European Cooperation in the field of Scientific and Technical Research - COST -

Brussels, 15 May 2014

COST 050/14

MEMORANDUM OF UNDERSTANDING

Subject : Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action MP1401: Advanced fibre laser and coherent source as tools for society, manufacturing and lifescience

Delegations will find attached the Memorandum of Understanding for COST Action MP1401 as approved by the COST Committee of Senior Officials (CSO) at its 190th meeting on 14 May 2014.

MEMORANDUM OF UNDERSTANDING
For the implementation of a European Concerted Research Action designated as

COST Action MP1401
ADVANCED FIBRE LASER AND COHERENT SOURCE AS TOOLS FOR SOCIETY, MANUFACTURING AND LIFESCIENCE

The Parties to this Memorandum of Understanding, declaring their common intention to participate in the concerted Action referred to above and described in the technical Annex to the Memorandum, have reached the following understanding:

1. The Action will be carried out in accordance with the provisions of document COST 4114/13 "COST Action Management" and document COST 4112/13 "Rules for Participation in and Implementation of COST Activities" , or in any new document amending or replacing them, the contents of which the Parties are fully aware of.

2. The main objective of the Action is to provide an arena for fibre lasers where experts in material science, laser and component groups, laser manufacturers and end-users actively interact and focus on common goals to boost a series of innovations and breakthroughs.

3. The economic dimension of the activities carried out under the Action has been estimated, on the basis of information available during the planning of the Action, at EUR 80 million in 2014 prices.

4. The Memorandum of Understanding will take effect on being accepted by at least five Parties.

5. The Memorandum of Understanding will remain in force for a period of 4 years, calculated from the date of the first meeting of the Management Committee, unless the duration of the Action is modified according to the provisions of section *2. Changes to a COST Action* in the document COST 4114/13.

A. ABSTRACT AND KEYWORDS

Among the different types of lasers, fibre lasers are, both in research and commercially, the youngest, yet the fastest growing, type of laser due to several factors. This COST Action will be the first arena where experts in fundamental material science, established laser and component groups, fibre laser manufacturers and End-Users will be able to interact actively, share ‘know-how’ and focus on common goals. The Action aims to boost a series of innovations in the field. Among them to cover the 3–6 microns’ wavelength interval, and beyond, to support mid-infrared applications and to enhance fibre performance in order to cover more efficiently visible and ultra-violet wavelengths for biophotonics and healthcare. The Action will also investigate glass materials and fibre design to overcome the actual limitation in output power. The improvements will mainly boost healthcare, to the benefit of society, and EU (European Union) manufacturing to retain and increase the manufacturing workforce within the EU. The Action will mentor a new generation of researchers by providing Early Stage Researchers with an opportunity to develop both scientific and management skills. At the same time the Action will actively promote gender balance, and Women Researchers to management positions.
Keywords: Fibre lasers, new glasses and new laser materials, advanced manufacturing, healthcare (and *in vivo*) diagnostics, environmental monitoring

B. BACKGROUND

B.1 General background

LASER (light amplification by the stimulated emission of radiation) and coherent light sources play a crucial role in everyday life, supporting new and cost effective manufacturing processes, new life science and medical innovation, faster-recovery surgical procedures, pollution-sensing and chemical-detection, as well as communication. Among the various types of lasers, fibre lasers are, both research-wise and commercially, the youngest, yet the fastest growing laser device due to several factors including reliability, efficiency, lower power consumption and overall cost, high power, excellent beam quality and flexibility (fibre optical nonlinearity is readily exploitable). A December 2013 report predicts double digit growth in 2014, three times the average Laser Market. Thus fibre lasers are now the preferred solution for applications such as new fast manufacturing processes (e.g. for the factory of the future (FoF)), robot-based processing, processing of new materials/organic electronic, solar cell mass production, healthcare, light sources in biophotonics, environmental control and security applications.

Fibre light sources rely on three main elements to generate light: suitable optically-active ions (e.g. erbium or ytterbium) emitting (or amplifying) at a specific wavelength, a proper waveguiding structure and nonlinear optical effects to shape the light output, for supercontinuum generation, frequency conversion, or to generate (ultra-)short pulses. This leads to several constraints. The main one is a limited output wavelength interval: to date direct efficient lasing operation is mainly limited to a few specific wavelengths from about 1 micron to 3 microns and based on only a few rare-earth ions (Nd, Yb, Er, Tm, Ho) of those available.

Within this main family of lasers the initial research focused on the development of the Er-based amplifiers (and lasers) to pave the way for high-bit rate optical communication and eye-safe applications, while the first decade of the present century saw a tremendous development of Yb-lasers with continuous power scaling up to 100 kW. The latter has had a fundamental impact on several EU manufacturing processes and has supported EU leadership in advanced manufacturing: from large-scale automotive manufacturing to micromachining, for instance Lab-on-a-Chip.

Recently, lasers emitting at 2 microns (based on Tm and Ho) have been of great interest, and the subject of several research programmes due to the possibility of interacting with softer matter (polymers) and performing specific applications: the 2 microns wavelength is safe for the human eye (eye-safe zone); molecules such as carbon dioxide and water vapour absorb and can then be detected; there is the possibility of cutting without bleeding of biological tissues *via* the resonant absorption of water. Treatment of prostatic hyperplasia, neuro-endoscopy and ophthalmology are examples of other relevant applications of lasers operating at wavelengths of 2 micron and above to medicine. However the available power level (pulsed peak power or continuous wave) is still limiting several applications. In fact, even for the well-developed Yb-lasers and the younger 2-microns' laser class, power scaling is a major issue from the point of view of both the fundamental physics (not-fully understood with regard to the mode-instability phenomenon and other nonlinear effects) and practical engineering and manufacturing constraints. This is presently a limitation on extending applications to printing, solar-cell processing, micromachining and high-volume manufacturing.

Moreover, extension of efficient fibre laser tools into the Ultra Violet (UV), Visible (VIS) and Mid-infrared (MIR) range (above 3 microns) spectral regions are still virtually unavailable. As a consequence, an entire class of materials cannot be properly processed and many applications cannot be fully addressed, with a detrimental impact on the EU economic EU competitiveness and EU citizens' quality of life.

The significance of the UV/VIS and MIR wavelength ranges relies on the unique properties of the light-matter interactions at those wavelengths. For example imaging, and analyses of biological tissues often requires excitation in the UV/VIS. An efficient new class of UV/VIS lasers would pave the way for diagnostic tools (imaging, two-photon microscopy), processing of solar cell materials, printing, and medical applications such as ophthalmology. In addition, healthcare applications would greatly benefit from the reliability, lower cost, ease of operation and compactness of fibre sources. The most challenging and fascinating wavelength interval is, however, the Mid-IR (MIR). The quest for MIR technology is one of the EU scientific and EU industrial communities' main challenges, see for example COST Action MP1204 (TERA-MIR Radiation: Materials, Generation, Detection and Applications). Furthermore, at even longer wavelengths (> 6 micron), the so called mid-infrared 'fingerprint' region is available. In this wavelength interval each specimen exhibits a unique absorption pattern: isomer identification and potentially 3-D structure evolutions of specimens offer a unique potentiality in life science. For example *in-vivo* diagnosis of cervical cancer would benefit from continuum sources at around 10 μm. Other applications of MIR laser sources in medicine are strongly required due to their unique capabilities: microsurgery (high tissue absorption in tissues), non-touch tissue removal, selective tissue ablation (organic micro-electronics dermatology and refractive surgery), sub-micron accuracy (comparable accuracy to UV sources but without genetic collateral damages), refractive and cornea reshaping and non-contact membranes cutting in the eye (capsulotomy and photodisruption). With the possibility of identifying specific specimens (isomers), the MIR applications are endless, and attempts so far range from the monitoring of geological sites for carbon dioxide during waste storage, to process control (e.g. optimisation of combustion processes in the oil industry) and to stand-off detection of explosives. In most cases a rough reliable and compact source would be of great benefit for moving into real-world applications. Finally, coherent sources able to interact with soft matter will support key industrial sectors such as the organic-micro-electronics industry and organic solar cell industries. The above brief summary also suggests that, since lasers are versatile tools, there are many applications not yet envisaged because of the lack of dissemination towards other scientific communities (e.g. medicine, chemistry).

