufacturer. More than a development chip, this demonstrator will be useable for wavefront sensing on the E-ELT with natural guide stars. The requirements for a final device which can be used with artificially produced laser guide stars are challenging as they combine several properties that to date have never been achieved at such a high specification on a single detector. This work package was completed successfully.



WP2 Camera Conceptual Design

WP3: Astrophotonics

Photonics is a term derived from Photon and Electronics and includes the generation, emission, transmission, modulation, signal processing, switching, amplification, and detection/sensing of light. It covers all technical applications of light over the whole spectrum from ultraviolet through the visible to the near, mid- and far-infrared. Most applications, however, are in the range of the visible and near infrared light. It is a technology used widely in the telecommunications industry which should have valuable applications in astronomy.

An international collaboration called Astro-Photonica Europa (APE), which is largely industrially-financed, has been established. Several research partners are able to participate in that collaboration through OPTICON support. The success in matching technology to astronomical capability provides a powerful justification for the activities of APE and for EU funding via OPTICON. It is also notable that APE provides a unique forum which allows astronomers working in very different fields (i.e. long-baseline optical/IR interferometry and highly-multiplexed spectroscopy) to exchange ideas and share technology.

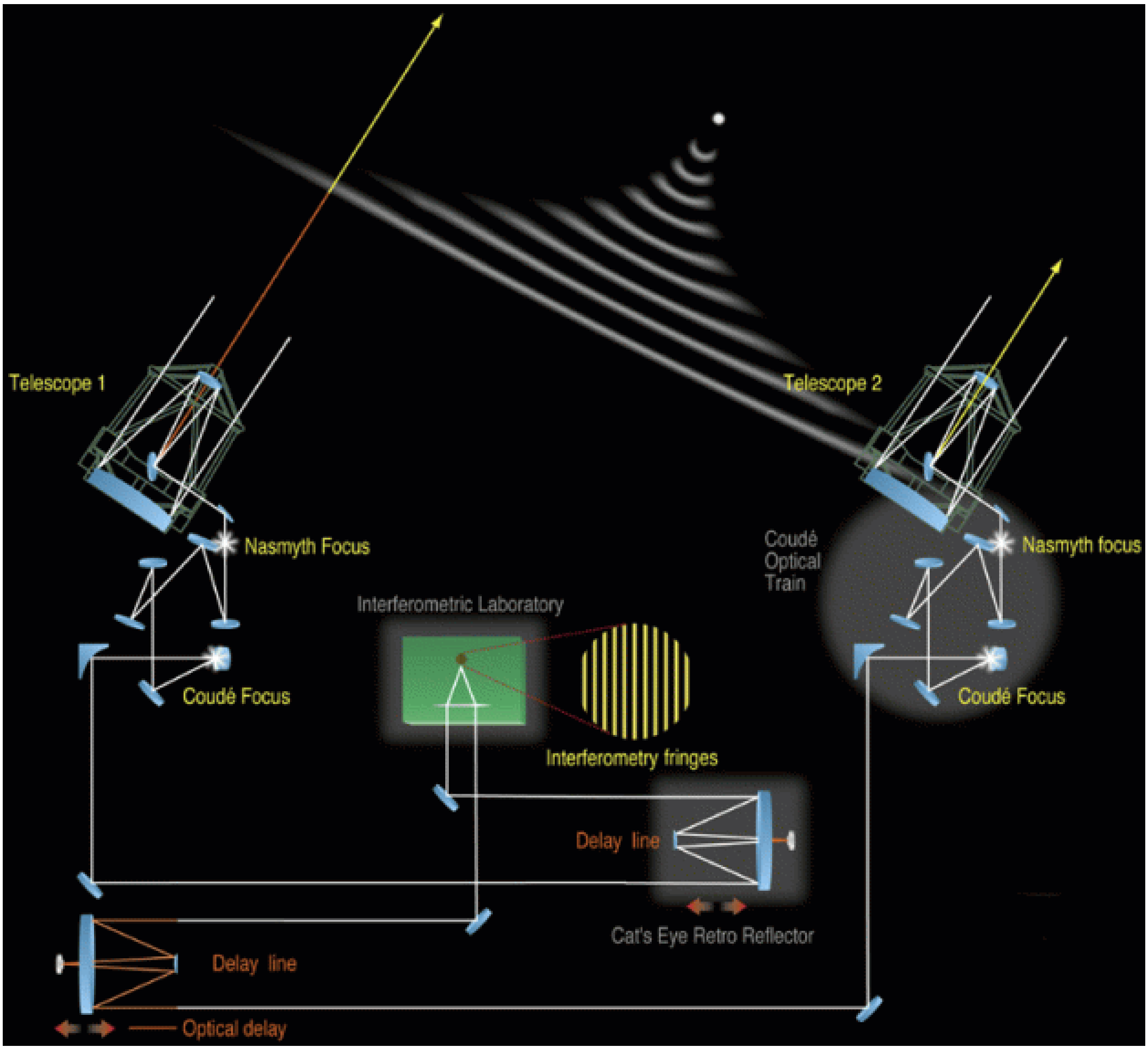
Technology research and development was, and continues to be, carried out by the members of APE using funding supplied from national and regional agencies as well as through OPTICON. Thus OPTICON's primary role has been to provide leverage to direct the products of the regional programmes in the most useful direction. Thus the main activities in the workpackage were: (1) Coordination including the activities of the coordinator and the management by the coordinating institute; (2) workpackages with specified deliverables; and (3) training and communication activities to educate and inform the wider community.

The programme is necessarily a bottom-up activity in that it seeks to determine the benefits to astronomy from existing devices and technologies. However this is tempered by a top-down understanding of the direction of current research in astrophysics and the specific needs of new observatories including Extremely Large Telescopes and new interferometric facilities. Ideally the bottom-up and top-down approach should mesh to provide new instrument capabilities. Thus, this work package has been able to direct and coordinate research out of all proportion to its funding. As well as a considerable number of publications in technical journals, a combined workshop and training school on Astrophotonics was held at Schloss Wiesenburg, Brandenburg, Germany, 24-28 September 2012. This was co-sponsored by OPTICON Durham University, InnoFSpec and the Leibniz Institute, Potsdam and the Municipality of Wiesenburg. Thirty students were enrolled, mostly, but not exclusively, young researchers. The scientific programme included 17 lectures each given by a different lecturer drawn from the Astrophotonic Europa partnership or from prominent astronomers or photonicists. The students were encouraged to bring posters which were judged. Prizes were awarded to the winners. Feedback from the students and lecturers was very positive and the local people were very enthusiastic.

Astrophotonics summer school participants at Schloss Wiesenburg, Brandenburg.

WP4: High Angular Resolution by Interferometry

Interferometry is a technique, first used by radio astronomers, in which the signals from two telescopes separated by a considerable distance are combined to mimic the resolving power of a single telescope equal in diameter to the separation of the two telescopes used. Since all the properties of the two beams have to be conserved before they are combined, expanding this technique to optical telescopes, where the wavelengths concerned are many times smaller than radio waves, requires exquisite precision. This is being achieved by the European Southern Observatory's VLT Interferometer (VLTI) where the light beams from several telescopes are passed via tunnels to an optical laboratory where the various beams can be combined. This technique can be used to create images and map structures on the surface of distant stars, objects which would normally appear only as a point of light in today's large telescopes.



The principle of Optical Interferometry, combining two beams, in phase, to mimic a huge telescope (Photo ESO)

Members of the OPTICON work package have taken part in the writing of the VLTI Mid-Term Implementation Plan, which was done under ESO management, but with important contributions from the European interferometric community. Apart from this short- to mid-term analysis, it is worth noting that ESO is still working, in parallel with the E-ELT, on a Long Range Plan for the la Silla-Paranal Observatory that should include the development of the VLTI optical interferometric instrumentation and/or the telescope array. A meeting in ESO/Garching in November 2011 was thus very important to develop ideas about the next 10 years of the VLTI.

An important part of the activities has been to organize the community with respect to the future of interferometry in Europe. Various activities have been developed and it was decided to create a Working Group for the Future of Optical Long Baseline Interferometry in Europe and to undertake a common action for the development of a general-user tool for image reconstruction. These activities were presented at an EII meeting in Amsterdam in July 2012 and form the core of the interferometry workpackage in the future.

At a more technical level, considerable work was done evaluating the parameters of the atmosphere over the ESO observatory at Paranal and how they relate to high precision fringe tracking. After a review of the status of atmospheric turbulence at Paranal, a synthesis of the literature and of the ESO technical reports has been made from the more than 60 articles dealing with that subject. Considerable work was done analyzing the initial results from the VLTI instruments FINITO and PRIMA. A better state machine for FINITO has been developed with good separation and robustness between Group Delay and Phase Tracking. This made it possible to have a better estimation of the performances and limits of FINITO, and helped produce a better calibration of the V^2 measurements of AMBER.

This image of the VLT at Paranal shows the tunnels which can used when the four 8m telescopes are operated as an Interferometer (Photo ESO)

The conclusions of this work are that new ways of calibrating various components have been identified, that we are now able to perform correct computation of the group delay and the phase delay and finally that we have obtained a correct estimation of the signal to noise ratio and of its threshold. This is very important for the second generation fringe trackers to be built for the VLTI. The following important lessons have been learned:

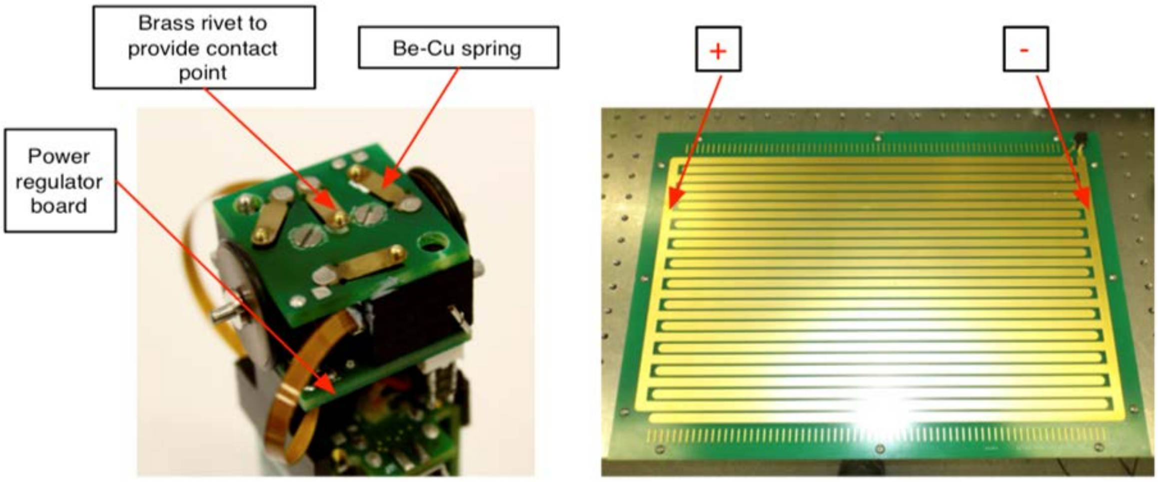
- The Importance of photometric channels
- No spatial filtering after beam combination
- The computation of sensitivity to hardware imperfections
- The importance of calibration and stability
- That linearity of measurement is essential
- The need for care regarding all possible sources of instrumental polarization

The majority of the other outputs from this activity are highly technical in nature and are described fully in the three periodic reports submitted by OPTICON during the contract.

WP5: Smart Instrument Technologies

Over several generations telescopes have become steadily larger and the instruments required to exploit those telescopes have grown corresponding larger as well. Today instruments for Europe's flagship VLT telescope may be several metres in size and weight several tonnes; already some of the next general VLT instruments are reaching masses close to the limit than can be supported by the telescope infrastructure. This situation is not sustainable, and instruments for the next generation of telescopes will have to include innovative ways to save space, weight and exploit the large focal planes offered by, for example, the European ELT.

A particular development, of general applicability but especially of relevance to future instruments on the Extremely Large Telescope, is micro-autonomous robots, by which an instrument can be made much smaller and lighter. These are small, self powered robots which can be driven around inside an instrument to position tiny mirrors that can pick of the light from selected targets in the image. Considerable progress has been made on prototype robots over the last three years. They can in principle replace the movable arms used to position mirrors in existing instruments such as the ESO KMOS instrument. KMOS has 24 robotic arms, but scaling up of this technology is likely to encounter problems as there will simply not be enough room for all the arms to move about without mutual interference.



