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

Brussels, 15 May 2014

COST 052/14

MEMORANDUM OF UNDERSTANDING

Subject :	Memorandum of Understanding for the implementation of a European Concerted Research Action designated as COST Action MP1403: Nanoscale Quantum Optics

Delegations will find attached the Memorandum of Understanding for COST Action MP1403 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 MP1403
NANOSCALE QUANTUM OPTICS

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 coordinate research activities in nanoscale quantum optics, explore innovative approaches across quantum science & technology, nanoscale optics & photonics and materials science, and facilitate the early-involvement of end-users.

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 88 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

The investigation of quantum phenomena in nanophotonics systems may lead to new scales of quantum complexity and constitutes the starting point for developing photonic technologies that deliver quantum-enhanced performances in real-world situations. This ambition demands new physical insight as well as cutting-edge engineering, with an interdisciplinary approach and a view towards how such ground-breaking technologies may be implemented and commercialized. The Action aims at promoting and coordinating forefront research in nanoscale quantum optics (NQO) through a competitive and organized network, which will define new and unexplored pathways for deploying quantum technologies in nanophotonics devices within the European Research Area. The main vision is to establish a fruitful and successful interaction among scientists and engineers from academia, research centres and industry, focusing on quantum science & technology, nanoscale optics & photonics, and materials science. The Action will address fundamental challenges in NQO, contribute to the discovery of novel phenomena and define new routes for applications in information & communication technology, sensing & metrology, and energy efficiency. Gathering a critical mass of experts the Action will serve as a platform in NQO and as such it will cooperate with industry and academia to promote innovation and education in a forefront research field.
Keywords: Light-matter interaction, nanoscale optics and photonics, quantum science and technology, quantum and nonlinear optics, nanostructured and advanced functional materials.

B. BACKGROUND

B.1 General background

Novel and more sophisticated technologies that exploit the laws of quantum physics form a cornerstone for the future well-being, economic growth and security of Europe. Here photonic devices have gained a prominent position because the absorption, emission, propagation or storage of a photon is a process that can be harnessed at a fundamental level. However, the interaction of light with single quantum systems under ambient conditions is typically very weak and difficult to control in the solid state. Furthermore, there are quantum phenomena occurring in matter at nanometer length- and femtosecond time-scales that are currently not well understood. These deficiencies have a direct and severe impact on creating a bridge between quantum physics and photonic devices. Nano-optics and nanophotonics precisely address the issue of controlling the interaction between few photons and tiny amounts of matter and the ability to efficiently funnel them down to nanoscale volumes. Several research efforts funded by national and EU projects in the last decades resulted into enormous progress in quantum physics and quantum optics, on the one hand, and in nano-optics and nanophotonics, on the other hand. The COST Action Nanoscale Quantum Optics is the instrument to proactively increase the interaction among the communities of nanophotonics, quantum optics and materials science and to support them towards common objectives. The grand vision is the development of new ideas, materials, and techniques to control the interaction between light and matter at will, even down to the level of individual quanta. The potential breakthroughs will have profound implications in fields as diverse as classical and quantum information processing & communication, sensing & metrology, light sources, and energy harvesting.

B.2 Current state of knowledge

State-of-the-art efforts currently concentrate on four general themes:
The development of novel materials (e.g. graphene, silicene, metamaterials) and optical devices (plasmonic structures, nanofibers, photonic crystals, optomechanical systems, superconducting detectors) that can facilitate and control strong quantum light-matter interactions, and the advance of novel experimental methods that enable quantum degrees of freedom (colour centres in solids, quantum dots, ions, molecules, neutral atoms) to be interfaced with these systems. Prominent efforts include:

- Quantum dot devices to generate single and entangled pairs of photons on demand.
- Novel devices such as nanoscale resonant structures, plasmonic waveguides or nano-fibres to achieve efficient coupling of single photons.
- Novel fabrication techniques for diamond-based photonics, which can be used to enhance optical coupling to individual defect colour centres (such as the nitrogen vacancy (NV)).
- Methods to trap cold neutral atoms to nanophotonic systems, such as tapered optical fibres, thus enabling a coherent atom-nanophotonics quantum interface.
- Metamaterials and graphene plasmonics are being actively explored as new platforms to channel light and control their interactions with quantum systems.