B.2 Current state of knowledge

Despite the importance given to extending the wavelength interval of fibre lasers, only a few solutions, not always applicable outside Research and Development (R&D) laboratories, address the challenges set out in section B.1, above. An overview of existing alternatives and, afterwards, a review of the field of fibre lasers are provided in the following section. In the UV/VIS interval, solid-state lasers (bulk, but also fibre), can use up-conversion schemes, external frequency doubling/tripling components or continuum generation techniques to address visible and UV/VIS wavelengths. In all cases performance is often limited in terms of achievable wavelength (e.g. frequency doubling schemes rely on original wavelength, Yb-silica lasers having an emission upper edge at around 1100 nm) or power (continuum sources are limited by the silica glass dispersion). Semiconductor lasers also cover the 400 nm to 700 nm wavelength interval, but have a limited performance, in particular for pump and probe experiments with short (ps) pulses. In the MIR interval, solid state lasers were able to demonstrate emission up to 3.9 micron, but at sub-mW power level and cryogenic temperature, while emission at about 4.3 micron was achieved in a dysprosium (Dy) doped crystal. Another type of laser, Cr:ZnSe (chromium-doped zinc selenide) and some other lasers with similar materials, can emit up to 3.5 microns. Bulk iron-doped lasers (Fe:ZnSe lasers) can emit further and cover a window from 3.7 microns to about 5 microns, although with a significantly limited power and overall performance. Other classes of lasers and coherent sources are also available: from quantum cascade lasers (QCL) and coherent sources based on difference frequency generation (DFG), to optical parametric oscillators (OPOs) and optical parametric amplifiers (OPAs). Quantum cascade lasers are the most promising: they can cover the entire target range. However, their power is limited to Watt level and the long term operational reliability at room temperature is still a key issue. OPOs, OPAs, DFGs can cover the entire target range, they are flexible and often offer high performance but they are limited mainly to R&D labs and are not a viable solution to real world applications due to cost and complexity. Medical applications, in particular, need reliable, compact and low cost (for extensive healthcare) devices, that are easy to use and maintain. This makes fibre lasers the natural choice.

The lack of suitable laser solutions at this time makes this Action and the challenges even more relevant for the wider EU scientific community and for EU end users. The Action strategy to address new wavelength intervals includes a wide range of approaches from developing new glass hosts, to exploring new laser transitions and new emitters, to implementing new components and new laser schemes. A brief summary of some of the most important state-of-the art results and open issues is now given:

UV/VISIBLE

Direct emission in the UV/VIS: This challenge requires glass with low phonon energy to allow efficient population inversion, high-quality, low losses, high solubility. Praseodyium (Pr), erbium (Er), thulium (Tm), neodymium (Nd), holmium (Ho), and cerium (Ce) are possible candidates, and have already shown potential in both fibre or waveguide laser device configurations. A few examples of lasing at UV/VIS wavelength by up-conversion lasers are Er (402 nm, 470 nm), Tm

(248 nm, 455 nm, 784 nm and 488 nm), Pr co-doped with Yb, (491 nm 520 nm, 605 nm 615 nm 635 nm), Ho (550 nm), Nd (412 nm, 590 nm). In all cases continuous wave operation in the sub-mW or mW level regime has been achieved, except for Pr/Yb lasers, where hundreds of mW has been reported; in all examples a soft low-phonon energy fluoride glass system was employed as the host for the rare earth ion emitters. However, for further progress, more stable and easy to integrate (splicing issues) fibre materials shall be investigated, in view of power scaling, filling the wavelength gaps, and moving to pulsed regimes.

Supercontinuum generation and spectrum slicing for spectroscopy and short pulse generation. At present, supercontinuum sources deliver only few tens to hundreds of microW/nm in the UV. This is due to the too high dispersion of silica glass fibre in this wavelength interval that limits the exploitation of optical nonlinear effects. Very recently, new techniques for extending supercontinuum sources into the UV region have become available, yet with limited performance. To overcome current limitations, in both power level and lasing wavelengths achievable, the community needs major improvements and breakthroughs. A worldwide concerted effort is now required which should be concentrated on the major research lines to address the challenges such as: developing new and improved soft glass to further reduce multiphonon decay; characterising active materials; designing new photonic crystal structures and new lasers schemes; using of new nonlinear schemes for frequency conversion. In all cases, however, the groups' work focussed on a specific part of the project, losing the overall picture. For example, optimization and integration of additional photonic components, or the use of alternative laser pumping schemes, may actually depend on results made available by components or semiconductor groups.

MIR LASERS

MIR fibre lasers have long been a dream of the photonic community and of end users in the scientific, medical and industrial sectors. Despite several papers showing detailed glass investigations and promising theoretical results, the quest is still ongoing. Nevertheless, interesting recent results show the timeliness of this Action. The demonstration of record low optical loss glass and continuum generation by using a highly-nonlinear germanium-core fibre, or gas-filled hollow core fibres are among of the most recent promising results.

The main challenges the material science and laser community are facing now, detailed in section D.1, are the following: **Glass host**: low-loss at MIR wavelength, high-solubility, high-quality manufacturing; highly-nonlinear high-quality glasses for continuum generation; **Active ions**: while active ions suitable for emission in the MIR such as Pr, Tm, Dy, Tb have been studied, there is a lack of spectroscopic investigation aimed at finding the quantities needed to simulate a laser system (rate-equations); this may be one of the reasons why promising theory never found experimental validation; **Pumping schemes**: pumping schemes need to fit into glass transparency windows and be effective for laser transitions; **Components**: several components are missing in the new wavelength ranges.

In the case of the more established lasers, the main challenge is related to power scaling. For one micron lasers pulsed operation still suffers from some significant limitations, arising from either the mode-instability phenomenon (when approaching 1-kW) or by the interplay of nonlinear phenomena to set a mJ limit for ns/ps pulses. It has to be noted here that limitation in 1 micron pulse peak power is the main limit for high-power UV/Visible sources based on frequency doubling. At two microns, continuous wave emission is still limited to the demonstration of 1 kW level and pulse peak power is still far away for the level needed for specific direct material processing (e.g. some type of organic material.) Today's research challenges are concentrated on solving/mitigating mode instability for Yb-doped pulsed oscillators and on developing new fibre designs and new glasses for scaling up the pulse energy and average power of 2 microns' single oscillators. High power 2 microns' oscillators may also play a key role as a front end for compact MIR frequency generation (for instance pumping GaAs based periodically-poled crystal).

B.3 Reasons for the Action

The extension to, and improvement of, performance in the two new wavelength ranges, the UV/VIS and the MIR, and the removal of the power scaling limitation of established sources, are recognized as major challenges that European scientists and industries will face in the next ten years.

Developing new directions in the fibre laser field demands a tenacious and multidisciplinary scientific and technological approach and a constant interaction between all of the Players, from condensed matter experts, to groups developing lasers and laser components, through to the final end users. In fact, the quest for new cost-effective manufacturing processes, a greener world and a better healthcare is overstraining the limit of existing solutions provided by lasers of any type. The added value of the Action will aim at providing both an arena where participants share know-how and make it accessible to all Players and a network where to pursue common paths into the development of not only new scientific tools but also new lasers able to impact EU society by connecting basic R&D to final end users.

Therefore a real breakthrough, able to impact the EU at large, needs the coordination of a common strategy and know-how. The Action will greatly contribute to fundamental understanding of optical and materials' related processes, laser design and to the technical knowledge, understanding and awareness of fibre laser systems, along the whole value chain. The interplay of aims (e.g. a better 2 micron laser could provide pumping for MIR sources) and overlapping of know-how (soft glasses for UV and MIR) suggests that the whole community should work together and share results, instead of focussing on only a limited wavelength interval. The proposed Action, already supported by many research groups and industries, both SMEs (small-to-medium-sized enterprises) and large enterprises, will indeed bring together a critical network of key experts and stakeholders, and will help to synergize, breed and bridge current activities. The four year framework and the added value of networking will provide the necessary framework to effectively face the challenges discussed in section B.2.