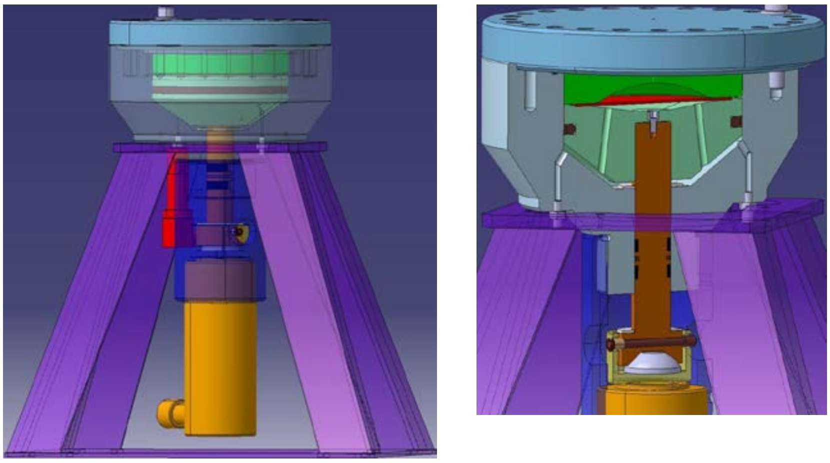
A Microrobot and the power grid over which it roams with very high precision. (Photo UKATC)

Another key technology for future instruments is the production of highly aspheric mirrors. The state-of-the-art in optical fabrication makes it possible to obtain highly aspheric reflective shapes, reaching several millimetres compared to the best fit sphere, but only for small mirrors. OPTICON has studied the potential of an innovative manufacturing process in optical fabrication, free of mechanical tool contact. This method, which is called hydro-forming, is based on the property of metallic materials to plasticize (their ability to be permanently deformed) and is already used to supply aluminium dishes for radio astronomy applications. The manufacturing process we are developing adapts the hydro-forming method for visible and near infrared applications.

Using Finite Element Analysis (FEA) the global geometrical profile of a substrate before deformation can be defined and the preliminary aspects of plastic behaviour of material can be highlighted. These made it possible to finalise the concept of the first ever hydro-forming machine prototype to produce a 100 mm optical diameter component. When completed, which will occur during our future contract, this prototype will allow us to compare the mechanical behaviour and the optical performances obtained by tests and by FEA for different metallic samples. An evaluation of the sensitivity of different working parameters will be established and the FEA models will be adjusted. Then, an optimization process applied on the FEA models will allow us to converge toward the manufacturing of highly aspheric shapes and free form surfaces.

Once this has been done, the formed samples will be characterized optically. The opto-mechanical results will allow a fine tuning of FEA parameters to optimize the residual from errors obtained through this process. Tests will start with axi-symmetric spherical and aspheric shapes and will continue with highly aspheric shapes and freeforms. In the next phase, hydroformed mirror activities will continue with increasing complexity of the shapes and the development of optical characterisation methods. Combining real tests and finite elements analysis, we will be able to highlight performance estimates, sensitivities and tolerances for freeform mirrors manufactured with this innovative process. The main aim will be the integration into one single system of a freeform mirror supplied by LAM with the smart active mechanical structure supplied by

ASTRON and UKATC, obtaining the first smart active freeform mirror demonstrator for visible and near infrared astronomy.



Prototype design: left, a global view and right, a zoom inside the cavity

To improve the optical modelling capability of highly aspheric optical components a new analytical definition was developed. This model is being implemented as a plug-in model in the ZEMAX ray tracing package and will then provide optical designers with ray-tracing capabilities to allow them to analyse optical designs containing highly aspheric optical components.

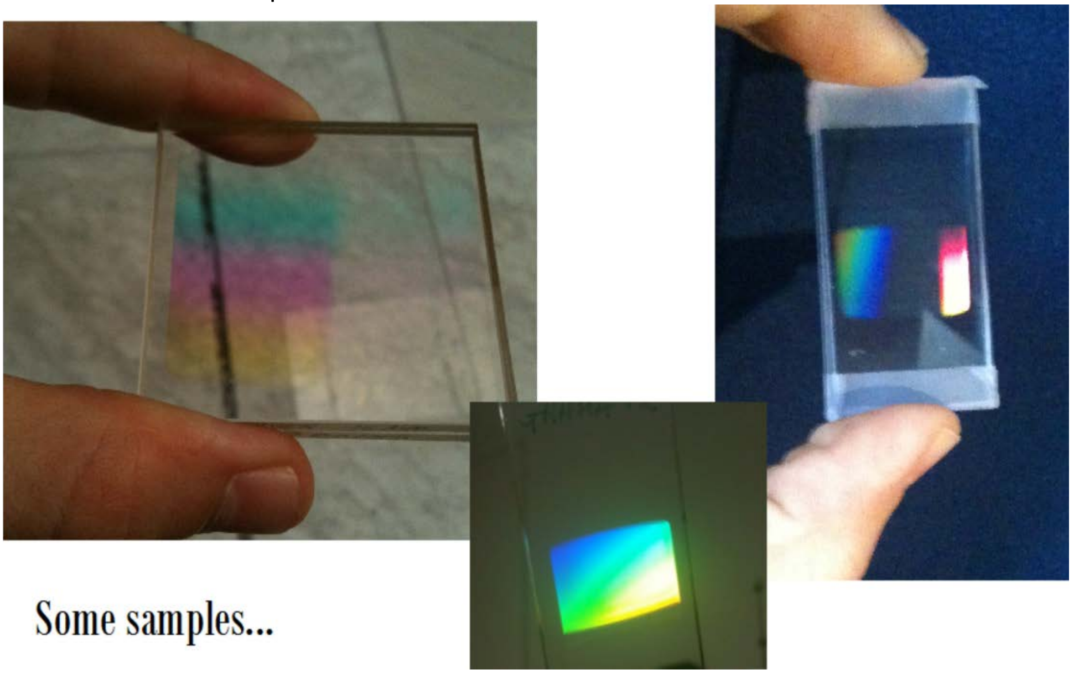
One unforeseen, but very satisfactory, outcome of the activity was a L'Oreal award for PhD student Zalpha Challita's work on this project. This award is presented by the L'Oreal cosmetics company as part of its national and international programme "For Women in Science". Through it, the L'Oreal foundation and UNESCO reward women for their scientific career. Since 2007, the French programme named L'Oreal France - UNESCO "Pour les femmes et la science", in partnership with the French Academy of Sciences, has rewarded women PhD students for their scientific work by giving them a grant of 15 000€. This grant is dedicated to prepare their professional career post-PhD by presenting their works in conferences, in international laboratories, etc. The project congratulates Zalpha on her award.

WP6: New Materials and Processes for Astronomical Instrumentation

Volume Phase Holographic Gratings (VPHG) are now being used extensively in astronomy because of their high diffraction efficiencies. VPH gratings are generally used in transmission with diffraction being caused by a near-sinusoidal variation in the refractive index perpendicular to the fringes (300-6000 lines/mm). For astronomy gratings, the active layer is typically 3-10 microns thick and is sandwiched between glass substrates a few millimeters in thickness. A common active layer is DCG (a Gelatin material) but chemical post-processing is extremely difficult and requires skilled and experienced technicians if it is to be carried out properly. This, together with the limited number of customers and consequent low annual revenues, limits the number of players in the market and also the possible areas of application.

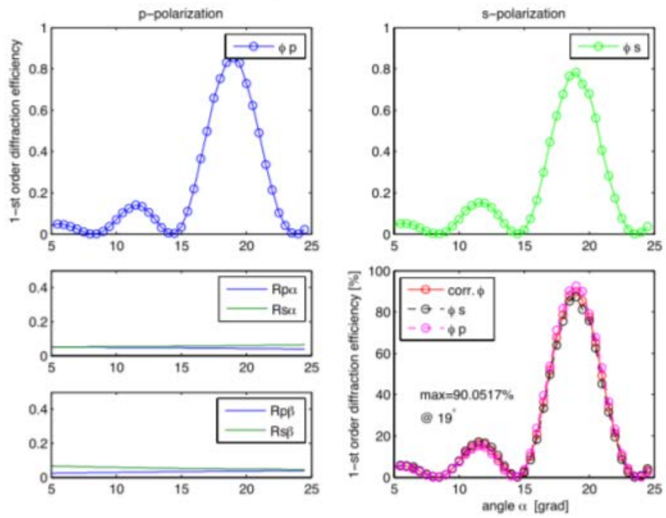
Until recently the main European supplier of substrates on which these gratings can be written was ATHOL in Belgium, but after a few years of successful deliveries the company lost a key person and with him the capability to deliver quality products to the community. Since the option to attempt to set-up another spin-off company to recover European VPHG production capability appeared to be very risky it was decided to concentrate on DCG alternatives, especially in the area of handling and post-processing that needed to be more repeatable and easy. We continued to follow the work of the few DCG-based VPHGs producers (all from outside Europe).

As an alternative we were able to obtain another species of tailored polymer from Polygrama (Sao Paulo, Brazil), a small lab developing photopolymers to customer specifications who agreed to produce some following a POLIMI designed recipe. After a number of iterations, high-grade gratings were made in INAF laboratories. Some of these samples are shown here.



Some samples...

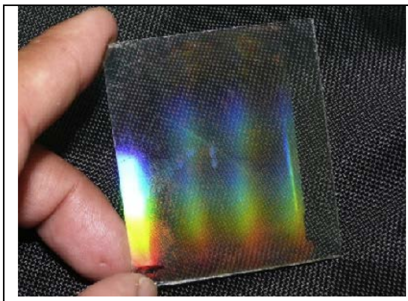
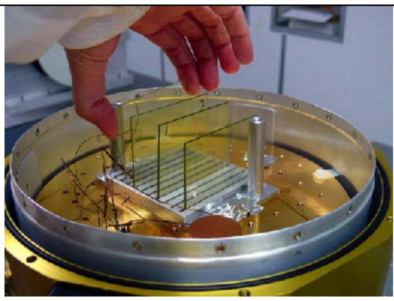
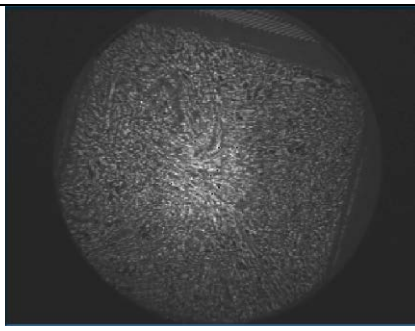
In late 2011 the company BAYER contacted the workpackage team offering the baseline version of their photopolymer films and an agreement to customize them to our needs (with some non-disclosure agreements etc.). The company's interest is linked to the solar energy business where large size holographic gratings are of potential use in co-generation solar farms. Astronomy is however a niche of "high visibility" and a possible interesting business. An 8x8 cm sample manufactured in INAF labs with a BAYER polymeric substrate and the related efficiency plots are shown here



Efficiency @ 633 nm

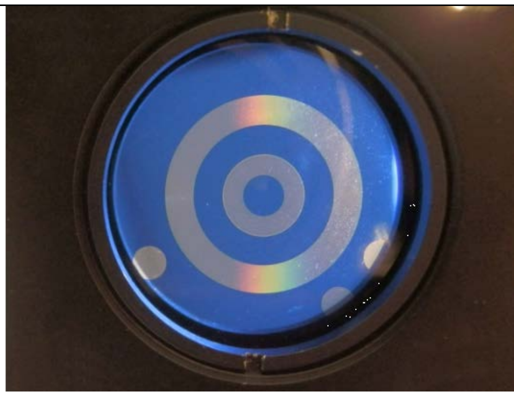
One of the VPHGs fabricated with the new polymer techniques has been tested in the AFOSC instrument at the Italian Asiago observatory where is currently installed and offered to astronomers.

In 2010 the OPTICON team established contacts with Elche University (Spain), who were manufacturing DCG-based gratings for laser applications. These devices are tuned to a specific application so they come only in one size and with a single grating spatial frequency, but they have excellent appearance and efficiency. A sample obtained was fully tested and characterized at cryogenic temperatures at IAC (Tenerife, Spain). The sample, the setup and an interferometric map are shown below.

Testing of DCG-based gratings developed for Laser Applications.