- Chip-based optomechanical systems have recently been cooled to their quantum ground states. Coherent interactions between light and phonons have been demonstrated, which enable new opportunities to use mechanical systems to manipulate quantum light.
- Superconducting devices for single photon detection over a large wavelength range, with high time resolution, efficiency and photon number resolution.

The theoretical development and experimental implementation of novel protocols to use NQO systems to generate non-classical states and utilize these states for diverse tasks in information processing, metrology, sensing, etc. NQO systems are uniquely suited because they are able to access novel parameter spaces that are not possible with macroscopic systems. For instance,

- NV centres have been demonstrated to serve as sensors of electric and magnetic fields with nanoscale resolution and under ambient conditions, which will have significant applications in areas such as bio and environmental sensing.
- Protocols to realize single-photon nonlinear optics and sources, quantum state transfer, and hybrid coupling of disparate quantum systems, also via quantum optomechanics, are being actively investigated.
- Many promising techniques to realize quantum gates for computing, entangle quantum bits, and generate non-classical optical fields are being pursued in NQO systems such as nanoscale cavities, graphene, plasmonic waveguides, and nanofibers.

The development of theoretical techniques to predict and quantitatively understand the rich quantum dynamics that emerges from strongly correlated quantum systems, and to understand and control the interaction of these quantum systems with complex electromagnetic environments. These efforts are critical both to position NQO systems as potentially ground breaking quantum technologies, and to leverage these systems as “simulators” of exotic quantum phenomena.

The exploration of quantum phenomena in biological systems (e.g. energy transport in light-harvesting complexes), the development of advanced experimental techniques to investigate them with high spatial and temporal resolution and the investigation of bio-inspired artificial systems that exhibit quantum effects (e.g. quantum simulators).

Furthermore, advances in these research areas may have implications on state-of-the-art technology and applications and be of immediate interest to industry, for example:

- Highly efficient single photon sources on demand and photon-number-resolved detectors would have impact in the field of secure quantum communication.

- The development of switches that operate at few photon levels could drastically mitigate the high energy required for optical communication and computation in supercomputers and it will also play a major role in the reduction of worldwide energy requirements in ICT technologies.
- Bio-inspired materials such as light-harvesting complexes could open new routes towards efficient photovoltaic cells.
- New approaches to single-molecule detection and quantum-enhanced measurements will expand sensor capabilities opening new scenarios particularly within the fields of metrology, security and safety.

B.3 Reasons for the Action

The main purpose of the COST Action Nanoscale Quantum Optics is to provide a platform where scientists and engineers can jointly analyse the state of the art and define coordinated efforts able to generate new approaches to existing problems and go beyond the current limits. This requires gathering a network of experts from the different communities of nanophotonics, quantum optics & quantum physics, materials science and providing them with means to effectively interact through the exchange of human resources and access to research infrastructure, joint meetings and a coordinated but flexible work plan. Furthermore, a COST Action will form the critical mass of scientists and engineers able to involve early end-users concerning innovation and education in a forefront research field. The improved know-how in this domain will open up new areas of research with relevance to physics, optics & photonics, materials science and spectroscopy. A wide range of strategic applications is foreseen and there is an extensive effort both in academia and industry to address the potential and the challenges of NQO. Europe has shown that it can take world leadership in top-level research domains provided that groups work collaboratively and resources are pooled. The central objective of the Action is the generation and dissemination of new scientific knowledge, sharing of technical and human resources, and to ensure that potentially disruptive technology is deployed. Through the combination of competences in several scientific disciplines, the Action will also contribute to the education and training of young scientists as well as support gender balance in a fast-growing and strategic research field of strong industrial impact.