The development of novel and efficient laser sources as a result of integrated research activities will be the main enabler to build the next generation of tools to support EU everyday activity in manufacturing, healthcare and environmental control. The anticipated high quality research outcomes will significantly contribute to EU scientific excellence impacting the worldwide academic laser research community, relevant industrial sectors, standardisation bodies and EU citizens' everyday quality of life.

The Action will clearly provide a strong scientific and technological improvement in the field of fibre lasers but will also go beyond: since lasers are problem solving tools (when invented the laser was defined as "*a solution looking for a problem*"). The Action expects to have a further relevant economic and social follow-up impact not yet envisaged. The need for new tools to manufacture cheaper solar cells, new and cheaper plastic and polymeric objects, faster high-density circuits, to provide better environmental control and chemical detections, and to improve people's healthcare will definitively face todays main EU economic and social needs. EU citizen's healthcare will greatly benefit from the Action achievements. For example innovative microscopes (UV/visible/MIR) and endoscopes (e.g. MIR) will help to understand cell processes, tissues and model organisms, and thus support the development of drugs tailored to a given patient for personalized medicine. Moreover, higher added value manufacturing will play a key role in helping to retain workforce within the EU.

The Action fills a gap in the training and preparation of a new generation of leading scientists by providing an invaluable multidisciplinary background to Early Stage Researchers (ESR) as well as opportunities for management experience. In addition, the Action will promote women researchers, in particular addressing the present gender unbalance in the technical and engineering areas.

B.4 Complementarity with other research programmes

The EU have already recognised the relevance and the timeliness of developing new laser sources to address challenges to the EU economy, retain workforce in EU and impact the everyday life of EU citizens, from greener environment to better healthcare. In Horizon2020, Photonics (including lasers) is a Key Enabling Technology (KET) while Advanced Manufacturing and Healthcare/Biophotonics will be among the main topics to be funded. The laser community have already shared a large amount of funding on projects relevant to this Action. At the EU level the most relevant are: APPOLO (advanced manufacturing using lasers), IP MINERVA (aim the first MIR 4.5 micron rare-earth doped laser; continuum sources for cancer detection and medical investigation); ISLA (2 microns' laser components); IMPROV (tuneable fibre pumped MIR pulsed source from 2.5 microns to 11 microns,); IP FAMOS (molecular optical Screening UV, visible); BRIDLE (semiconductor lasers); MODE-GAP (2 microns' high-speed communications, need for fibre amplifiers,). In more general projects, like ACTPHAST (Manufacturing) and OASIS (Life Science), laser-based tools will play a key role. In addition there is a legacy of, among others, recently ended LIFT and nEUROpt projects, and several ongoing national projects.

The Action aims not only to be complementary, but also supportive, of the above and several other existing and future European and national/regional projects. The Action will establish direct links with existing projects (links have been already built during Action preparation), bring all these research groups together and support, extend and complement their activities in basic research, technology development, and applications in a number of different ways. This will avoid duplication of work, support a more efficient use of resources and EU funding, provide multidisciplinary background and support the partner individual projects by integrating experts in an efficient and cooperative network. The Action will also develop standardised characterisation methods and application procedures that will support fibre laser commercialization and applications, and will interact with Photonic Clusters and regional policy within the existing Strategies for Smart Specialisations (RIS3) platform, providing expertise and an EU-level overview of the field.

Support will be given to COST Actions that may use innovative laser sources for their purposes such as MP1306 (Modern Tools for Spectroscopy on Advanced Materials: a European Modelling Platform), ES1309 (Innovative optical Tools for proximal sensing of ecophysiological processes), BM1204 (An integrated European platform for pancreas cancer research: from basic science to clinical and public health interventions for a rare disease), BM1205 (European Network for Skin Cancer Detection using Laser Imaging), FA1102 (Optimizing and standardizing non-destructive imaging and spectroscopic methods to improve the determination of body composition and meat quality in farm animals), MP1205 (Advances in Optofluidics: Integration of Optical Control and Photonics with Microfluidics), IC1101 (Optical Wireless Communications - An Emerging

Technology), MP1204 (TERA-MIR Radiation: Materials, Generation, Detection and Applications), TD1001 (Novel and Reliable Optical Fibre Sensor Systems for Future Security and Safety Applications). A strong link with all above Actions will be established. The Action will also contact other relevant projects, STREP, IP, CSA, ERC, EFS, both presently running and those emerging out of the next calls within Information and communications technology (ICT), factory of the future (FoF) and COST Open Call. The Action will also contact projects and Actions with overlapping know-how. Further on, the Action will be supportive and complementary, by offering new tools for investigation/processing to all "organic"-device based projects.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the Action is to provide the first arena for fibre lasers where experts in fundamental material science, established laser and component groups, fibre laser manufacturers and end-users will be able to actively interact, share know-how and focus on common goals. The Action aims at boosting a series of innovations and breakthroughs in the field of fibre lasers, thus opening new wavelength ranges and overcoming existing limitations. The Action, through a multidisciplinary approach, wishes to address several key topics better defined in section C.2 to extend the wavelength range of fibre and waveguide lasers, supporting the development of sources in the UV, in the 3-14 micron wavelength interval range, and investigate power scaling. The Action will broaden the EU know-how in a fundamental area that will support strong economic (e.g. manufacturing) and social (environmental and healthcare) advancement. The Action will also prepare a new generation of young researchers able to take forward its legacy and strengthen the position of EU in the field of lasers and their applications. Finally, the Action will actively promote gender balance issues to foster a new and more balanced community, with a workload compatible with personal and family life.

C.2 Objectives

The principal objective of the Action is to build on the different and complementary skills of partners to address its task to extend the family of fibre lasers to new wavelengths and hence to new applications. The Action objectives are divided into networking, scientific/technical and techno-economic objectives as follows:

Networking Objectives

- Establish a network of international relations at the EU and global levels within the field of fibre lasers and their applications by promoting an interdisciplinary approach.
- Establish strong personal long-term links to facilitate interchange of researchers and sharing of ‘know-how’ and facilities. Promote consortia to apply for Horizon2020 calls.
- Provide a framework to develop ESR careers and train the next generation of senior scientists in the field.
- Provide a common area where women researchers can develop their career path and are inspired by role models.
- Facilitate the contact between laser researchers, laser industry (with focus on SMEs) and end users.
- Disseminate results within the scientific and industrial community and raise the awareness of the general public.
- Extend knowledge towards developing countries and strengthen the EU leadership at the world level.

Scientific/Technical Objectives

- Exploit new glass materials to optimise laser performance; Characterise rare-earth ions in different host glasses; Model active materials.
- Investigate laser sources at above 3 microns using innovative laser materials.
- Extend to the 3-14 microns wavelength range continuum coherent generation in fibres based on new glass hosts and a new class of rare earth emitters.
- Develop new fibres and components for UV, MIR and high power laser and fibre light sources; Improve laser and continuum generation power levels.
- Develop UV/VIS/infrared sources for biomedicine and healthcare and micromachining.
- Enhance the flexibility of fibre lasers through new approaches to wavelength tuning, frequency generation and mode locking.
- Enable power scaling of existing laser sources at 1 micron and support further development of sources at 2-2.3 microns wavelength.
- Investigate tailored components for efficient 3-14 microns frequency conversion stages.

- Investigate soft-matter and organic matter interactions for plastics and biological tissue.
- Propose standards within appropriate committees for laser components and laser sources.

Techno-Economic Objectives

- Create a common awareness of potential impact of laser based tools for EU industries and SMEs.
- Connect academic laser researchers, laser industries and component manufacturers to speed up the development and market impact of new laser sources.
- Evaluate the impact of laser-based applications and disseminate the results to the relevant stakeholders.
- Ensure the Action supports EU industrial leadership in the field of lasers and their applications by providing high quality research and technology transfer.
- Study economic issues and trends, outlining drivers and localizing market fallouts.