Finally, as part of a search for new materials and processes for reflective and refractive optics it seems that the application of photochromic rewriteable polymers for the production of HOE (Holographic Optical Elements) is extremely promising. Many tests have been done in the context of the OPTICON programme both for the qualification of the writing process and for the evaluation of performance. The early tests performed in the INAF laboratories evolved during the project to professional quality CGH written in collaboration with Institut fuer Technische Optik - UNI-Stuttgart. Both are shown here

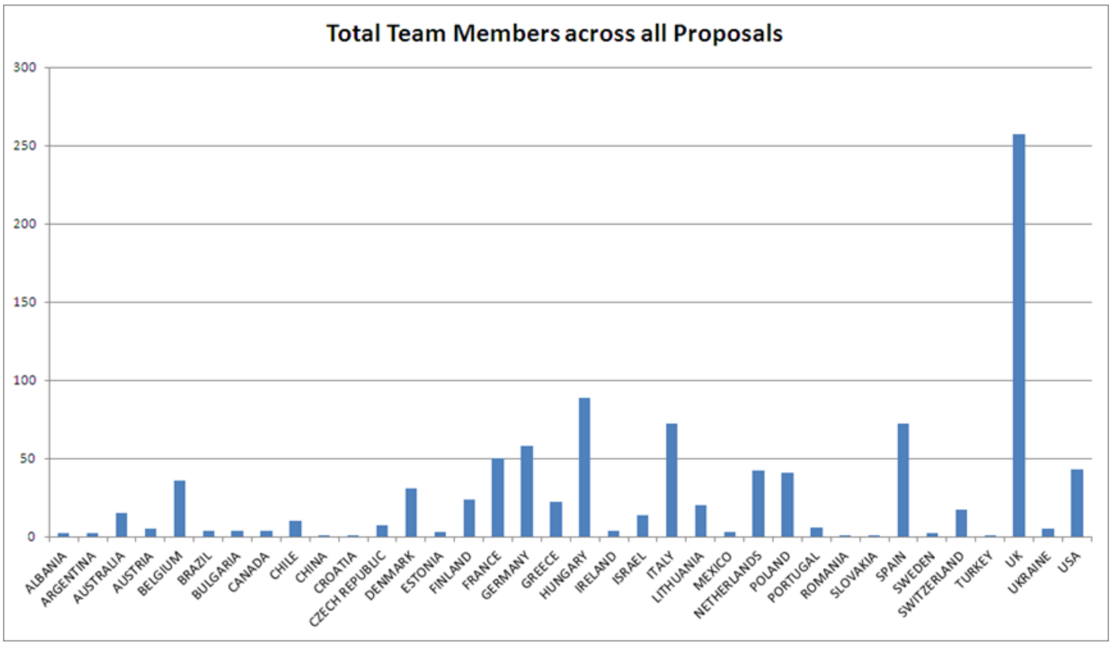



WP7: Transnational Access

As a first step towards a more European approach the solar telescope time funded under the EC Trans-National Access scheme began to be awarded by a single panel drawn from members of the EAST consortium (WP 12.3). This panel also accepted the responsibility of allocating solar time to be awarded on the four solar telescopes in the Canary Islands as part of the international agreements connected with the La Palma and Tenerife observatories (The ‘CCI International Time Programme’). In semester 2010B we launched the new OPTICON Common Time Allocation Process for night time telescopes. Proposals were entered via the NORTHSTAR system, developed jointly by FP6 and FP7 contracts to Radionet and OPTICON, and were reviewed by an international panel.

This panel (the CTAC) comprises 7 independent scientists drawn from 7 different national communities and normally linked to their own national time allocation process as either current or recent members of national panels. This ensures both a valuable mix of skills and provides essential feedback between the OPTICON and the various national processes. The panel ranks the proposals by scientific merit and the ranked list is then submitted to the telescope director's forum (part of WP12) for approval. Once this approval is received (and to date the CTAC rankings have always been accepted without modification) the highest ranking proposals are then scheduled on the various telescopes until either no time is available on the requested facilities or the funds available for the TNA programme for that semester are exhausted. This resource cut-off has always occurred at a higher, often very much higher, ranking than the lowest scientifically acceptable proposal, confirming the high standards of the proposals submitted.

This programme continued until the end of the contract and remains popular in our new contract. The steady rise in the number of proposals submitted seen in the first few semesters levelled out but the proposals received remain of a high standard. Most of the facilities in the TNA programme are requested and while the AAT and the NOT telescopes continue to be popular due to their specific capabilities; allocations have been made across a wide range of telescopes each semester. The oversubscription factor of about 3 is typical for telescopes in this class.



To summarise, in the 5 semesters since the CTAC scheme was introduced we have received 216 proposals involving 969 team members from 35 countries. The nationality breakdown of these teams is shown above. We have investigated the large over-representation of UK astronomers applying to the TNA programme and concluded that this is mainly a function of UK astronomers having a wide range of scientific interests, having a few projects (notably extra-solar planets) which require access to specialised instruments not available on UK telescopes and to having a long tradition of applying to international facilities.

The topics covered by these projects included studies of solar system objects, extra-solar planets, young stars, variable stars and a small number of projects on external galaxies.

Regular articles about the Trans-National Access programme appear in the newsletter of the European Astronomical Society.

WP8: Management

The Management Board is responsible for making strategic decisions. Meetings are held roughly annually so that the work package leaders can provide overview presentations of their activities, status, and progress to the whole consortium. The Executive oversee the day-to-day implementation of the OPTICON programme. Both groups met regularly during the contract. The project scientist maintains close links with the various work packages, and reports regularly to the co-ordinator so that, should it be required, appropriate intervention can be organised in a timely fashion.

WP9.1: Key Technology Network

Technology and astronomy have always been closely linked, even since the time of Galileo and Newton it was new technologies of the day that allowed telescopes to be developed and improved. This process continues today, but on a much more far reaching scale as new technologies spring up across Europe and in many disciplines. To try and bring these two communities, which are diverse but at the same time following similar paths, together OPTICON set up an activity especially to do this. The network chair, Colin Cunningham, made strong connections from the OPTICON activities with a technology foresight activity for space science (TECHBREAK), run by the ESF for ESA. Two recent workshops covered the following topics:

1: Polarimetry with Extremely Large Telescopes (Utrecht, November 2011)

Polarimetric observations would enable some of the most exciting science cases of the near future: direct detection and characterization of Earth-like exo-planets, revealing the structure of active galaxies in the early Universe, measurements of stellar magnetic fields, and mapping of structures around young stars and in supernovae. The light-collecting power of the Extremely Large Telescopes will offer unprecedented opportunities for astronomical polarimetry, but the technical challenges of such giant facilities do not easily lead to a design that facilitates polarimetry with commensurate precision. This workshop included presentations on state-of-the-art astronomy research and instrumentation, panel discussions, posters, and demonstrations of experimental set-ups and industry technology, from a range of specialists (scientists, instrumentalists, engineers). One of the conclusions from the workshop was that it was crucial that the polarimetry community team up and develop the 'highlight' science cases for the E-ELT, as well as exploring future options for current 4-10m class telescopes

Workshop 2: Disruptive Technologies for Astronomy (Marseille, April 2012)

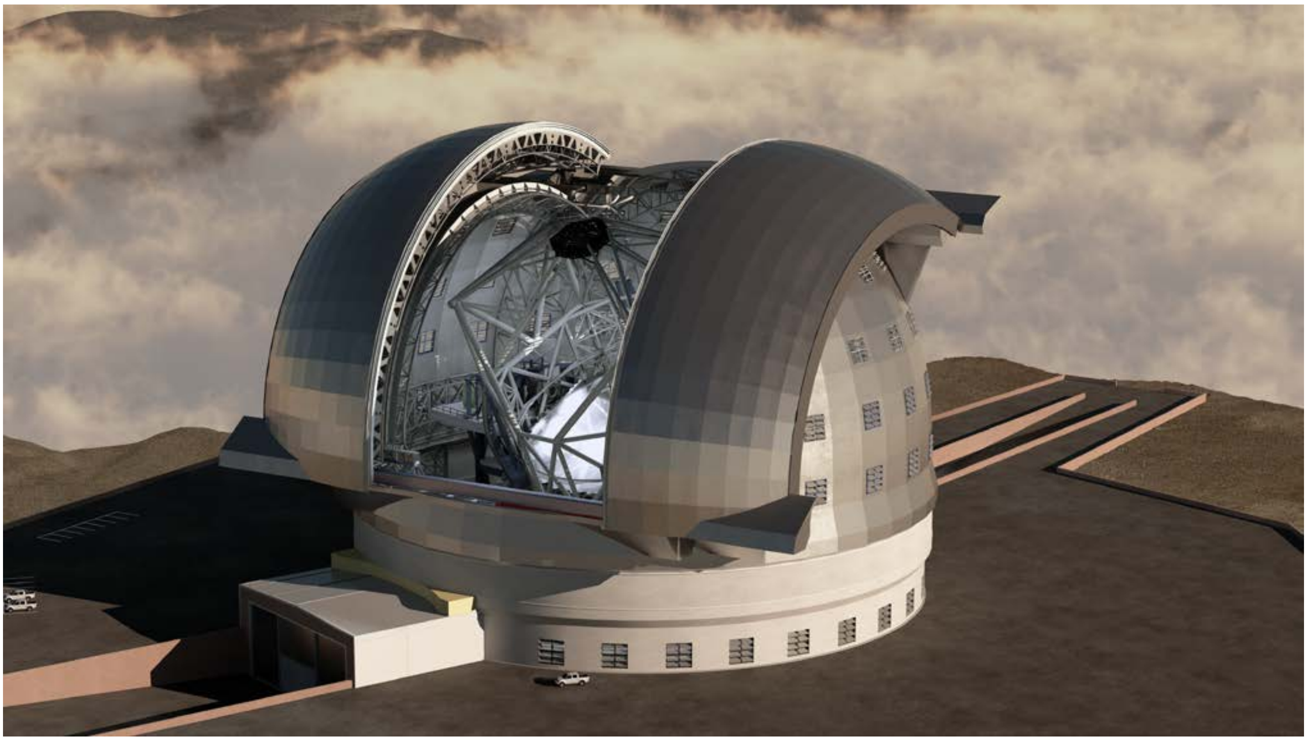
Advances in astronomy are often enabled by adoption of new technology. In some instances this is where the technology has been invented specifically for astronomy, but more usually it is adopted from another scientific or industrial area of application. The adoption of new technology typically occurs via one of two processes. The more usual is *incremental* progress by a series of small improvements, but occasionally this process is *disruptive*, where a new technology completely replaces an older one, for example the replacement of music discs (on Vinyl or CD) with direct music downloading changed the music retail landscape entirely. This workshop brought scientists and instrumentalists to identify the science challenges and drivers of the future, the features needed to achieve these (of telescopes, instrumentation, and analysis), and the technological components/solutions needed to enable them. These discussions were captured in detail in a paper presented at the 2013 SPIE Astronomical Instrumentation conference: '*Innovative Technology for Optical & Infrared Astronomy*' by Cunningham et al. (Proc. SPIE, 8450, 31). This paper was also used to seed the discussion of a session on 'revolutionary technologies' in one of the SPIE sessions of the 2012 Amsterdam conference.

WP9.2: Software Standards

The main objective to develop detailed software standards for an open, modular system for processing and analysis of astronomical data by end users was completed in 2011. Most of its outputs can be downloaded free of charge for use as required.

WP10.1: Science Case for the European ELT

The main activity of this WP was to organise meetings and talks to engage the scientific community with the E-ELT project. In 2011 the activity organised a major meeting: "Feeding the Giants: ELTs in the era of Surveys", on the island of Ischia, Italy from 29 August to 2nd September. The focus of the meeting was to explore science cases that exploit the synergy between large survey facilities and future extremely large telescopes. The meeting attended by about 75 people and was very successful. The programme included reviews of current and future survey facilities, and future extremely large telescopes (focussed on the E-ELT, but other projects such as the American led TMT and GMT were also represented). Further presentations addressed the developments that these facilities will bring to a wide range of science areas, including extra-solar planets, star formation, stellar populations, galaxy formation/evolution and cosmology. A discussion was held in a "World Café" format, allowing several small groups to discuss a series of specific questions. There was also a public event held one evening during the conference, where the E-ELT Programme scientist (Roberto Gilmozzi) gave a public talk and small telescopes were set up for public viewing of the night sky.