B.4 Complementarity with other research programmes

Some recent and ongoing COST Actions have separately addressed quantum physics, such as MP1006 and MP1001, and nanophotonics, such as MP0702 and MP0803. Furthermore, there are recently established national programmes focused on research and applications of NQO, such as the Spanish "nanolight.es", the Swiss NCCR "QSIT – Quantum Science & Technology," the German BMBF "Novel Optics", and joint research projects, such as "Metrology for Industrial Quantum Communication - MIQC" and "Single-photon sources for quantum technologies – SiQuTe". Initiating a transnational networking activity combining expertise from quantum physics and nano-optics to open innovative research directions represents a unique opportunity to consolidate this trend in academia and industry within the European Research Area and to strengthen leadership in the emerging interdisciplinary field of NQO.

C. OBJECTIVES AND BENEFITS

C.1 Aim

The aim of the COST Action Nanoscale Quantum Optics is to support and coordinate research activities in nanoscale quantum optics, explore innovative approaches by identifying, establishing and exploiting cross-links between quantum science & technology, nanoscale optics & photonics and materials science, and facilitate the early-involvement of end-users.

C.2 Objectives

Support and consolidate the research community working on NQO. The Action needs to overcome the fragmentation in its fields of activity and boost the collaboration among its members.
Create a strong consensus and awareness of the importance of NQO to leverage cross-interactions within and outside the Action, including target groups and end users.
Strengthen cooperation with industry. Identify what new photonics properties and functionalities will be needed to improve present components that they do not yet know how to achieve. Ensure that disruptive research is not overlooked. Better match their knowledge and skill needs.
Support gender balance and the involvement of Early Stage Researchers (ESRs). ESRs and young female scientists shall largely contribute to move across different communities, define innovative research approaches and generate new opportunities. The objective is also to promote a larger participation of female scientists through the policy of mainstreaming gender balance through all Action activities.
Promote education, training and skill development in NQO. Interacting with leading groups from

academia, industry and private / public associations, as well as regional and national photonics clusters to identify opportunities and encourage specialized curricula and training programs in NQO.

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

Management Committee (MC) and Working Group (WG) meetings will be the occasion for face-to-face interactions. They will provide an ideal setting for monitoring the state-of-the art, discuss results and challenges, define research priorities and initiate new collaborations as well as consortia that will apply for funding research projects. Workshops, conferences, mutual publications in high impact journals and joint patent applications will be organized and supported in order to strengthen the research community of NQO, disseminate results, create awareness of the importance of NQO and generate intellectual property. Short-Term Scientific Missions (STSMs) will further collaborative research among the Action members, encourage the mobility of ESRs, including young female scientists, and facilitate access to advanced research infrastructure. Training Schools, ESR Workshops and Summer Internships will promote the education and training of ESRs and young female scientists in academia and industry. Female scientists participation will be proactively encouraged as outlined in E.4 and gender balance monitored for all activities. Early-involvement of end users will be driven by an Advisory Board on innovation and education, which will aim at cooperating with universities, public research institutions and industry. An advanced book setting the current state of progress and future challenges in NQO and a research & innovation roadmap for NQO on innovation and education will consolidate the NQO community and set the basis for future actions. The Action will develop strategies to successfully participate in research funding programmes, such as Marie Curie actions, FET schemes and ERC grants, to strengthen its research activities and to promote ERSs among its members. Soft networking channels, such as a website, e-mail distribution lists and a newsletter, will store and disseminate information about the Action activities and reach out to a wider community. The Action objectives and activities will be continuously monitored and their results disseminated.

C.4 Potential impact of the Action

The Action will address scientific issues that are at the forefront of research and shape a research community. As such concrete deliverables are difficult to envisage. Nonetheless, important scientific achievements are expected from the cross-fertilization of cutting-edge research.

Furthermore, this strategy has the potential to generate disruptive technology and give rise to intellectual property and start-up companies. These will create scientific and industrial leadership as well as long-term competitiveness in, but not limited to, information & communication technology, sensing & metrology and energy efficiency within the European Research Area (ERA). In fact, the Action combines two of the three photonics research and innovation challenges identified by the Multiannual Strategic Roadmap 2014-2020 of Photonics 21. The Action will also contribute to the education and training of ESRs and it will produce future leaders and a highly skilled workforce in a fast-growing and strategic research field worldwide, which will in turn enrich the European societal and economic potential. Through the proactive involvement of female scientists, the Action will also have a positive impact on gender equality in science and technology. The Action will also give a chance to the involved developing countries to become attractive and highly performing partners in the ERA, and will support their participation to transnational projects.