From a quantitative point of view the Action defines a measure for the evaluation of the above objectives by using a few parameters. The Action will be considered successful with the achievement of the goals listed below. (If a specific time is not indicated, objectives relate to the full duration of the Action).

- Number of translational collaborative research proposals prepared by Action members: 2 IPs, 3 STREPS, 7 Regional projects. Number of standard proposal: 1 (e.g. CEN/TC 123, ITS, IEC…)
- Number of joint publications between Action Partners: 5/year journals. 15/year conferences. To balance dissemination/impact (journal) and networking (conferences)
- Number of dissemination items: 10 white papers, 1 Book
- Number of Short Term Missions supported by the Action: 10/year
- Number of Actively involved partners (target by year 1): 200+ (individuals), 100+ Institutions, 30+ companies; Number of non-COST countries: 20
- Number of Training Schools organized by the Action: 2 (first organized by month 18)
- Number of working group (WG) related workshops: 1/year; number of large conferences: 1/year

- Number of women researchers (target by year 1): 80+ as WG participants, 25+ involved in MC and WG/SG coordination
- Number of ESRs (target by year 1): **80**+ as WG participants, **16**+ involved in MC and WG/SG coordination

A general time framework is provided in section F.
With respect to the scientific output, the Action aims at targeting innovative breakthroughs that will reach or pave the way to significant advancement. Quantitative goals are: solving the mode-instability problem; reaching +2 kW level at 2 micron; UV continuous sources with mW/nm power density level; investigating the route to 10 mJ level from amplified lasers systems (MOPA) at tens of kHz rep rate; demonstrating the first fibre laser operating at above 4 micron; providing standards for laser and fibre parameters measurements; development of theoretical models to accurately simulate MIR sources. Innovative breakthroughs will be monitored by the number of peer-reviewed Action published papers. More details will be discussed in section D.

C.3 How networking within the Action will yield the objectives?

The above objectives, so far unsuccessfully addressed by a single partner or small/large consortia, can definitively be achieved only within a large and open consortium such as this Action, able to enhance co-operation and provide ideas for disruptive solutions in the field of fibre and waveguide sources. This Action will be the first, and will provide a unique multidisciplinary, future-oriented, arena where experts of fundamental material science, established fibre laser and optical component groups, manufacturers and fibre laser end-users will be able to actively interact, share know-how and focus on common goals. This Action's large network will provide three key advantages: 1) the participants will deal with a problem by sharing different expertise, needs and points of views (e.g. material scientists, laser researchers and engineers) to pave the way for a breakthrough promoting real-world devices and applications; 2) Shared know-how among groups so far focussed on a specific topic, while investigating the same object (e.g. Tm is studied for UV, IR and MIR, soft glasses are used for UV and MIR); 3) Direct relationship with end user or supplier (e.g. a new pump scheme is envisaged and the diode pumping feasibility can be discussed with partners with semiconductor expertise)
The Action has already defined a large network committed to further involve colleagues in their own field. Each Institution agrees in favouring, in a pro-active way, ESRs and women researchers to be involved in the Action, and to support their active participations in Action management,

meetings, conferences and STSMs (Short-Term Scientific Missions).
The Action objectives will be achieved by exploiting the several networking opportunities offered by the COST scheme (quantified in section C2.2 and further detailed in section E): (i) STMSs to facilitate knowledge transfer and common project development, support ESR careers and training, promote, support and provide counselling for female researchers in their careers. Provide management experience opportunities for ESRs and women researchers; (ii) Organization of Training Schools with the aim of supporting ESRs career development and provide them with a multidisciplinary panel of experts; (iii) Promotion of special outreach activities for women to support gender balance and get ESRs fully involved; (iv) Action bi-annual WG meetings, organization of Core Group Meetings on specific topics to facilitate the development in the specific area, organization of an Annual General Conference to promote knowledge sharing and a multidisciplinary focus, disseminate Action activities at major conferences and workshops and engage with and participate in international conferences and workshops. (v) Organization of round-robin activities and focussed project as study-groups; invite experts from other fields and project to be sure the Action is aware of the state-of the art of competing technologies, engage with non-COST institutions using, where available, COST bilateral schemes; (vi) Publish comprehensive reference manuals, peer-reviewed papers and a final book to summarise the work done; (vii) Engage with, and participate in, regional photonic networks, develop specific links with non-EU groups and organizations, develop new standards for new sources and components, using the possibility of having a COST liaison member participating in standards committees. The large network established by the Action will provide the required manpower and multidisciplinary know-how. Action members will be able to access to the equipment they may need to pursue the Action goals. The Action has already discussed collaborations with non-COST institutions on fundamental material science and the numerical modelling of nonlinear processes. The benefit of support from EU leading material groups will strongly encompass the sharing of Action results outside COST area, since the main impact for the EU will be the availability of new laser devices.
The Action network already comprises over 65 affiliated partners, with over 10 industries, 7 laser application centres and 8 clusters and governmental bodies. A strong effort has been made to include from the beginning women scientists (above 35%) and ESRs (over 15 of them).

C.4 Potential impact of the Action

***Benefit of EU at large (scientific and economic, quality of life)*:** The Action will provide a significant scientific and technological advance in the field of fibre lasers, related components and their applications with a strong impact on industry and society. The Action expects new UV/VIS/IR/MIR lasers to benefit a host of applications which can only be partially envisaged at this stage. The availability of new laser-based tools for manufacturing cost-effective solar cells, new and cost-effective plastic and polymeric objects, to provide green energy, better environmental control and chemical detection and improve personal healthcare will definitively impact on the main present economic and social needs of the EU. The Action's achievements will impact the EU in several fields, including overall quality of life, healthcare (sub-micron surgery, preventative medicine and the early detection of diseases, non-invasive or minimally invasive treatments will help to improve the health and mobility of patients and could lead to substantial cost savings with reduced hospitalization time), biophotonics (Lab-on-a-Chip), manufacturing (faster/robot-based processes, prototyping, new components, reduced cost, organic materials), environmental control (pollution sensing), green energy production (solar cells, combustion process improvement, enhanced battery production), security. Industrial partners will benefit from a range of new tools impacting areas of global interest, such as the bio- and life-sciences, the environment, energy production, security, and high-value manufacturing. Too stress the potential impact on applications the Action aims to support we cite, as an example, two market-enabling actions: (i) photonic tools for solar excellence: demonstrate cost efficient laser based production of solar cells and modules with increased efficiency; (ii) cancer tissue diagnostics for the 21st century: To demonstrate earlier detection of cancer to allow faster and more effective cancer treatment. The first requires new high-power VIS/UV laser sources, the second new MIR diagnostic laser-based tools.

Benefits for networking partners: Partners will be able to liaise with a large number of groups. This will provide support to their research and will help to focus on results, thanks to the interaction with potential end users. It will enhance possibilities of successfully participating in joint project proposals. Industrial partners will gain an overview of possible customers/applications. The Action will also actively engage with professional associations like the European Photonic Society, the European Optical Society, Photonic21, the European Ceramic Society and all other relevant societies, including non-EU ones. Partners will benefit from this collaboration by accessing a large amount of information.

***Benefits for gender balance issue*:** The Action will strongly support balancing gender in all Action management positions. This will foster a long term improvement of gender balance issues in EU scientific and technological fields. The Action will not only support the career perspective, but also the "quality" of the career, making sure that Action activities are compatible with personal life.

***Benefits for ESRs*:** The Action will strongly support ESRs to take responsibility in Action management, workshop and conference organization and will give them priority in STSMs. A key focus will be given to training to provide ESRs with a background and experiences to support their next career step.