Impression of the 40m class European Extremely Large Telescope. (Photo ESO)

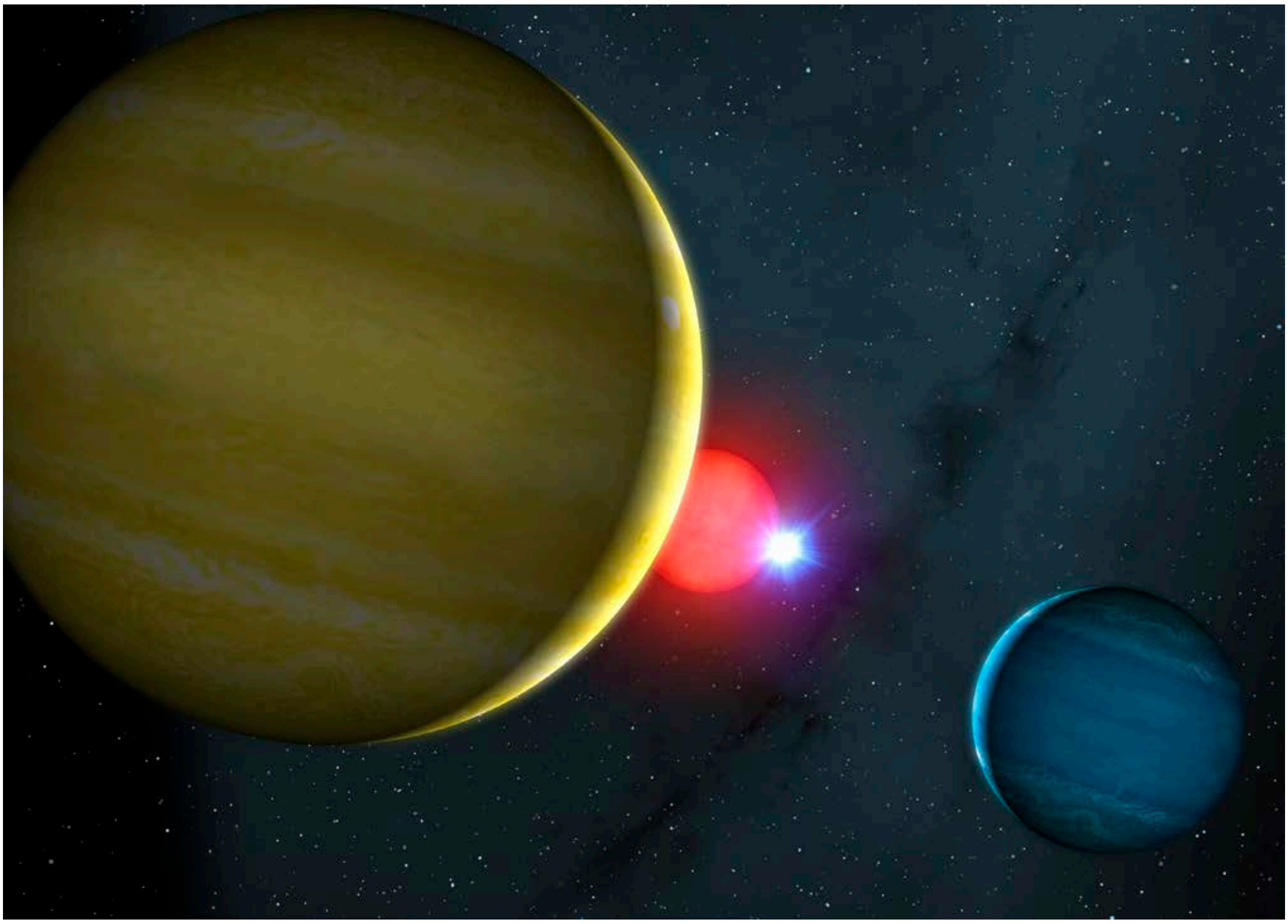
In addition we organised a smaller meeting during the EWASS (European Week of Astronomy and Space Science) in Rome, July 2012. The "Special Session" on E-ELT was held on 5 July. 70 people registered, and around 40 attended at any time. Presentations were given on E-ELT science cases, operations and instruments. There was plenty of lively discussion, especially on science policy for large observing campaigns, and instrumentation plans (especially on the expected performance of AO systems and relative priorities of mid-infrared and multi-object spectrographs). The programme and links to presentations can be found on the meeting web site, http://www.mporzio.astro.it/ewass_elt/

Along with organising meetings we have presented the E-ELT project and the science it can achieve in talks at several scientific institutions around Europe and in talks and/or posters at major international conferences (including the IAU General assembly in Beijing, China, August 2012). The above meetings and talks satisfy the WP objective of informing and engaging the scientific community, in particular future E-ELT users

Another important aspect of this WP was to inform the general public about the project. This has been achieved with a series of public talks (including the public event in Ischia already described above), either as individual events or as part of larger public events. For example A. Calamida gave a public talk on the E-ELT at Researchers Night 2011, which was part of a major public science event coordinated across 320 European cities.

WP10.2: European Network for High Time Resolution Astrophysics (HTRA)

High Time Resolution Astrophysics is one of the few remaining domains of astronomical space which has not been fully explored. Observations with time resolutions of milliseconds can shed light on the physics of extreme objects, for example flows of material falling into black holes and emitting flickering pulses of light as it does so. A few dedicated instruments exist for these kinds of studies but they are often small and privately owned so not available for the wider community. With its huge light gathering power the E-ELT will provide plenty of photons for HTRA projects, but only if the instruments and systems are designed with sufficient flexibility to accommodate the rather special needs of the HTRA community.



Astronomers at the University of Warwick and the University of Sheffield using an instrument especially developed for HTRA observations helped discover an unusual star system which looks like, and may even once have behaved like, a game of snooker. (see University of Warwick press release at http://www2.warwick.ac.uk/newsandevents/pressreleases/uk_astronomers_help/)

To bring together members of this small and diverse community OPTICON set up a network the members of which met face to face on several occasions. They created a single working group to promote and develop the different areas of HTRA, deciding to concentrate upon educating the community for developing HTRA on existing 8-10m class telescopes and on the E-ELT. A week long school on “Principles of Multi-wavelength High Time Resolution Astrophysics” was held in Sardinia from October 10th-15th 2011 to bring together the next generation of HTRA scientists, i.e. those just starting PhDs, to enable networking as well as developing skills in HTRA science and analysis tools.

WP11.1: Community Development

Young people are the future of astronomy; it is they who will inherit the E-ELT and future large facilities. However as observatories become more complicated, and more remote, the opportunity to gain 'hands on' experience of the observing process is becoming more and more rare. While it can be argued that this is how future astronomy will be done and there is no need for the next generation of scientists to 'get their hands dirty' , there is certainly a case that understanding the basic principles of observing and data reduction is a key skill in understanding and interpreting any observations delivered by large facilities.

To address this problem OPTICON embraced the NEON observing schools which were previously funded under another EU instrument. These schools bring together groups of new astronomers and immerse them in a condensed programme of actual observing, data reduction and the presentation of results. This is combined with advice on proposal writing and job hunting.

A series of NEON observing schools were held through the contract, each engaging 16-24 early stage researchers. For example one was held at the Moletai Observatory (Lituania) in July 2011, taking advantage of the small telescopes there for imaging and the friendly surroundings of the observatory. This was complemented by the remote use of the Nordic Optical Telescope in La Palma for spectroscopy. Another school was held at in 2012 at the Asiago Observatory in Italy. In 2011, an instrumentation school was organised jointly with the AIP in Potsdam, Germany on "Opto-Mechanical design in Astronomy". A meeting was also organised with SREAC (Sub-Regional European Astronomical Community) South-Eastern Europe members in Sofia, Romania to discuss their specific needs for the future and see how we could raise the participation from eastern EU-members in OPTICON activities overall.

Participants of the OPTICON/Neon summer school at the Moletai Observatory, Lithuania, 2011.

A new initiative was to begin to prepare other OPTICON "Enhancement" activities and to consult with partners about their needs and wishes. Some synergies were searched for, for instance by inviting participation of UK PhD students to training sessions organised for French students. An exploratory visit was made to Romania in order to prepare the organisation of a future "Awareness conference" there, which took place under the new OPTICON contract after a delay due to some administrative difficulties.

WP11.2: The European Interferometry Initiative (EII)

The EII is a umbrella group which brings together specialists in this subject from across Europe to exchange ideas and develop plans (see https://sites.google.com/a/european-interferometry.eu/home/). This group worked closely with workpackage 4 through the period of the contract and it held a major meeting in Amsterdam in 2012 in conjunction with the much larger SPIE technical meeting.

The work package continued to arrange short technical visits for the exchange of ideas and good practice under the Fizeau exchange programme. Calls were issued at 6 month intervals throughout the contract and many dozens of visits were supported. The procedure is very rigorous, involving peer review of the proposed visits and is highly thought of with the community it serves.

This poster advertising the exchange programme was widely distributed. (Photo P Garcia and the EII)

Two working groups on “Circumstellar disks and planets” and “AGNs and the galactic centre” met and published their conclusions and recommendations.

WP12.1: Telescope Directors Forum and Common TAC

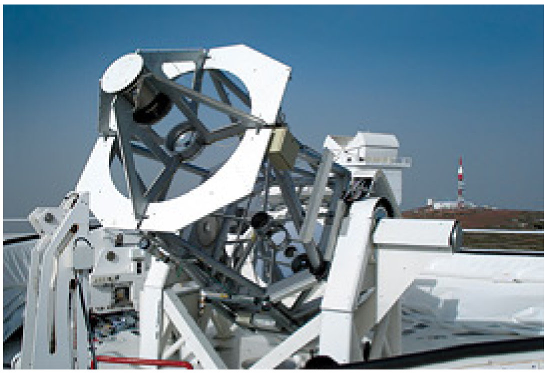
The directors of all the telescopes which participate in the TNA programme (WP7) met approximately annually to review developments, exchange information and monitor the progress of the TNA programme. In particular they approved the ranked lists of proposals prepared by the OPTICON Time Allocation Committee and provided oversight of the TNA programme generally. They also contributed technical information to the European Telescope Strategy Review Committee.

WP12.2: Planning for a Viable Future

This multi-pronged activity aimed at optimising and, where possible, integrating the operation of Europe’s 2-4m night time telescopes and Europe’s 4 major solar telescopes. OPTICON and ASTRONET collaborated in this process, and established a joint review which has published its conclusions on the ASTRONET website http://www.astronet-eu.org. The OPTICON project scientist prepared a paper for ASTRONET on how the panel’s recommendation of a single integrated telescope time allocation process based on the OPTICON experience might be implemented.

WP12.3: The European Association for Solar Telescopes (EAST)

European astronomers operate a number of solar telescopes, the most significant being a suite of telescopes in the Canary Islands (on Tenerife and La Palma). These offer world class facilities to European solar astronomers, a capability which will be enhanced by the new 1.5m GREGOR telescope. GREGOR is a project of a consortium of the Kiepenheuer-Institut für Sonnenphysik, the Leibniz Institute for Astrophysics Potsdam, the Institut für Astrophysik Göttingen, the Max-Planck-Institut für Sonnensystemforschung and other international partners. The telescope is designed for high-precision measurements of the sun’s magnetic field and the gas motion in the solar photosphere and chromosphere with a resolution of 70 km on the Sun. It can also be used for high resolution stellar spectroscopy.



The new GREGOR solar telescope (Photo KIS)

The EAST network has addressed key objectives towards plans for the next step after GREGOR, a large solar telescope to be included in the ASTRONET Science Vision Roadmap. The project is known as the European Solar Telescope (EST) and is comparable and competitive with its US equivalent, the Advanced Technology Solar Telescope (ATST). The network organised participation in joint ATST-EAST workshops in Solar Physics, the most recent of which was entitled “Magnetic Fields from the Photosphere to the Corona” and was held in November 2011 in Washington D.C, as well as supporting various solar astronomy meetings across Europe.

Finally, the group oversaw the solar astronomy element of the OPTICON Transnational Access programme setting up a special time allocation process for EC supported solar astronomy observing which ran in parallel with the night time CTAC described above..

A measure of the success of this activity is that the solar astronomy community was able to secure a contract of its own (SOLARNET) in the final FP7 infrastructure call.

4.1.4 Potential impact and the main dissemination activities

The majority of the key individual impacts and their outreach activities are give in the text describing each workpackage and the list of event and papers given in the Appendices. These will not be repeated in details here. Globally OPTICON has made, often in conjunction with other players, considerable impact in the following areas.

Maintained European leadership in the technologies and techniques of Adaptive Optics (WP1, 2)

Developed synergies between European technology players and the astronomical community, making the industrial concerns aware of expertise in the scientific community and vice versa. (WP3, 5, 6, 9.1)

Considerable co-ordination of the European Interferometry Community (WP4, 11.2)

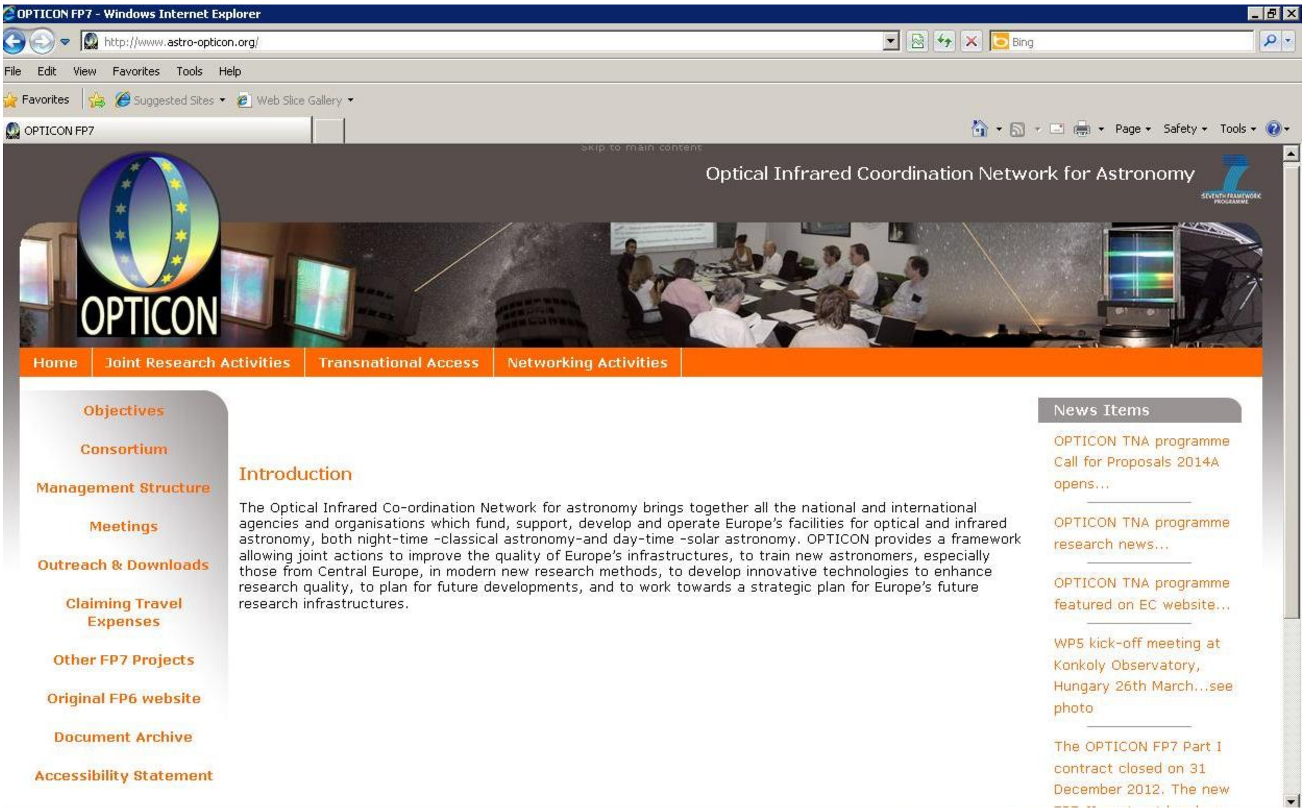
Opened a range of European observatories to new user communities (WP7) and made significant efforts to engage with thee new communities so they can take advantage of these opportunities, for example by offering a single proposal process (WP12) and training schools (WP11.1).