C.5 Target groups/end users

1. **Research Institutions**: the Academic Sector (members and EU at large) will enhance its research potential and will be provided with new possibilities for research activities, scientific cooperation and exploiting its research to a commercial level.
2. **Companies**: Industries (SMEs and large ones) active in topics related to the Action (e.g. laser and laser-component manufacturers) will benefit from having an updated overview of the fibre-laser field and direct access to the latest laser technologies. Industrial partners will be able to link with Action research laboratories.
3. **End-User Industries or entities** will benefit from availability of new lasers sources and will be able to improve their processes (e.g. manufacturing companies, hospitals, environmental bodies)
4. **ESRs** of both genders will be adequately involved in the Action deployment. The Action will also benefit the professional development of ESR career by providing several opportunities for networking, training and growing management skills: Workshops, Conferences, STSMs, Training Schools to enrich the ESR experience. Not least the industrial partners will have first opportunity to employ young researchers involved in the Action (trained within the Action) with crucial interdisciplinary expertise in the relevant fields.
5. **Women Researchers** will be offered management positions and a pro-active career support. The possibility of having several role-models among Action senior partners will encourage young women researchers
6. **The general public** will have indirect benefit through improvement of aspects of their lives thanks to new laser tools. In particular better healthcare and the retention of workforce within the EU thanks to advanced manufacturing processes.
7. **Photonic Associations, relevant Professional Associations, Photonic |Clusters and Member of Regional/National Policy Boards** will benefit from the material (disseminations) and link opportunities provided by the Action.

Academic and Industrial Partners will benefit from links with non-COST entities.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The Action will investigate innovative materials, components, techniques and laser schemes to provide, for the first time, efficient laser action outside the main wavelength intervals and to overcome the existing power-limits of established laser sources. The Action targets the understanding and implementation of photonic elements, and diffusing ‘know-how’ to all interested groups. In particular the Action will address the possibility of enhanced fibre functionality including tuning mechanisms, enhanced fibre designs and wavelength combiners. The Action plans to actively interact with leading semiconductor laser groups to understand the availability of new pumping wavelengths that may be required. The interaction with fibre laser companies and end-users is crucial to demonstrate the feasibility of the proposed solutions, to define a pathway for the development of future novel components and to bring Action innovative R&D results to a level of real-world (TR level 7) application. In particular the Action will focus in the following areas to meet the Action goals and the state-of-the art challenges outlined in section B.2:

UV/Visible wavelength interval

1. Develop new and improved soft glasses to further reduce multiphonon decay (investigate tellurite, germanate, chalcogenide and heavy metal oxide glasses with emphasis on impurity level, quality of glass. Loss, rare-earth solubility and fibre manufacturing process)
2. Characterise active materials (Er, Ce, Tm, Yb, Nd, Pr doped)
3. Optimize integration with additional components: e.g. integration with external components such as mirrors (Fibre-Bragg Gratings, FBG) either by improving splicing techniques of soft glass fiber with silica fibres (different melting temperature) or by direct FBG inscription into soft glass.
4. Use alternative pumping schemes based on newly available laser wavelengths and higher power visible semiconductor lasers
5. Design new photonic crystal structures (e.g. Kagome fibres, exploiting high-order propagation where dispersion characteristics is blue shifted) and investigate innovative nonlinear generation schemes (e.g. tapered fibres)

6. Use of new lasers schemes (e.g. gas-filled hollow core fibre)

7. Use of new nonlinear schemes for frequency conversion (e.g. Third-harmonic generation in tapered fibres)

MIR wavelength interval

1. The glass host needs to minimize the losses in the MIR wavelength and should provide at the same time good chemical properties for fibre manufacturing process and high(suitable)-doping level. Moreover the glass should be transparent at pump wavelength, possibly an efficient one at1-2 microns. Unfortunately MIR glasses may absorb at around 1 micron and higher with further limits due to two-photon absorption. Finally MIR transitions are low energy transitions and therefore extremely low phonon energy is required. Recent advances demonstrated undoped chalcogenide-glass passive optical fibres may now be made with ultra-low loss of 12 dB/km with sulphide glasses and of 50dB/km with selenide glass. Rare earth ion doped chalcogenide glasses of the host type Ge-As-Se-Ga may now be made as active fibre of loss in the order of 1 dB/m at 6.5 micron. Combination of all desired properties is one of the Action’s main common goals.

2. Active ions: while active ions suitable for emission in the MIR such as Pr, Tm, Dy, Tb have been studied, there is a lack of spectroscopic investigation aimed to find the quantities needed to simulate a laser system (rate-equations), therefore modelling results may be revised. This may be one of the reasons why promising theory never found experimental validation.

3. Pumping schemes: Pumping schemes need to be compatible (pump wavelength) with the glass transparency windows and be effective for laser transitions. A set of pump sources emitting at new, optimized, wavelengths could be necessary.

4. Components: Several components are missing in the new wavelength range: mode-lockers, filters, mirrors, even when available are very costly.

Power scaling

1. Investigate mode-instability and pulse peak power constrains.

2. Develop fibres and passive components for 2-micron kW-class oscillators. Attention will be devoted to overcoming the clustering problem, improving the efficiency of laser

transitions and fibre quality, with possible modification of standard silica-based glass matrix.

The network will leverage the following activities needed to meet the scientific challenges of the Action.

Activity 1: Investigation of laser materials and development of new active materials: to support power scaling and emission at new wavelengths (UV/visible, MIR) the partners will investigate spectroscopic properties of rare-earth ions such as Yb, Er, Ho, Tm, Dy, Tb, Ce and will investigate the impact of glass host on lasing performance. Suitable hosts with appropriate phonon energies (e.g. transparent in the MIR wavelength range and at the pump wavelength) will be developed: current glass systems will be optimized by improving the fabrication procedure in terms of raw materials purification, melting conditions and minimization of impurities (OH, rare earth contaminations); in parallel new glass systems will be explored based on literature findings in the field of glass system investigation.

Activity 2: Development of active and passive fibres (including micro-structured fibres): large-mode area fibres for reduction of nonlinear effects; active photonic crystal fibres for high peak power lasers and with optimised structure for MIR lasers; passive nonlinear (e.g. crystalline core) and photonic crystal fibres for supercontinuum generation in the UV and MIR wavelength regions; Round-Robin activities for characterization of developed fibres and components.

Activity 3: Study of new approaches to wavelength tuning, frequency generation (optimised frequency doubling, tapered fibres, Raman scattering) and mode locking (e.g. exploiting fibre nonlinearity, carbon-nanotubes, graphene and other new materials); investigation of Acousto-Optic Filters (e.g. using calomel crystal). Modelling and exploitation of the nonlinear optical effects in soft-glass fibres for supercontinuum generation (tellurite and fluoride out to 5.5 micron, chalcogenide out to 14 microns' wavelength). Investigation of Raman effects in crystalline fibre with glass clad for supercontinuum generation.

Activity 4: Modelling of laser materials, laser components and laser/amplifiers devices. Define Round-Robin activities to validate modelling.

Activity 5: Development of new laser sources: light sources for UV/IR/MIR, development of laser sources for applications in healthcare, manufacturing and environmental monitoring.

Activity 6: Investigation of laser-matter interaction: soft-matter interaction for plastic and biological tissue, organic electronic; UV/MIR source-based medical diagnostic; materials processing using high-power CW (continuous wave) and pulsed lasers. High-power lasers for materials' processing.

Activity 7: Proposal of standards and investigation of techno-economic impacts. This activity includes contact with End-Users and Supplier in order to assess the commercial impact of the scientific work.

All activities have been kept very general to allow for the inclusion of new topics during the lifetime of the Action. The activities will be split into study groups as indicated in section E.2. The Action will be open to new members and will also actively seek members if a specific know-how is identified as lacking. **Human and technological resources:** Action members will share know-how and well-equipped laboratories. Among major equipment and shared know-how we list: (i) material synthesis and processing, furnaces for glass synthesis (ii) materials characterization techniques (X-Ray, X-ray diffraction (XRD), scanning electron microscope (SEM), transmission electron microscopy (TEM), atomic force microscopy (AFM), differential scanning calorimetry (DSC), differential thermal analysis (DTA), thermomechanical analysis (TMA), optical and electronic microscopy) (iii) fibre drawing towers technology and specialty fibre fabrication; (iv) fabrication of custom optical components (couplers, gratings, nonlinear elements), (v) components and device testing facility (from UV to 10 micron); (vi) laser source prototype test setups, (vii) software and modelling expertise (viii) optical benches and equipment for laser and sources demonstration (laser scanner, beam deliver element, two-photon microscopy and Raman spectroscopy set-up); (ix) laboratory for physical characterization down to cryogenic temperatures; (x) laboratory for synthesis (including inorganic-chemistry laboratories); (xi) laboratory for optical characterisation and (xii) laboratory for laser testing.

While first demonstrations in the near UV/VIS has already been documented the MIR route is still open. The Action partners have a large experience in the field and a careful investigation of the problem was done before planning the Action. We report the envisaged Action routes toward MIR sources that will be investigated in **WG1** and **WG2**:

- Investigate and optimise soft glass compositions (reduce impurities and improve glass stability). Investigate new chalcogenide, fluoride and fluorotellurite glasses e.g. indium fluoride fibres. Optimise glass structure and chemical durability.
- Investigate rare-earth doped (such as Dy, Pr, Tb, Er) soft glasses for direct emission. Find the right compromise between rare-earth solubility, propagation loss and glass quality.
- Coordinate results: use first MIR lasers (4-5 micron) as primary pump for MIR devices in the 6-10 micron wavelength interval.

- Coordinate activities with semiconductor groups and companies for primary pumps above 2 microns (e.g. new InP-based emitter).
- Model and investigate gas-filled micro-structured fibres (e.g. with HI, CO_2, CO). Investigate Raman-shifts to cover wavelength gaps and extended wavelength emission.
- Model and exploit optical nonlinear effects in soft-glass fibres for continuum generation (fluoride and tellurite out to 5.5 microns, chalcogenide out to 14 microns). Investigate Raman effects in crystalline fibres with glass cladding for supercontinuum generation exploiting high nonlinear optical coefficients.
- Development of primary fibre pumps for supercontinuum generation: e.g. Q-switched Er:ZBLAN lasers or >4 microns' mode-locked Pr-doped laser. Development of integrated MIR OPOs using IR fibre laser front -end
- Investigate use of graphene for pulsed sources. Investigate Acousto-Optic Filters using calomel crystal. Promote development of fused MIR components.

D.2 Scientific work plan methods and means

The Action will achieve its scientific objectives through three inter-related Working Groups (WGs) and a special interest group (SIG), each divided into specific study groups (SGs), detailed in section E.2. Each WG will coordinate its own activity and will work closely under the supervision of a WG Coordinator (see Section E.1) to optimise multidisciplinary approaches.

WG1- Materials, Fibres, Components and Technology: This WG will deal with the development and characterisation of novel materials and fundamental components: **Activities 1 and 2**.

The activity will be structured into three interplaying lines of research:

1. Active materials for UV/visible/MIR direct generation and non-linear materials for supercontinuum generation. The Action members working on glass manufacturing and characterization will study new compositions and dopants to enhance the performance of existing materials and to explore new materials. The Action aims to study include low phonon energy glasses both oxide based (tellurite, germanate) as well as non-oxide as well (fluoride, chalcogenide). Dopants for light generation will include rare earth ions (Dy3+, Tb3+, Eu3+, Tm3+, Pr3+, etc.) while for nonlinear devices undoped glasses will be explored with compositions tuned to maximize non linearity while at the same time to minimize propagation loss.

2. Development of fibres (including photonic crystal fibres) both active and passive. Novel passive fibres to provide efficient nonlinear effects in the UV and MIR will be developed. New fibre configurations will be explored for power scaling and to overcome constrains on peak power level in the IR wavelength interval. Beam quality degradation issues due to power scaling will also be addressed.

3. New passive components for feedback (gratings), filtering, tuning and mode-locking (using fibre nonlinearity and new materials). The aim will be to move forward in integrating discrete components with the final objective of all-fibre sources in the MIR. The WG members will investigate the availability of suitable pump sources. Round-robin activity will be planned to compare characterisation methods and potential standards will be proposed to the Special Interest Group. Multifunctional fibres will be explored to incorporate functions that are mainly currently carried out by non-fibre based components, e.g. polarization of light.

Main expected achievements: Novel active materials; Novel types of fibres and optical components, multifunctional fibres, flexible large mode area fibres. Complete characterisation of new laser materials and glass hosts; Novel non-linear materials; Development of ultra-low losses materials and fibres for UV and MIR devices; Development of new photonic crystal fibre concepts to enhanced continuum generation in the UV and MIR (up to 14 micron); new tuning and mode-locking techniques.

WG2- New laser and amplifier devices: This WG will deal with the development of devices based on the new components developed in WG1 and on the optimization of sources using existing compensates **(Activities 3 and 4)**. The main activities are:

1. Modelling laser devices. This activity will include modelling of laser using new active materials (such as Tb) or new type of fibres (such as multi-core fibres). The use of complex algorithms to find optimised solutions based on multiple parameters will also be implemented;

2. Investigation of MIR sources. The Action will study the first fibre laser above 4 microns using, likely, emission from Dy or Pr ions. Emission at around 8 microns will be evaluated using Tb doping (however this will be a blue-sky research). Availability of new ultra low-loss and highly optically nonlinear fibres will be used to investigate enhanced supercontinuum sources in the MIR, with emission out to 14 micron;

3. UV/VIS laser generation and its power scaling will be pursued by either direct emission or by nonlinear generation in new micro-structured optical fibres. This will be alongside by more conventional enhanced frequency duplication of highly-coherent IR sources

4. The last activity on the previous point will benefit from the power scaling of existing lasers as sources in the 1-2 microns range (primary sources for frequency duplications) carried out in this WG. The main tasks will be: suppression of modal instability, use of highly-doped materials and use of large-mode area fibres. The development of special components for the achievement of all fibre laser sources will be carried out in connection with WG1. Tuneable, single-frequency, new wavelength lasers sources will be used investigated for enhanced spectroscopy to identify chemical specimens.

Main expected achievements: Modelling and software for complex laser systems: efficient modelling tools for MIR lasers, high-power lasers and continuum generation. Development of MIR continuous wave and enhanced supercontinuum generation in the MIR (up to 14 micron); Solutions provided to modal instabilities in kW level class lasers; The development of >5 mJ pulsed lasers for manufacturing. Power scaling to 4 kW single emitter at 1 micron and 1.5 kW at 2 microns (continuous wave). Efficient and compact all-fibre UV sources. Extension of continuum sources to the UV (down to 250 nm) with a power density level of hundreds of microW/nm to mW/nm, a suitable value for most applications. The Action partners have already connected with several relevant projects to secure funding and with the support of the added value of Action networking they will be able to successfully address Action topics. However a few risks remain. Blue-sky research is aimed at direct laser emission above 6 micron. Front end pumping at 2 microns of soft glasses could be limited by glass damage and a more basic approach to reach MIR generation would rely on a 2 microns' pumped compact non-linear stage.

WG3- Applications: This WG will deal with applications (**Activities 5 and 6**). In this case the Action will either propose applications of new sources or new/enhanced applications for existing sources. The main targets will be:

1. Bring together all Action participants to outline the main targets/issues/needs achieved and needed in the field. Provide to all Action members and the EU general public a global view on standards and technological perspectives. Evaluate existing programmes that overlap with objectives of the Action and support synergies at EU level and avoid duplications. Study the standardisation status with particular attention to recommendations on lasers, safety and components.

2. Provide a market drivers' analysis (Advanced Manufacturing, Healthcare and ICT). This will provide guidelines for manufacturers. Indeed the availability of low cost components is necessary for a strong commercial impact of new devices. On the other end until a market is established, it is unlikely that new components will be provided a low cost. This group will investigate possibilities of low cost components for UV and MIR laser development;

3. Evaluations of the technological impacts and social benefits. Contact outside this Action all the possible stakeholders like, industries, governmental bodies, consortia, EU projects, other COST Actions.