Supported Technology Development for European Solar telescopes (WP1), enabled access to existing facilities (WP7) and enabled strategic planning for future facilities (WP12)

Provided a communications pathway between the general user community and the future European ELT project teams (WP 10)

4.1.5 Project Public Website and Contact Details

The OPTICON Website can be found at the following url : www.astro-opticon.org. A link to the 2009-2012 pages can be found in the sidebar.



The OPTICON 'Front Page' provides access to information about all OPTICON activities.

The project co-ordinator was: Professor Gerard Gilmore, FInstP, ScD, FRS,
Professor of Experimental Philosophy,
Institute of Astronomy, University of Cambridge, Cambridge, CB3 0HA, UK.
Phone +44 (0)1223 337506 e-mail: gil@ast.cam.ac.uk;

The Project scientist was: Dr John Davies, UK Astronomy Technology Centre, Royal Observatory, Blackford Hill, Edinburgh, EH9 3HJ, UK. e-mail John.Davies@stfc.ac.uk

4.2 Use and dissemination of foreground

Dissemination measures

The beneficiaries of the project results are in several categories, requiring separate consideration. These include individual research astronomers, astronomers interested in specific subjects or facilities, scientists involved in technical RTD activities, industry, and funding agencies. The coordinator and project scientist have provided invited overview talks of OPTICON activities at meetings such as the European Wide EWASS/JENAM conferences organised by the European Astronomical Society. These are disseminated globally through the usual international astronomy e-preprint servers (arXiv) and in published conference proceedings.

The results of widest geographical and user interest are the access programme (WP7, WP12.1, WP12.3) and its associated training and scientific enhancement opportunities (WP11). Beneficiaries of this programme work in astronomy across Europe, distributing their experiences through local contact. Information is disseminated via web-page calls on which are published for proposals, via e-mail exploders (over 800 addresses receive notice of forthcoming TNA calls) and articles in newsletters.

Project specific interests include the several organised communities which operate as networks under the OPTICON umbrella. These are EAST (WP12.3), covering all solar astronomy Institutes in Europe, EII (WP11.2 and WP4) , including all institutes with an interest in Interferometric astronomy, HTRA (WP10.2), including all astronomers interested in high time resolution astrophysics, and E-ELT (WP10.1), including the extremely wide community with a scientific interest in definition of the next-generation large astronomical facilities. In all these cases OPTICON sponsors both specialised workshops of specific interest to the expert, open conferences of interest to all astronomers as an opportunity to learn new subjects, and contribute new science ideas to them, and publication of the workshop and conference proceedings. These books, major publications in themselves, are (usually) part of astronomy series produced by major publishers, and so are routinely made available in every university and observatory library world-wide.

The technical results of RTD activities are of interest to scientists involved in instrument developments, experimental physicists, industry, and (potentially) to a wider commercial community. Scientists involved in instrumentation and technical development are kept informed both internally inside OPTICON – note that every major instrumentation group is involved in some way in OPTICON – and externally, through presentations at specialist meetings. The major international specialist meetings are those of the Society of Photo-Optical Instrumentation Engineers (SPIE). SPIE meetings attract thousands of scientists and engineers from both academe and industry, and are the primary global forum for technical information exchange. OPTICON acts as a co-sponsor of those SPIE meetings relevant to astronomical technology, ensuring an extremely high international information exchange profile. Some sessions at these conferences have been chaired by engineers who lead our working groups, indicative of the high profile of these individuals. Large numbers of SPIE papers have been published by persons within OPTICON work packages and these are listed in the Annex. Internally inside OPTICON, communication between the participants is ensured at the project-wide level by a requirement that every OPTICON activity provides an overview of its activities at Board meetings.

Dissemination of results of industrial relevance is subject to the IPR issues covered in the Consortium Agreement. This ensures that all OPTICON participants have access to a free license for any patented technology during the project.

The primary deliverables from OPTICON of importance to national agencies are the outcomes of the technology RTD work packages, and the outcome of the joint strategic planning for the future use of medium sized telescopes. In the first of these the agencies are involved through their institutes, as described above and additionally through the Key Technology Planning activity (WP9.1). This activity exists to ensure an updated future technology road map is developed and maintained. This roadmap is developed in partnership with relevant national and international (ESA, ESO) strategic planning, and is disseminated back through those partnerships. The strategic planning work is a joint activity with ASTRONET, which is an agency partnership, and is being developed iteratively with the funding agencies, ensuring their full participation and involvement. One output of this has been the highly successful ETSRC process and its report described as part of WP 12.2.

OPTICON does not undertake a large suite of public facing activities aimed at educating the general population about European astronomy for the simple reason that individual agencies, and the European Southern Observatory, already have large and quite excellent outreach programmes. Where appropriate OPTICON links its activities to these agencies, and from time to time organises specific public facing events. An example of this was the World Café event associated with the conference on “Feeding the Giants: ELTs in the era of Surveys" and other activities described under WP 10.1 above.

Section A (public)

TEMPLATE A1: LIST OF SCIENTIFIC (PEER REVIEWED) PUBLICATIONS, STARTING WITH THE MOST IMPORTANT ONES										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[1] (if available)	Is/Will open access[2] provided to this publication?
1	On-Line Long-Exposure Phase Diversity: a powerful tool for Sensing Quasi-Static	L Mugnier	Optics Express	16 (22)	Optical Society of America	Washington DC	2008	18406-18416	10.1364/OE.16.018406	no
2	Linear quadratic gaussian control for adaptive optics and multiconjugate adaptive optics: experimental and numerical analysis	C. Petit	JOSA A	26(6)	Optical Society of America	Washington DC	2009	1307-1325	10.1364/JOSAA.26.001307	no
3	MOAO first on-sky demonstration with CANARY	E. Gendron	A&A	529	EDP Sciences	France	2011	L2	10.1051/0004-6361/201116658	no
4	Analytical expression of long-exposure adaptive-optics-corrected coronagraphic image. First application to exoplanet detection	J-F Sauvage	JOSA A	27 (11)	Optical Society of America	Washington DC	2010	A157- A170	10.1364/OL.37.004808	no
5	Coronagraphic phase diversity: a simple focal	J-F Sauvage	Optics Letters	37(23)	Optical Society	Washington DC	2012	4808- 4810	10.1117/12.925382	no

[1] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[2] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

	plane sensor for high-contrast				of America					
6	Tip–tilt disturbance model identification for Kalman-based control scheme: application to XAO and ELT systems	Serge Meimon	JOSA A	27(11)	Optical Society of America	Washington DC	2010	A122- A132	10.1364/JOSAA.27.00A122	no
7	Min.-variance control for woofer–tweeter systems in AO	Correia	JOSA A	27(11)	Optical Society of America	Washington DC	2010	A133-A144	10.1364/JOSAA.27.00A133	no
8	The LBT real-time based control software to mitigate and compensate vibrations	Borelli, J	SPIE	7740	SPIE	Bellingham, Washington, USA	2010	4	10.1117/12.857436	no
9	Wide-field AO correction: the large wavefront sensor detector of ARGOS	Orban de Xivry, Gilles	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	178	10.1117/12.857230	no
10	Final design of the wavefront sensor unit for ARGOS, the LBT's LGS facility	Busoni L.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	186	10.1117/12.858206	no
11	Point-spread function reconstruction for the ground layer adaptive optics system ARGOS	Peter, D	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	161	10.1117/12.856982	no
12	ARGOS: a laser star constellation for the LBT	S. Kanneganti	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	147	10.1117/12.862448	no
13	Diffraction-limited upgrade to ARGOS: the LBT's ground-layer adaptive optics system	M. Hart	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	104	10.1117/12.857769	no
14	Calibration strategy and optics for ARGOS at the LBT	C.. Schwab	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	100	10.1117/12.857231	no
15	Diffraction limited operation with ARGOS: a hybrid AO	M. Bonaglia	SPIE	7736	SPIE	Bellingham,	2010	97	10.1117/12.858209	no

	system					Washington, USA				
16	An optimized controller for ARGOS: using multiple wavefront sensor signals for homogeneous correction over the field	Peter D.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	38	10.1117/12.857012	no
17	ARGOS: the laser guide star system for the LBT	Rabien S.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	12	10.1117/12.857210	no
18	Design of a CGH corrected calibration objective for the AO system at the Large Binocular Telescope	Schwab C.	SPIE	7652	SPIE	Bellingham, Washington, USA	2010	25-37	10.1117/12.871060	no
19	First laboratory validation of LQG control with the CANARY MOAO pathfinder	Sivo G.	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	10	0.1117/12.926257	no
20	Tests of open-loop LGS tomography with CANARY	T. Morris	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	9	10.1117/12.926985	no
21	Temporal convergence of phase spatial covariance matrix measurements in tomographic adaptive optics	Martin Olivier	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	14	10.1117/12.924845	no
22	Towards MOAO on the ELT: the CANARY program	E. Gendron	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
23	CANARY Phase B: the LGS upgrade to the CANARY tomographic MOAO pathfinder	T. Morris	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
24	Detailed analysis of the first MOAO results obtained by CANARY at the WHT	F. Vidal	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
25	MOAO Real-Time LQG implementation on	G. Sivo	AO4ELT2	http://ao4elt2.lesia.o	AO4ELT organizat	Paris	2011			yes

	CANARY			bspm.fr/	ion					
26	An optimized calibration strategy for high order adaptive optics systems : the Slope-Oriented Hadamard Actuation	S. Meimon	AO4ELT	EDP Sciences http://dx.doi.org/10.1051/ ao4elt/ 201000001	EDP Sciences	France	2009		10.1051/ao4elt/ 201007009	no
27	Sensing quasi-static aberrations of adaptive optics systems on-line with long-exposure phase diversity	L-M Mugnier	AO4ELT	EDP Sciences http://dx.doi.org/10.1051/ ao4elt/ 201000001	EDP Sciences	France	2009		10.1051/ao4elt/ 201005006	no
28	Optimized phase diversity sensor for wideband analysis on long-exposure AO corrected images: theory, simulations, and experimental validations.	S. Dandy	SPIE	7736	SPIE	Bellingham, Washington, USA	2010			no
29	Are integral controllers adapted to the new era of ELT adaptive optics?	J-M Conan	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
30	The Slope-Oriented Hadamard scheme for in-lab or on-sky interaction matrix calibration	S. Meinon	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
31	Post-coronagraphic wave-front sensing dedicated to exoplanet detection	J-F Sauvage	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
32	SPHERE non-common path aberrations measurement and pre-compensation with optimized phase diversity processes: experimental results	J-F Sauvage	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
33	Service-oriented architecture for the ARGOS instrument control software	Borelli, J	SPIE	8451	SPIE	Bellingham, Washingto	2012	9	10.1117/12.926515	no

						n, USA				
34	Instrument control software development process for the multi-star AO system ARGOS	Kulas M	SPIE	8451	SPIE	Bellingham, Washington, USA	2012	7	10.1117/12.926051	no
35	LUCI in the sky: performance and lessons learned in the first two years of near-infrared multi-object spectroscopy at the LBT	Buschkamp P	SPIE	8446	SPIE	Bellingham, Washington, USA	2012	11	10.1117/12.926989	no
36	Testing and integrating the laser system of ARGOS: the ground layer adaptive optics for LBT	Loose C.	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	11	10.1117/12.927101	no
37	Status of the ARGOS ground layer adaptive optics system	Gaessler	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	10	10.1117/12.926167	no
38	Design of the wavefront sensor unit of ARGOS, the LBT laser guide star system	Bonaglia M.	arXiv:1203.5081		Open Archives Initiative	Web	2012			yes
39	Status report on the Large Binocular Telescope's ARGOS ground-layer AO system	Hart M.	SPIE	8149	SPIE	Bellingham, Washington, USA	2011	11	10.1117/12.893916	no
40	An automated aircraft detection system to prevent illumination from the laser guide star beacons at the MMT and LBT	Newman K.	SPIE	8149	SPIE	Bellingham, Washington, USA	2011	9	10.1117/12.893787	no
41	The Large Binocular Telescope's ARGOS ground-layer AO system	Hart M.	SPIE	8149	SPIE	Bellingham, Washington, USA	2011			no
42	PM fiber lasers at 589nm: a 20W transportable laser system for LGS return flux studies	Bonaccini D.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	12	10.1117/12.857991	no
43	Diode-seeded fiber-based sodium laser guide stars ready for deployment	W. G. Kaenders	SPIE	7736	SPIE	Bellingham, Washingto	2010	7	10.1117/12.871383	no

						n, USA				
44	Design and Performance of Raman Fiber Amplifier Based 589-nm Guide Star Lasers for ESO VLT and Their Suitability for Future ELT AO Systems	V. Karpov	http://ao4elt2.lesia.obspm.fr/		AO4ELT organization	Paris	2011			yes
45	18+2 W at 589 nm via Frequency Doubling of Diode-Laser-Seeded 1178-nm CW PM Raman Fiber Amplifier for Deployment at ESO VLT	W. G. Kaenders	Proc.of the Conf. on Lasers and Electro-Optics				2011	C1089		
46	RFA-based 589-nm guide star lasers for ESO VLT: a paradigm shift in performance, operational simplicity, reliability, and maintenance; Axel Friedenauer	V. Karpov	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	10	10.1117/12.923869	no
47	The ESO transportable LGS Unit for measurements of the LGS photon return and other experiments	Bonaccini D.	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	12	10.1117/12.926898	no
48	Real-time control developments for the CANARY MOAO instrument at Durham	A. Basden	http://ao4elt2.lesia.obspm.fr/		AO4ELT organization	Paris	2011			yes
49	On-Line Long-Exposure Phase Diversity: a powerful tool for Sensing Quasi-Static	L Mugnier	Optics Express	16 (22)			2008	18406-18416	10.1364/OE.16.018406	no
50	Linear quadratic gaussian control for adaptive optics and multiconjugate adaptive optics: experimental and numerical analysis	C. Petit	JOSA A	26(6)	Optical Society of America	Washington DC	2009			no
51	MOAO first on-sky demonstration with CANARY	E. Gendron	A&A	529	EDP Sciences	France	2011	L2	10.1051/0004-6361/201116658	no
52	Analytical expression of long-exposure adaptive-	J-F Sauvage	JOSA A	27 (11)	Optical Society	Washington DC	2010	A157- A170		no

	optics-corrected coronagraphic image. First application to exoplanet detection				of America					
53	Coronagraphic phase diversity: a simple focal plane sensor for high-contrast	J-F Sauvage	Optics Letters	37(23)	Optical Society of America	Washington DC	2012	4808- 4810	10.1364/OL.37.004808	no
54	Tip–tilt disturbance model identification for Kalman-based control scheme: application to XAO and ELT systems	Serge Meimon	JOSA A	27(11)	Optical Society of America	Washington DC	2010	A122- A132	10.1364/JOSAA.27.00A122	no
55	Min.-variance control for woofer–tweeter systems in AO	Correia	JOSA A		Optical Society of America	Washington DC	2010		10.1364/BOE.2.001986	no
56	The LBT real-time based control software to mitigate and compensate vibrations	Borelli, J	SPIE	7740	SPIE	Bellingham, Washington, USA	2010	4	10.1117/12.857436	no
57	Wide-field AO correction: the large wavefront sensor detector of ARGOS	Orban de Xivry, Gilles	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	178	10.1117/12.857230	no
58	Final design of the wavefront sensor unit for ARGOS, the LBT's LGS facility	Busoni L.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	186	10.1117/12.858206	no
59	Point-spread function reconstruction for the ground layer adaptive optics system ARGOS	Peter, D	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	161	10.1117/12.856982	no
60	ARGOS: a laser star constellation for the LBT	S. Kanneganti	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	147	10.1117/12.862448	no
61	Diffraction-limited upgrade to ARGOS: the LBT's ground-layer adaptive optics	M. Hart	SPIE	7736	SPIE	Bellingham, Washingto	2010	104	10.1117/12.857769	no

	system					n, USA				
62	Calibration strategy and optics for ARGOS at the LBT	C.. Schwab	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	100	10.1117/12.857231	no
63	Diffraction limited operation with ARGOS: a hybrid AO system	M. Bonaglia	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	97	10.1117/12.858209	no
64	An optimized controller for ARGOS: using multiple wavefront sensor signals for homogeneous correction over the field	Peter D.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	38	10.1117/12.857012	no
65	ARGOS: the laser guide star system for the LBT	Rabien S.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	12	10.1117/12.857210	no
66	Design of a CGH corrected calibration objective for the AO system at the Large Binocular Telescope	Schwab C.	SPIE	7652	SPIE	Bellingham, Washington, USA	2010	25	10.1117/12.871060	no
67	First laboratory validation of LQG control with the CANARY MOAO pathfinder	Sivo G.	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	10	10.1117/12.926257	no
68	Tests of open-loop LGS tomography with CANARY	T. Morris	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	9	10.1117/12.926985	no
69	Temporal convergence of phase spatial covariance matrix measurements in tomographic adaptive optics	Martin Olivier	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	14	10.1117/12.924845	no
70	Towards MOAO on the ELT: the CANARY program	E. Gendron	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
71	CANARY Phase B: the LGS upgrade to the CANARY tomographic MOAO	T. Morris	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes

	pathfinder									
72	Detailed analysis of the first MOAO results obtained by CANARY at the WHT	F. Vidal	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
73	MOAO Real-Time LQG implementation on CANARY	G. Sivo	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
74	An optimized calibration strategy for high order adaptive optics systems : the Slope-Oriented Hadamard Actuation	S. Meimon	AO4ELT	EDP Sciences http://dx.doi.org/10.1051/ ao4elt/ 201000001			2009		10.1051/ao4elt/ 201007009	no
75	Sensing quasi-static aberrations of adaptive optics systems on-line with long-exposure phase diversity	L-M Mugnier	AO4ELT	EDP Sciences http://dx.doi.org/10.1051/ ao4elt/ 201000001			2009		10.1051/ao4elt/ 201005006	no
76	Optimized phase diversity sensor for wideband analysis on long-exposure AO corrected images: theory, simulations, and experimental validations.	S. Dandy	SPIE	7736	SPIE	Bellingham, Washington, USA	2010		10.1117/12.857291	no
77	Are integral controllers adapted to the new era of ELT adaptive optics?	J-M Conan	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
78	The Slope-Oriented Hadamard scheme for in-lab or on-sky interaction matrix calibration	S. Meinon	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
79	Post-coronagraphic wave-front sensing dedicated to exoplanet detection	J-F Sauvage	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
80	SPHERE non-common path aberrations measurement and	J-F Sauvage	AO4ELT2	http://ao4elt2.lesia.o	AO4ELT organizat	Paris	2011			yes

	pre-compensation with optimized phase diversity processes: experimental results			bspm.fr/	ion					
81	Service-oriented architecture for the ARGOS instrument control software	Borelli, J	SPIE	8451	SPIE	Bellingham, Washington, USA	2012	9	10.1117/12.926515	no
82	Instrument control software development process for the multi-star AO system ARGOS	Kulas M	SPIE	8451	SPIE	Bellingham, Washington, USA	2012	7	10.1117/12.926051	no
83	LUCI in the sky: performance and lessons learned in the first two years of near-infrared multi-object spectroscopy at the LBT	Buschkamp P	SPIE	8446	SPIE	Bellingham, Washington, USA	2012	11	10.1117/12.926989	no
84	Testing and integrating the laser system of ARGOS: the ground layer adaptive optics for LBT	Loose C.	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	11	10.1117/12.927101	no
85	Status of the ARGOS ground layer adaptive optics system	Gaessler	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	10	10.1117/12.926167	no
86	Design of the wavefront sensor unit of ARGOS, the LBT laser guide star system	Bonaglia M.	arXiv:1203.5081		Open Archives Initiative	Web	2012			yes
87	Status report on the Large Binocular Telescope's ARGOS ground-layer AO system	Hart M.	SPIE	8149	SPIE	Bellingham, Washington, USA	2011	11	10.1117/12.893916	no
88	An automated aircraft detection system to prevent illumination from the laser guide star beacons at the MMT and LBT	Newman K.	SPIE	8149	SPIE	Bellingham, Washington, USA	2011	9	10.1117/12.893787	no
89	The Large Binocular Telescope's ARGOS ground-layer AO system	Hart M.	SPIE	8149	SPIE	Bellingham, Washington, USA	2011		10.1117/12.893916	no

90	PM fiber lasers at 589nm: a 20W transportable laser system for LGS return flux studies	Bonaccini D.	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	12	10.1117/12.857991	no
91	Diode-seeded fiber-based sodium laser guide stars ready for deployment	W. G. Kaenders	SPIE	7736	SPIE	Bellingham, Washington, USA	2010	7	10.1117/12.871383	no
92	Design and Performance of Raman Fiber Amplifier Based 589-nm Guide Star Lasers for ESO VLT and Their Suitability for Future ELT AO Systems	V. Karpov	AO4ELT2	http://ao4elt2.lesia.obspm.fr	AO4ELT organization	Paris	2011			yes
93	18+2 W at 589 nm via Frequency Doubling of Diode-Laser-Seeded 1178-nm CW PM Raman Fiber Amplifier for Deployment at ESO VLT	W. G. Kaenders	Proc.of the Conf. on Lasers and Electro-Optics				2011	C1089	10.1109/IQEC-CLEO.2011.6194133	
94	RFA-based 589-nm guide star lasers for ESO VLT: a paradigm shift in performance, operational simplicity, reliability, and maintenance; Axel Friedenauer	V. Karpov	SPIE	8447	SPIE	Bellingham, Washington, USA	2012	10	10.1117/12.923869	no
95	The ESO transportable LGS Unit for measurements of the LGS photon return and other experiments	Bonaccini D.	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	12	10.1117/12.926898	no
96	Real-time control developments for the CANARY MOAO instrument at Durham	A. Basden	AO4ELT2	http://ao4elt2.lesia.obspm.fr/	AO4ELT organization	Paris	2011			yes
97	A decadal survey of AO wavefront sensing detector developments in Europe	P. Feautrier	AO4ELT2	http://ao4elt2.lesia.obspm.fr, id.37	AO4ELT organization	Paris	2011			yes
98	Advances in detector technologies for visible and infrared wavefront sensing	P. Feautrier	SPIE	SPIE Volume 8447, Adaptive Optics Systems III, article	SPIE	Bellingham, Washington	2012	33 pp	10.1117/12.925067	no

				id. 84470Q		n, USA				
99	Backside-illuminated, high-QE, 3e- RoN, fast 700fps, 1760x1680 pixels CMOS imager for AO with highly parallel readout	M. Downing	SPIE	SPIE 8453, High Energy, Optical, and Infrared Detectors for Astronomy V, 84530C	SPIE	Bellingham, Washington, USA	2012	13	10.1117/12.925616	no
100	Circumstellar disks and planets. Science cases for next-generation optical/infrared long-baseline interferometers	S. Wolf	The Astronomy and Astrophysics Review	20	EDP Sciences	France	2012	52, 83pp.	10.1007/s00159-012-0052-1	no
101	Very Large Telescope Interferometer observations of the dust geometry around R Coronae Borealis stars	S. N. Bright	Monthly Notices of the Royal Astronomical Society	414	EDP Sciences	France	2011	1195-1206	10.1111/j.1365-2966.2011.18449.x	no
102	Pre-main-sequence binaries with tidally disrupted discs: the Brγ in HD 104237	P.J.V. Garcia	Monthly Notices of the Royal Astronomical Society	430	EDP Sciences	France	2013	1839-1853	10.1093/mnras/stt005	no
103	The geometry of the close environment of SV Piscium as probed by VLTI/MIDI	D. Klotz	Astronomy & Astrophysics	541	EDP Sciences	France	2012	A164, 10pp.	10.1051/0004-6361/201118290	no
104	Dynamics during outburst. VLTI observations of the young eruptive star V1647 Orionis during its 2003-2006 outburst	L. Mosoni	Astronomy & Astrophysics	552	EDP Sciences	France	2013	A62, 13 pp.	10.1051/0004-6361/201218770	no
105	The Hα line forming region of AB Aurigae spatially resolved at sub-AU with the VEGA/CHARA spectro-interferometer	K. Rousselet-Perraut	Astronomy & Astrophysics	516	EDP Sciences	France	2010	L1, 4 pp.	10.1051/0004-6361/201014720	no
106	Hot exozodiacal dust resolved around Vega with IOTA/IONIC	D. Defrère	Astronomy & Astrophysics	534	EDP Sciences	France	2011	A5, 10 pp.	10.1051/0004-6361/201117017	no