Main expected achievements: Support the impact of laser device through white papers. Support the interaction between components provider, laser manufacturers and end users to speed up impact of Action scientific outputs. Provide the public with an understanding of the impact of lasers on society.

E. ORGANISATION

E.1 Coordination and organisation

The Action is managed by a **Management Committee (MC)** headed by an Action Chair (**AC**) and an Action Vice-Chair (**AVC**). It is composed of up to two representatives of each participating countries and acts according to the Rules and Procedures for Implementing COST Actions. It issues the reports and interacts with the COST Office.

To effectively manage the Action and pursue the objectives, the MC will appoint:

- **Working Group Leaders (WGL)** and **two Deputy Leaders (WGDL)**. They will coordinate the WGs both scientifically and administratively. In each WG one deputy will be ESR and one female researcher will be elected. WG members choose the projects of common interest. **Topic Leaders (TLs),** two for each SG, will be appointed. They are in charge of a specific topic within the WG. WGL/WGLDs are in charge of workshop organization. This will also hold for the Special Interest Group (SIG).

- **Working Groups Coordinator (WGC)**. The WGC overlook the synergies between the WGs and makes proposals to the WGLs to share expertise and activities.

- **Dissemination and Communication Manager (DCM)**. The DCM is responsible for the dissemination and outreach activities in the Action. He/she presides in particular over the building, updating and maintenance of the Action's website and ensures that the Action website provides all of the necessary information. Moreover the DCM will be the editor of the quarterly newsletter.

- **Short Term Scientific Missions Manager (STSMM)**. The STSMM receives the proposals for STSMs. He/she, with the support of WGL/WGDLs involved, controls the adequacy for meeting the aims of the Action and if necessary ranks them in the light of their quality and the budget available. He/she works in close contact with the Steering Committee which he/she is a member of.
- **Training School Manager (TSM)**. He/she will be in charge of the training school organization with the collaborations of WGLs. Workshops organisers will be appointed by the MC and managed by WGLs.
- **Gender issue and ESR manager (GEM).** He/she will supervise the Action support to ESR and gender issues. They will act to address issues raised with the help of suitably qualified mentor(s) (e.g. a woman senior scientist in a senior role). The GEM will supervise the special website section devoted to ESRs and women researchers.
- **External Liaison Manager** (**ELM**): to coordinate external liaison and nomination of members to liaise with specific existing relevant EU project and COST Actions.
- **Industry and Economic Advisory Board**: The chair of SIG1 will act as chair of this board further composed by ELM and 10 others elected members to cover different types of partners (SMEs, large companies, hospitals, and governmental bodies). The aim is to coordinate liaison with stakeholders (industry and governmental bodies).
- **Steering Committee (SC)**. Election of Steering Group to support Action management and the Chairperson to coordinate interdisciplinary research and collaboration between academies and industries. It is composed of the Action Chair, the Action Vice-Chair, the Working Group Leaders, the Working Group Coordinator, the Gender issue and ESR manager, **the** Dissemination and Communication Manager, the Training School Manager and the xternal Liaison Manager. The SC will be in charge of the annual conference.

As a basic communication tool among the partners, and between the Action and other parties, a website will be planned and set-up shortly after the kick-off meeting. The website will be also used for dissemination and exploitation of the Action results. The website will contain all relevant

information to run the Action and disseminate the activity: basic information on the Action; the WGs activities and contact names; the projects with WG; the members; how to join the Action; a public and a restricted download section reserved to members.
The website will also collect useful information on funding calls and the formation of consortia will be encouraged via email circulations. One specific section of the website will be devoted to female researchers and one to ESRs to disseminate information in the most effective way.

E.2 Working Groups

In line with the major research tasks and actions defined in the previous sections and to fulfil the Milestones and Deliverables of section C, the Action proponents have defined three key Working Groups (WGs) and Study-Groups (SG) envisaged a Special Interest Group (SIG):
WG1- Materials, Fibres, Components and Technology

- SG.1.1 Rare-earth materials, un-doped glasses, and characterisation
- SG.1.2 Fibre development and fabrication technology
- SG.1.3 Gratings, filters and passive components
- SG.1.4 Methods for modelocking, tuning

WG2- New laser, amplifier devices and coherent light sources

- SG.2.1 Modelling and design Tools
- SG.2.2 MIR coherent line sources and continuum sources
- SG.2.3 UV coherent line sources and continuum sources
- SG.2.4 Power scaling issues

WG3- Applications

- SG.3.1 Manufacturing
- SG.3.2 Healthcare and biomedical applications
- SG.3.3 Environment, Green Photonics, energy production, sensing and security

SIG1- Techno-economic aspects

- S.I.G.1 Global view on standards and technological perspectives
- S.I.G.2 Market drivers analysis (Advance Manufacturing, Healthcare and ICT)
- S.I.G.3 Technological impacts and social benefits

According to an open approach the topics of WG workshop will be on demand, to ensure that the Action focuses on the most promising research lines. The Action is organized as bottom-up structure. Each WG will carry out specific research lines to meet the Action main goals. WGs will provide an arena to freely develop the Action and opportunity for members not part of the MC to actively contribute to shape the Action. The Action will invite experts in other type of lasers or end-users to provide tutorials during Action meetings and will promote joint meetings with other COST Actions (for example end users in BMBS, FA and ICT domains), other networks and industries. Each WG and the SIG will contribute to define at least one topical workshop/year during the life of the Action and this will be used to focus on most interesting topics and as a main opportunity to disseminate and enlarge the Action. Study groups, not originally planned within a WG, can be further defined if the need arises.

E.3 Liaison and interaction with other research programmes

The scientific plan and challenges show the need of a strong multidisciplinary network and of liaisons to share the developed know how. The External Liaison Manager (ELM) will identify relevant external activities (international/EU/national projects, other COST Actions, international/EU/national/regional bodies). The ELM will nominate a partner to be responsible of a specific liaison. During the kick-off meeting partners involved in relevant external activities will be nominated.

The ELM and liaison members will report to the Action during the Action meetings. This will facilitate joint activities among WGs and other research programs. The interaction will also consider invitations to external group/bodies to present their work at WG Meetings and establishing joint events.

Among EU projects the Action will target are IP MINERVA, ISLA, IMPROV, APPOLO, ACTPHAST, OASIS, FAMOS. MODE-GAP (detailed in Section B.4). The Action will also actively interact with COST Actions detailed in Section B.4: including MP1306, ES1309, BM1204, BM1205, FA1102, MP1205, IC1101, MP1204, and TD1001. This will allow the Action partners to interplay with projects ranging from material science and lasers, to cancer detection, to advanced manufacturing and food quality.

The annual conference will be held possibly joint with a mayor conference in the field to promote occasion of personal liaison with other scientists. Moreover the Action will make it easier for partners to address European facilities and will actively engage with projects like OASIS (life science and agrifood), ACTPHAST and APOLLO (manufacturing). The Action will actively act as a reference point for sharing information from all projects using its public website facility.

E.4 Gender balance and involvement of early-stage researchers

This COST Action will respect an appropriate gender balance in all its activities and the Management Committee will place this as a standard item on all its MC agendas. The Action will also be committed to considerably involve early-stage researchers. This item will also be placed as a standard item on all MC agendas.

The Action will have the objective of Gender balance and involvement of early-stage researchers as a main priority. The Action aims to fulfil its targets by

1. Electing at least one woman scientist and one woman ESR (if not coincident) as WGL or WGL deputy.
2. Alternating gender in the AC and AVC positions
3. Involving ESR and women researchers in workshop, conference organization and training school organization/chairing, in order to avoid propagation and engraining of career stereotypes.
4. Promoting senior women researchers as spokespersons for the Action towards Stakeholders.
5. A specific representative of woman ESR and senior researcher will be appointed to the SC.