107	Hot circumstellar material resolved around β Pic with VLTI/PIONIER	D. Defrère	Astronomy & Astrophysics	546	EDP Sciences	France	2012	L9, 4 pp.	10.1051/0004-6361/201220287	no
108	AMBER/VLTI observations of five giant stars	F. Cusano	Astronomy & Astrophysics	539	EDP Sciences	France	2012	A58, 7 pp.	10.1051/0004-6361/201116731	no
109	Beyond the diffraction limit of optical/IR interferometers. I. Angular diameter and rotation parameters of Achernar from differential phases	A. Dominiciano de Souza	Astronomy & Astrophysics	545	EDP Sciences	France	2012	A130, 10 pp.	10.1051/0004-6361/201218782	no
110	Determination of the stellar parameters of C-rich hydrostatic stars from spectro-interferometric observations	C. Paladini	Astronomy & Astrophysics	533	EDP Sciences	France	2011	A27, 18 pp.	10.1051/0004-6361/201116538	no
111	The nearby eclipsing stellar system δ Velorum. IV. Differential astrometry with VLT/NACO at the 100 microarcsecond level	P. Kervella	Astronomy & Astrophysics	552	EDP Sciences	France	2013	A18, 7 pp.	10.1051/0004-6361/201220440	no
112	The final design of the GRAVITY acquisition camera and associated VLTI beam monitoring strategy	A. Amorim	Proceedings of the SPIE	8445	SPIE	Bellingham, Washington, USA	2012	844534, 14 pp	10.1117/12.925993	no
113	The GRAVITY acquisition and guiding system	A. Amorim	Proceedings of the SPIE	7734	SPIE	Bellingham, Washington, USA	2010	773415, 12 pp	10.1117/12.856907	no
114	Least-squares deconvolution of AMBER dispersed visibilities	P.J.V. Garcia	Proceedings of the SPIE	8445	SPIE	Bellingham, Washington, USA	2012	844517, 10 pp.	10.1117/12.925280	no

115	The MROI fringe tracker: closing the loop on ICoNN	T.M. McCracken	Proceedings of the SPIE	8445	SPIE	Bellingham, Washington, USA	2012	84451N, 10 pp.	10.1117/12.925457	no
116	Intrincate visibility effects from resolved emission of young stellar objects: the case of MWC158 observed with the VLTI	J. Kluska	Proceedings of the SPIE	8445	SPIE	Bellingham, Washington, USA	2012	84450O, 14 pp.	10.1117/12.925456	no
117	DiffRACT: differential remapped aperture coronagraphic telescope	F. Allouche	Proceedings of the SPIE	8446	SPIE	Bellingham, Washington, USA	2012	84467E, 6 pp.	10.1117/12.926022	no
118	Discrete optical multi-aperture combiner: instrumental concept	S. Minardi	Proceedings of the SPIE	8445	SPIE	Bellingham, Washington, USA	2012	844526, 7 pp.	10.1117/12.926045	no
119	First results from fringe tracking with the PRIMA fringe sensor unit	J. Sahlmann	Proceedings of the SPIE	7734	SPIE	Bellingham, Washington, USA	2010	773422, 12 pp.	10.1117/12.856896	no
120	Observing compact disks inside pre-PNe with the VLTI	S.N. Bright	Proceedings of the International Astronomical Union	283	Cambridge University Press	Cambridge, UK	2012	p. 115-118	10.1017/S1743921312010800	no
121	PTPS Candidate Exoplanet Host Star Radii Determination with CHARA Array	P. Zieliński	Proceedings of the International Astronomical Union	282	Cambridge University Press	Cambridge, UK	2012	p. 203-204	10.1017/S1743921311027360	no
122	SCIROCCO+: Simulation Code of Interferometric-observations for ROtators and CirCumstellar Objects	M. Hadjara	EAS Publications Series	59	European Astronomy	Paris	2013	p. 131-140	10.1051/eas/1359007	no

	including Non-Radial Pulsations				Society					
123	Exploring the water and carbon monoxide shell around Betelgeuse with VLTI/AMBER	M. Montargès	EAS Publications Series	60	European Astronomy Society	Paris	2013	p. 167-172	10.1051/eas/1360019	no
124	GRAVITY: Observing the Universe in Motion	F. Heisenhauer	The Messenger	143	European Southern Observatory	Garching, Germany	2011	p. 16-24		no
125	Optimizing optical systems with active components	T. Agócs	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	13	10.1117/12.925326	no
126	Extremely aspheric surfaces: toward a manufacturing process based on Active Optics	Z. Challita	SPIE	8169	SPIE	Bellingham, Washington, USA	2011	9	10.1117/12.925540	no
127	Extremely aspheric mirrors: prototype development of an innovative manufacturing process based on active optics	Z. Challita	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	9	10.1117/12.925540	no
128	Design of a Micro-Autonomous Robot for Use in Astronomical Instruments	W. Cochrane	International Journal of Optomechatronics		Taylor and Francis	Oxford, UK	2012	199-212	10.1080/15599612.2012.700550	no
129	Optimizing an active extreme asphere based optical system	T. Agócs	SPIE	8550	SPIE	Bellingham, Washington, USA	2012		10.1117/12.981338	no
130	Potential of phase-diversity for metrology of active instruments	V. Korkiakoski	SPIE	8450	SPIE	Bellingham, Washington	2012	11	10.1117/12.926290	no

						n, USA				
131	A new generation active arrays for optical flexibility in astronomical instrumentation	G. Kroes	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	16	10.1117/12.926481	no
132	MAPS: where have the robots got to?	W. Taylor	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	9	10.1117/12.927106	no
133	Recent testing of a micro autonomous positioning system for multi-object instrumentation	W. Cochrane	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	14	10.1117/12.924644	no
134	New modelling of freeform surfaces for optical design of astronomical instruments	S. Pascal	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	10	10.1117/12.925299	no
135	Modelling highly aspherical optical surfaces using new polynomial formalism into Zemax	S. Vives	SPIE	8172	SPIE	Bellingham, Washington, USA	2011		10.1117/12.896906	no
136	Smart Focal Plane technologies for VLT Instruments	C. Cunningham	ESO Symposium: Science with the VLT in the ELT Era		European Southern Observatory	Garching, Germany	2009	369-	10.1007/978-1-4020-9190-2_62	no
137	Smart instrument technologies to meet extreme instrument stability requirements	C Cunningham	SPIE	7018	SPIE	Bellingham, Washington, USA	2008	8	10.1117/12.789237	no
138	Future Technologies for Optical and Infrared	C. Cunningha	Experimental Astronomy	26	Springer	Germany	2009	179-199	10.1007/s10686-009-9149-6	no

	Telescopes and Instruments	m								
139	Future Optical Technologies for Telescopes and Instruments'	C. Cunningham	Nature Photonics	3	Nature Publishing Group	London, UK	2009	239-241	10.1038/nphoton.2009.49	no
140	The OPTICON technology roadmap for optical and infrared astronomy	C. Cunningham	SPIE	7739	SPIE	Bellingham, Washington, USA	2010	14	10.1117/12.857240	no
141	Innovative Technology for Optical & IR Astronomy	C. Cunningham	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	14	10.1117/12.925573	no
142	Defining requirements and identifying relevant technologies in astrophotonics	J. Allington-Smith	SPIE	7739	SPIE	Bellingham, Washington, USA	2010	13	10.1117/12.857228	no
141	Astrophotonic spectroscopy: defining the potential advantage	Allington-Smith J.	MNRAS	404	Royal Astronomical Society	London, UK	2010	p. 232-238	10.1111/j.1365-2966.2009.16173.x	No
142	Answering the Big Questions in Astronomy with Astrophotonic Spectroscopy	J. Allington-Smith	CLEO/Europe and EQEC 2011 Conference Digest, OSA Technical Digest (CD)	Paper JSIII1_1	Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943670	no
143	Fibers are Looking Up: Optical Fiber Transition Structures in Astrophotonics	T. Birks	Frontiers in Optics, OSA Technical Digest (CD)	Paper FTuU1	Optical Society of America	Washington DC	2011		10.1364/FIO.2010.FTuU1	no
144	Multicore optical fibres for astrophotonics	T. Birks	CLEO/Europe and EQEC 2011 Conference Digest, OSA Technical	Paper JSIII2_1	Optical Society of America	Washington DC	2011		10.1109/CLEOE.2011.5943675	no

			Digest (CD)							
145	Instruments without optics: an integrated photonic spectrograph	J. Bland-Hawthorn	SPIE	6269	SPIE	Bellingham, Washington, USA	2006	14	10.1117/12.670931	no
146	Photonic OH suppression of the infrared night sky: first on-sky results	Bland-Hawthorn, J	Anglo-Australian Observatory Newsletter	115	Anglo-Asutralian Observatroy	NSW, Australia	2009			yes
147	Astrophotonics: a new era for astronomical instruments	J. Bland-Hawthorn	Optics Express	17			2009	1880-1884	10.1364/OE.17.001880	no
148	PIMMS: photonic integrated multimode microspectrograph	J. Bland-Hawthorn	SPIE	7735	SPIE	Bellingham, Washington, USA	2010	9	10.1117/12.856347	no
149	3D spectrophotometric imaging opens a new window into the cosmos	J. Bland-Hawthorn	Laser Focus World	46(12)	Pennwell Corporation	New Hampshire, USA	2010	60-64		no
150	Sampling of the telescope image plane using single and few-mode fibre arrays	Jason C. Corbett	Optics Express	17	Optical Society of America	Washington DC	2009	1885-1901	10.1364/OE.17.001885	no
151	Characterization and on-sky demonstration of an integrated photonic spectrograph for astronomy	Cvetojevic, N.	Optics Express	17	Optical Society of America	Washington DC	2009	18643-18650	10.1364/OE.17.018643	no
152	Performance of astronomical beam combiner prototypes fabricated by hybrid sol-gel technology	Ghasempour, Askari	Optics Express	18	Optical Society of America	Washington DC	2010	9413-9422	10.1364/OE.18.009413	no
153	Dragonfly: On-chip Pupil remapping for Optical Stellar Interferometry	N. Jovanovic	CLEO/Europe and EQEC 2011 Conference Digest, OSA		Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943673	no

			Technical Digest (CD)							
154	On-chip spectro-detection for fully integrated coherent beam combiners	Pierre Kern	Optics Express	17	Optical Society of America	Washington DC	2009	1976-1987	10.1364/OE.17.001976	no
155	PIONIER: combining 4 telescopes of the Very Large Telescope Interferometer using a photonics beam combiner	Pierre Kern	CLEO/Europe and EQEC 2011 Conference Digest, OSA Technical Digest (CD)	Paper JSIII1_2	Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943671	no
156	Mid-infrared guided optics: a perspective for astronomical instruments	Labadie, Lucas	Optics Express	17 (3)	Optical Society of America	Washington DC	2009	1947-1962	10.1364/OE.17.001947	no
157	First fringes with an integrated-optics beam combiner at 10 µm. A new step towards instrument miniaturization for mid-infrared interferometry	Labadie, Lucas	A&A	531, A48	EDP Sciences	France	2011	7	10.1051/0004-6361/201116727	no
158	Ultrafast laser inscription of near-infrared waveguides in polycrystalline ZnSe,	J. R. Macdonald	Optics Letters	35	Optical Society of America	Washington DC	2010	4036-4038	10.1364/OL.35.004036	no
159	Realization of the compact static Fourier transform spectrometer LLIFTS in glass integrated optics	Bruno Martin	Optics Letters	34	Optical Society of America	Washington DC	2010	2291-2293	10.1364/OL.34.002291	no
160	Interferometric beam combination with discrete optics	S. Minardi	SPIE	7734-136	SPIE	Bellingham, Washington, USA	2010	3009-	10.1364/OL.35.003009	no
161	A three-dimensional photonic beam combiner for astronomical interferometry	S. Minardi	CLEO Europe/EQEC		Optical Society of	Washington DC	2011	1	10.1109/CLEOE.2011.5943672	no

					America					
162	Strategies for spectroscopy on Extremely Large Telescopes - II. Diverse-field spectroscopy	Murray, G.J.	MNRAS	399	Royal Astronomical Society	London, UK	2009	209-218	10.1111/j.1365-2966.2009.15170.x	no
163	Approaching cm/sec Calibration of High Resolution Astronomical Spectrograph	A. Manescau	CLEO/Europe and EQEC 2011 Conference Digest, OSA Technical Digest (CD)	Paper JSIII1_5	Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943674	no
164	Efficient multi-mode to single-mode coupling in a photonic lantern	Danny Noordegraaf	Optics Express	17	Optical Society of America	Washington DC	2009	1988-1994	10.1364/OE.17.001988	no
165	Strategies for spectroscopy on extremely large telescopes - III. Remapping switched fibre systems	Poppett, C.L	MNRAS	399, 443-452	Royal Astronomical Society	London, UK	2009	443-452	10.1111/j.1365-2966.2009.15296.x	no
166	The application of Multicore Photonic Crystal Fibres (M-PCF) in Astronomical Instrumentation	Poppett, C.L	CLEO/Europe and EQEC 2011 Conference Digest, OSA Technical Digest (CD)	Paper JSIII_P8	Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943687	no
167	Ultrafast Laser Inscription of Mid-IR Integrated Optics for Astronomy	A. Rodenas	CLEO/Europe and EQEC Conference Digest, OSA Technical Digest (CD)	Paper JSIII_P2	Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943681	no
168	Ultrafast laser inscription: an enabling technology for astrophotonics	Robert R. Thomson	Optics Express	17	Optical Society of America	Washington DC	2009	1963-1969	10.1364/OE.17.001963	no
169	An integrated fan-out device for astrophotonics	Robert R. Thomson	Frontiers in Optics, Optical	Vol. 2,	Optical Society of	Washington DC	2011	pp. 7-8	10.1364/FIO.2010.PDPA3	no

			Society of America		America					
170	Ultrafast laser inscription of an integrated photonic lantern	Robert R. Thomson	Optics Express	19	Optical Society of America	Washington DC	2011	5698-5705	10.1364/OE.19.005698	no
171	Ultrafast laser inscription of an integrated multimode-to-single-modes waveguide transition for astrophotonics	Robert R. Thomson	CLEO/Europe and EQEC Conference Digest, OSA Technical Digest (CD)	Paper JSIII2_2	Optical Society of America	Washington DC	2011	1	10.1109/CLEOE.2011.5943676	no
172	"Photonic lantern" spectral filters in multi-core fibre	T. Birks	Optics Express	20	Optical Society of America	Washington DC	2012	13996-14008	10.1364/OE.20.013996	no
173	Light interference detection on-chip by integrated SNSPD counters	Cavalier, P.	AIP Advances	http://aipadvances.peerx-press.org/cgi-bin/main.plex Vol. 1, 042120	American Institute of Physics Publishing	Melville, New York, USA	2011		10.1063/1.3656744	
174	Optical design of optical switches for diverse field spectroscopy	Content, R.	SPIE	7739	SPIE	Bellingham, Washington, USA	2010	9	10.1117/12.857939	no
175	Potential applications of ring resonators for astronomical instrumentation	Ellis, S.c.	SPIE	8450	SPIE	Bellingham, Washington, USA	2012	8	10.1117/12.925804	no

176	Modelling the application of integrated photonic spectrographs to astronomy	Harris, R. J.	SPIE	8444	SPIE	Bellingham, Washington, USA	2012		10.1117/12.926205	no
177	Three-dimensional mid-infrared photonic circuits in chalcogenide glass	Rodenas, A.	Optics Letters	37	Optical Society of America	Washington DC	2012	392-394	10.1364/OL.37.000392	no
178	Ultrafast laser inscription of a 121-waveguide fan-out for astrophotonics	Thomson, R. R.	Optics Letters	37	Optical Society of America	Washington DC	2012	2331	10.1364/OL.37.002331	no

TEMPLATE A2: LIST OF DISSEMINATION ACTIVITIES								
NO.	Type of activities[3]	Main leader	Title	Date/Period	Place	Type of audience[4]	Size of audience	Countries addressed
1	Posters	D. Peter/C. Schwab	ARGOS related presentations	22-26 June 2009	AO for ELT Conference, Paris, France	Scientific Community	183	Worldwide
2	Web	WP1	http://www.eso.org/sci/facilities/develop/ao/fp7/index.html website for WP1: Adaptive Optics Systems			Scientific Community		Worldwide
3	Conference		AO for ELT Conference	22-26 June 2009	Paris, France	Scientific Community	183	Worldwide
4	Conference	I. Hook	Astronomy with Megastructures: Joint Science with the E-ELT and SKA	10-14 May 2010	Crete, Greece	Scientific Community	98	Worldwide
5	Conference	I. Hook	Feeding the Giants: ELTs in the era of Surveys	29 August – 2 September 2011	Ischia, Italy	Scientific Community	75	Worldwide
6	Conference	I. Hook	EWASS 2012 Special session: The European Extremely Large Telescope	5 July 2012	Rome, Italy	Scientific Community	70	All Europe
7	Publication	I. Hook	The Science case for the European ELT (in conference proceedings of the ESO workshop “Science wit the VLT in the ELT Era”	2009		Scientific Community		Worldwide
8	Publication	I. Hook	Report on the ESO workshop “E-ELT design reference mission and Science Plan”	2009		Scientific Community		Worldwide
9	Presentation (and	J. Allingto	Defining requirements and identifying relevant technologies in astrophotonics	July 2010	The 2010 SPIE Symposium on Astronomical Telescopes and	Scientific Community	100’s	Worldwide

[3] A drop down list allows choosing the dissemination activity: publications, conferences, workshops, web, press releases, flyers, articles published in the popular press, videos, media briefings, presentations, exhibitions, thesis, interviews, films, TV clips, posters, Other.

[4] A drop down list allows choosing the type of public: Scientific Community (higher education, Research), Industry, Civil Society, Policy makers, Medias, Other ('multiple choices' is possible).

	corresponding conference proceedings paper)	n-Smith			Instrumentation			
10	Poster (and corresponding conference proceedings paper)	A. Calamida	Observing Brown Dwarfs in the Magellanic Cloud Star-Forming Regions with the E-ELT	25 May 2011	RIA Workshop on Gaia "Stellar Clusters & Associations", Granada, Spain	Scientific Community	150	Worldwide
11	Presentation (and corresponding conference proceedings paper)	I. Hook	Transients with Euclid and the European ELT	20 September 2011	IAU symposium 285, Oxford, UK	Scientific community	240	Worldwide
12	Presentation (and corresponding conference proceedings paper)	I. Hook	Supernovae and Cosmology with future European facilities	24 April 2012	Royal Society discussion meeting, London, UK	Scientific community	100	Worldwide
13	Poster	A. Calamida	Observing star forming regions and young massive embedded clusters with the E-ELT	27 August 2012	IAU General Assembly, Beijing, China	Scientific community	80	Worldwide
14	Poster and presentation	A. Calamida	Exploring the unknown: the extremely large telescope of the future	28 August 2012	IAU General Assembly, Beijing, China	Scientific community	80	
15	Presentation	A. Calamida	The Euorpean ELT	23 September 2011	European Researchers night, Rome, Italy	general public	100	Italy and Europe
16	Presentation	A. Calamida	The European ELT	27 January 2012	Trieste, Italy	Scientific community, general public	80	Italy
17	Presentation	A. Calamida	The European ELT	3 May 2012	Bologna, Italy	Scientific community	40	Italy

18	Presentation	A. Calamida	The European ELT	18 June 2012	CNAI workshop, Rome, Italy	Scientific Community, general public	30 + wider audience connected remotely	Italy
19	Presentation	R. Gilmozzi	Telescopi del futuro: alla ricerca di altre terre attorno ad altri soli	30 August 2011	Ischia, Italy	General public	50	Italy and Europe
20	Presentation	A. Calamida	Ageing the Universe with E-ELT	5 July 2012	Rome, Italy	Scientific community	70	Europe
21	Presentation	A. Calamida	The European ELT	31 July 2012	Abruzzo, Italy	General public	30	Italy
22	Presentation	A. Calamida	The European ELT	28 September 2012	Padova, Italy	Scientific community, general public	80	Italy
23	Presentation	I. Hook	The European ELT	September 2010	European Researchers night, Frascati, Italy	General public	50 + wider audience connected remotely	Italy and Europe
24	Presentation	A. Calamida	The European ELT	May 2011	Osservatorio Astronomico di Capodimonte, Italy	Scientific community	50	Italy
25	Presentation	I. Hook	The European ELT	4 May 2011	SAIT meeting (Italian National astronomy meeting) Palermo, Italy	Scientific community	60	Italy
26	Presentation and corresponding conference proceedings	I. Hook	The European ELT Workshop: “High Tine Resolution Astrophysics IV - The Era of Extremely Large Telescopes",	May 2010	Crete, Greece	Scientific community	50	Worldwide
27	Poster	P. Grosbol	Toward a reference implementation of a standardized Astronomical Software Environment	October 2009	Astronomical Data Analysis Software and Systems XIX	Scientific community	50+	Worldwide

					Conference, Sapporo, Japan			
28	Conference proceedings	P. Grosbol	Making Access to Astronomical Software More Efficient	11 August 2009	IAU SpS5 meeting, Rio de Janeiro, Brazil	Scientific community	100's	Worldwide
29	Publication	P. Grosbol	White Paper on the Architecture of Future Astronomical Software Environments	5 February 2009	US National Virtual Observatory	Scientific community	100's	Worldwide
30	Publication	P. Grosbol	High-Level Requirements for a Future Astronomical Software System	29 February 2009	US National Virtual Observatory	Scientific community	100's	Worldwide
31	Web	P. Grosbol	Network 9.2: Future Astronomical Software Environments (FASE) web		https://www.eso.org/wiki/bin/view/Opticon	Scientific community		Worldwide
32	Publication	NRAO	Applications Framework Architecture and System Elements	12 July 2009	International Virtual Observatory Alliance	Scientific community	100's	Worldwide
33	Web	Davies, J.	OPTICON FP7 website	2009	http://www.astro-opticon.org/	Scientific community/Policy makers/Media/Public		Worldwide
34	Web	Allington-Smith, J.	Astrophotonica Europa private web		http://star-www.dur.ac.uk/~jra/Astrophotonica	Scientific community	100	Worldwide
35	Web	Allington-Smith, J.	Astrophotonica Europa public web		http://star-www.dur.ac.uk/~jra/Astrophotonica-public/APE-public.html	Media/Public/Industry		Worldwide
36	Conference	Allington-Smith, J., Haynes, R	Summer School on Astrophotonics	24-28 September 2012	Brandenburg, Germany	Scientific community/Young Researchers	47	Worldwide
37	Conference proceedings	WP12.3	Proceedings of the November 2011 WP12. 3 EAST Workshop published as the Astronomical Society of the Pacific Conference Series, 2012, Volume 463	May 2011	Freiburg, DE	Scientific community	100's	Worldwide
38	Conference proceedings	WP12.3	1st EAST – ATST Workshop in Solar Physics "Science with Large Solar Telescopes" published as Proceedings: Astronomical Notes, 2010, Volume 331, Number 6	14-16 October 2009	Freiburg, DE	Scientific community	100's	Worldwide
39	Conference proceedings	WP12.3	2nd ATST - EAST Workshop in Solar Physics Proceedings: Astronomical Society of the Pacific Conference Series, 2012, Volume 463, "The Second ATST-EAST Meeting: Magnetic Fields from the Photosphere to the Corona"	9 – 11 November 2011	Washington DC, USA.	Scientific community	100's	Worldwide

40	Conference	WP11	WP11 Awareness Conference @ JENAM, Lisbon	6-9 September 2011	Lisbon, Portugal	Scientific community	50	Worldwide
41	Web	WP11.2	European Interferometry website, https://sites.google.com/a/european-interferometry.eu/home/			Scientific community/Policy makers/Media/Public	100's	Worldwide
42	Workshop	WP11	WP11 Instrumental Workshop,	20-23 June 2011	Potsdam	Scientific community	40	Worldwide
43	Workshop	WP10.2	Workshop "Principles of Multi-wavelength High Time Resolution Astrophysics"	10th-15th October, 2011	Sardinia, Italy	Scientific community	70	Worldwide
44	Conference proceedings	WP10.2	Proceedings of workshop "Principles of Multi-wavelength High Time Resolution Astrophysics": http://www.htra.ie/htra11/index.php	10th-15th October, 2011	Sardinia, Italy	Scientific community	100's	Worldwide

TEMPLATE B1: LIST OF APPLICATIONS FOR PATENTS, TRADEMARKS, REGISTERED DESIGNS, ETC.					
Type of IP Rights[5]:	Confidential Click on YES/NO	Foreseen embargo date dd/mm/yyyy	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)
Patent	yes		EP2081264	Narrow band fiber Raman optical amplifier	D. Bonaccini Calia, W. Hackenberg, Y. Feng, L. Taylor, R. Holzloehner
Patent	yes		DE102011011290	Laser system to generate a laser guide star	W. Kaenders, A. Friedenauer;

[5] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

5 FINAL REPORT ON THE DISTRIBUTION OF THE EUROPEAN UNION FINANCIAL CONTRIBUTION

This report shall be submitted to the Commission within 30 days after receipt of the final payment of the European Union financial contribution.

Report on the distribution of the European Union financial contribution between beneficiaries

Name of beneficiary	Final amount of EU contribution per beneficiary in Euros
1.	
2.	
n	
Total	