The MC will explore and adopt the best practices across Europe. It will promote the active participation of women scientists in positions of responsibility and monitor the evolution of the gender balance during the Action, by taking active part in gender equality networks and workshops. The STSMM will continuously encourage women ESRs to apply for STSMs. Women ESR and senior researchers will be given priority for STSMs to promote their mobility. Short term missions for women scientists with children will be especially encouraged.
ESRs will be invited, if not able to present a regular presentation, to periodically provide an update of their activity through a dedicated 5-min talk session during WG meetings/topical meetings and the annual conferences. The possibility of giving a presentation on the basis of a 6 months period would ensure an effective supervision of ESR work.
The Action website will contain a section for empowerment activities for ESR of both genders

(jobs, training opportunities). Women senior researchers and ESR members will act as role models in communication activities, in order to fight any "unconscious" bias against women scientists.

F. TIMETABLE

The Action is planned to run for four years. This long timeframe allows to establish an efficient interaction between Action members and provide the desired outcomes. Preliminary work will be done before the kick-off meeting to involve more groups. The first kick-off meeting will nominate members to all the management and coordination positions and will provide the guidelines for the first year: to establish the Action (website, mailing list) and start on the projects as defined by SGs. The SC, with input from the interaction between scientific groups and industries, will be able to constantly review the direction of the efforts. The first year will be devoted to looking for partners if any key know-how is found missing. The kick-off meeting will also define the first and the second MC/WG Meetings location and date, the location and date of the first topical WG meeting and, possibly, of the first annual conference (linked to the second MC meeting).
At the end of each year, together with the Action annual conference, the Action strategies will be reviewed and, if necessary, redirected. Action review will consider Action evaluation and feedback from scientific and industrial members, as well as feedback from external entities. The SC, with the support of the MC, will ensure the Action is focused and that an excellent interaction is established between WGs. The Action provisional timetable is the following:

	Year 1		Year 2		Year 3		Year 4	
	Q1&Q2	Q3&Q4	Q1&Q2	Q3&Q4	Q1&Q2	Q3&Q4	Q1&Q2	Q3&Q4
MC and WG Meeting Action Review and STSM Call	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**

Training school			X			X		
Topical Meeting		X	X		X		X	
Annual Conference		X		X		X		X
Newsletter	X	X	X	X	X	X	X	X

The above timetable provides a time framework for quantitative milestones (e.g. Training Schools). The annual conference is initially scheduled for early fall but it may be moved to springtime after discussion with all partners during the first Action bi-annual meeting. Other time constraints for Action milestones/objectives are listed in section C.2.

A main self-review effort will be done at Month 18. To focus the effort during the Action bi-annual meeting WGs will provide a list of research topics to which priority will be given in the STSM call. A STSM call will be sent to all participants after each Action bi-annual meeting.

In accordance with section C.3, the topics of WG workshop will be on demand, to ensure the Action focuses on the right topics. Website updates will be done on three monthly basis. The final schedule of the WG-meeting-annual conference and of the topical WG workshops within each year will be finalized by the MC on an annual basis.

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: BE, CH, CZ, DE, DK, EL, ES, FI, FR, HR, HU, IL, IT, LT, NO, PL, PT, RS, SE, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 80 Million € for the total duration of the Action. This estimate is valid under the assumption that all the countries mentioned above, but no other countries, will participate in the Action. Any departure from this will change the total cost accordingly.

H. DISSEMINATION PLAN

H.1 Who?

A key part of the Action is the dissemination plan to make available Action results to all the relevant entities (external dissemination) and foster collaborations among members and with external groups. The Action will carry out regular meetings for internal (WG meetings during Action bi-annual meetings) and internal/external dissemination (annual conference, Training Schools, core group meetings). The Action will also use the website, with both a public and a private (Action member only) and an open area as well as a public newsletter (each 3 months) to disseminate results.
A mailing list collecting interested people will also be used to disseminate Action activities and outcomes as well as general public.
The Action will address the following groups:

- External researchers directly involved in the area;
- External researchers externally involved in the area (e.g. field of biophysics);
- Universities/research institutions/academies interested in the topics of the Actions;
- Industries and industrial associations with interest in the topics of the Action;
- End users interested in the outcomes (e.g. healthcare and manufacturing) and possible applications;
- Relevant COST Action members (MP1205, IC1101, MP1204, TD1001) and members of past Actions (MP0702, IC299, IC297)
- Members of relevant Horizon2020 programs and regional programs (the Action already envisages the following links: APPOLO, ACTPHAST, MINERVA, ISLA, IMPROV, FAMOS, BRIDLE, MODE-GAP).
- General Public

The Action will also specifically target ESRs, with possible involvement in Training Schools (external ESR will be able to access Training Schools but only if places are available) and will support the gender balance issues (see section E for more details) by promoting this in all collaborations and external activities.
The Action will also target Special interest groups such as:

- Photonics/healthcare/food regional clusters
- Relevant national and governmental bodies
- Bodies involved in Smart Specialization Strategies.

Relevant standardisation bodies European Committee for Standardisation, Technical committee 123 (CEN/TC 123) International Telecommunication Union (ITU). European Telecommunications Standards Institute (ETSI), International Electrotechnical Commission (ICE)

H.2 What?

The dissemination methods used for this Action will include:

1. Setting-up of an Action website with two levels of access. The Action website will be set up on the server of one of the partner's institutions. The website will be coordinated by the Dissemination and Communication Manager (DCM) appointed by the MC and supported by the WG coordinators. The Website will be made of two separated areas. Public access area: this section will provide means for disseminating Action events, outcomes and public materials. Information of all past/upcoming events, the past/upcoming Actions (e.g. update on Standardization issues), the Action Newsletter, Actions publications (paper and presentation slides (if available)), white papers will be available in this section. COST member only access area: this section, password protected, will allow the exchange of sensitive material and discussion of ongoing activities. The section will contain: information on COST-only events, MC meetings minutes, WG minutes, STSM scientific reports, and all scientific and administrative reports (including financial reports).
2. A two-level email list will be created: a COST member only list to discuss internal questions; an open list including all relevant external partners to disseminate results, newsletters or events.
3. Meetings will be scheduled: 1/year on topic defined by WGs. One annual conference/year to disseminate results across all Actions and to the public. Joint events and participation to external workshops and symposia is also considered a main priority by Action members.
4. The Action will produce: scientific publications in peer-reviewed journals, conference papers, white papers and scientific reports, Annual conference proceedings, Training School proceedings, a final Action report and a final Action book. Non-technical items to disseminate to the large public will be also produced.
5. Internal dissemination will be promoted using STSM and Training Schools.

6. Dissemination to other European activities/Actions/bodies will be carried out by liaison members.
7. Dissemination to special interest group such, governmental and Smart Specialization Strategies will be made using national/local members supported by the liaison partner and the MC.
8. Scientific dissemination will be done by publications in high-impact journals, attendance to major conferences, production of a final Action book and white papers to cover main research lines and applications. All will be posted available on the Action public website.

H.3 How?

Several dissemination methods, as detailed in section H.2, will be used in the best way to maximise the impact of the Action. All means and strategies will be revised annually, considering the outcome of the Action evaluation, feedback on previous dissemination efforts, the possible shift in topics of interest and the progress in the scientific field. The main dissemination method will be the Action website. A static dissemination (relaying of material of interest to external people) will be carried out using the website where all available material will be posted (see section H.2 for details). A proactive dissemination will be pursued by using the mailing list (see section H.2 for details). Feedback will be allowed and encouraged both on the website and on the mailing list. The website will contained dedicated pages to ESRs, women scientists and a non-technical page to address the general public.

A further dissemination action will be done to promote research grant applications and ESR career. The website will post news of funding calls, requests of research partners and open positions (with focus on ESR and PhD open positions). The mailing list, workshop, the annual conference and other Actions events will raise the awareness of the Action and will promote the visit of the website.

The Action aims to exchange links with other relevant websites (e.g. websites of Photonic Clusters, the European Enterprise Network and so on) to reach a wider audience as well as to inform all Action potential stakeholders of the Action activities.

Attendance at the Action conferences, workshops and meetings will be encouraged to disseminate the Action results. Action results will also be published in peer-reviewed journals. To reach a more general public a non-technical section of the website will be implemented and public white paper will be published to raise awareness of Action activities.