C.5 Target groups/end users

Scientists and engineers from academia, research centres and industry working in NQO and related fields. In particular, ESRs and female scientists will find support for developing a high-profile career in academia or industry. Technical management and human resources from photonics-based or photonics-enabled industry, with a focus on quantum photonics solutions and products, will be addressed by the Action's innovation and educational activities. These will also address regional and national photonics clusters, in order to promote the dissemination of NQO into local actions. The general public will be informed about the Action's activities, which impact on areas of long-term socio-economical benefit, e.g. information technology, sensing, energy efficiency, and it will have the opportunity to increase knowledge on the deployment of elusive concepts like, e.g. quantum entanglement.

D. SCIENTIFIC PROGRAMME

D.1 Scientific focus

The scientific programme will be flexible to fully accommodate the explorative scientific scope of NQO, but it will also address three major application areas that already exhibit clear evidence that the combination of quantum optics with nanophotonics is technologically valuable: (1) information & communication technology (ICT), e.g. to improve single-photon sources and photon number-resolved detectors for secure communication as well as quantum-optical solutions for ICT; (2)

sensing & metrology, e.g. nanosensors and quantum-enhanced measurement devices; (3) energy efficiency, e.g. development of new solutions for photovoltaics and energy saving. At present, several universities as well as public and private research laboratories worldwide are conducting research to introduce quantum technologies in these applications. However, the roadmap towards compact and efficient quantum devices still requires a substantial basic research approach. We have thus identified four research priorities that deal with problems and limitations in the operation of existing quantum technologies, and that may contribute to the discovery and understanding of novel quantum phenomena for future applications: (1) Generation, detection & storage of quantum states of light at the nanoscale; (2) Nonlinearities and ultrafast processes in nanostructured media; (3) Nanoscale quantum coherence; (4) Cooperative effects, correlations and many-body physics tailored by strongly confined optical fields. The first two priorities will also target technological aspects, such as performances and integration of quantum photonics devices, whereas the other two include rather exploratory activities.

The investigation of these concepts and phenomena at the nanoscale is not a trivial task and requires an extensive effort on several fronts. The key idea here is to exploit the interaction among leading experts working in different areas to improve synergy, set a common language, and foster new ideas. In this regard, another important step will be to ensure that theory and modeling, advanced quantum optical experiments, new materials and nanofabrication are well represented by the Action members. It is worth noting that the communities involved in the Action are strongly committed to three of the Key Enabling Technologies (KETs) recognized at the European level, i.e. nanotechnology, photonics and advanced materials, thus ensuring a synergic cross-KET approach to important application fields.

D.2 Scientific work plan methods and means

Distinctive and autonomous research communities have so far generally pursued separately the three application areas targeted by the Action. This fact represents a considerable obstacle to the cross fertilization of research activities and to the development of innovative solutions in order to address common challenges, which are increasingly more pressing in these technology sectors. For example, efficiency has become an important issue in the energy supply as well as in information technology, where the power required for data traffic is turning into a significant percentage of the total energy consumption. To encourage the exchange of ideas, the formulation of innovative concepts, the development of unconventional research approaches and ultimately the generation of ground-breaking technologies, the Action will organize its scientific activities into four Working

Groups (WGs) according to the four research priorities that have been identified, hence mixing theory, experiments and materials development from quantum-optics to nanophotonics as well as expertise in the three major application areas in the Action focus. The Action will support this structure for stimulating scientific interaction through networking and dissemination, as outlined in sections C, E, F and H. Moreover, to facilitate the scientific exchange and to establish a common playground, the Action will encourage some overlap between the WGs, which will occur through the organization of joint events concerned with:

- Investigation of innovative materials (e.g. diamond nanostructures, plasmonics structures, graphene, silicene, hybrid organic/inorganic) and techniques to combine them with quantum systems with a high and reproducible precision (e.g. scanning-probe techniques, two-step lithography, ion-beam milling and deposition). High-throughput and low-cost fabrication methods for hybrid nanodevices (e.g. self-assembly, nano-imprinting).
- Optical methods for investigating quantum light-matter interfaces (e.g. single-molecule spectroscopy, stimulated-Raman adiabatic passage (STIRAP) and coherent population trapping), the development of novel approaches at the interface between quantum optics, nano-optics & nanophotonics and advanced spectroscopy (e.g. nanoantenna-based spectroscopy, coherent multidimensional nanoscopy) and also modern x-ray and neutron scattering techniques. This aims at leveraging state-of-the-art experimental capabilities for new quantum technologies.
- Advance theoretical techniques to quantitatively understand these phenomena (e.g. non-canonical quantization schemes, non-Markovian bath interaction models), including novel computational methods (e.g. hybrid electromagnetics / quantum mechanical algorithms such as the finite-difference time-domain method coupled with the Schrödinger equation).

The research topics of the Action scientific work plan include, but may not be limited to:

WG1: Generation, detection & storage of quantum states of light at the nanoscale with emphasis on efficiency, fidelity and rate.

- Exploit the latest advances in the nanoscale control of optical fields to strongly enhance the interaction of photons with single quantum emitters thus addressing some major roadblocks of quantum information, including the emerging area of quantum plasmonics. These involve, for example, the production of scalable hybrid quantum systems that feature lifetime-limited transitions above cryogenic temperatures and that are able to generate an efficient stream of indistinguishable single photons. In this framework, the Action will perform a comparative study of single-photon sources.

- An important topic will be the study of new nanomaterials and metamaterials for nonclassical light sources. For instance, progress in graphene plasmonics is expected to have far-reaching implications. In particular, it may offer an ideal platform for cavity quantum electrodynamics (QED) in the solid state. Estimates indicate that the regime where single-quantum surface plasmon-polariton excitations can be generated and manipulated is within reach. This will have various practical implications, such as quantum control of single photons or entangled photon pairs, and enables the development of novel single-molecule sensing approaches.
- Generation and detection of single photons at infrared telecom wavelengths is still a challenging frame, although InAs QDs and superconducting detectors are improving at a fast pace. Suitably designed nanostructures may enhance the efficiency of photo-detectors. Furthermore, materials like graphene, NbTiN, NbSi and superconducting metamaterials may provide more efficient and tunable devices and the study of quantum-optical effects in such functional photonic materials is relevant.
- Develop advanced nanophotonics couplers and waveguides optimized for applications in integrated quantum photonics.

WG2: Nonlinearities and ultrafast processes in nanostructured media.

- When an emitter is strongly coupled to a nanoscale field it combines the physics of cavity QED (e.g. quantum coherence, few-photon nonlinearities) with ultrafast dynamics that may be coherently controlled with femtosecond lasers at the quantum level. These settings may be pursued to achieve ultrafast optical switching with energies down to a few aJ, or be used to create artificial light-harvesting complexes (in combination with possible artificial “reaction centres”, in analogous way to the well-known universal scheme of photosynthetic reaction centres of Nature) that convert single photons into electrical charges with a very high efficiency and rate.

- Nanofabrication of parametric devices for correlated photons and squeezed light generation to take quantum light sources closer to applications, like quantum key distribution (QKD) and quantum sensing, as it will facilitate scalability and increase robustness.

- Many questions remain regarding the role of plasmonics in enhancing (quantum) nonlinear processes for exciting novel applications, including strong coupling with quantum emitters, quantum frequency conversion of single photons, and nonlinear multiphoton processes. Plasmon-enhanced nonlinear effects could advance the development of nanoscale coherent light sources for lasing, nanoscopy and nano-imaging.

- The development of sensory tools based on quantum nonlinearities, including optomechanical quantum transducers constitutes an important topic to be covered.

WG3: Nanoscale quantum coherence. Quantum coherence phenomena such as entanglement lie at the heart quantum science and technology and they represent the basis, for instance, for quantum information & computation, quantum metrology and energy transfer in light-harvesting complexes.

- Investigate quantum coherence properties of nano-materials and combine them with photonic nano-structures to enhance and control quantum coherent dynamics and phenomena, such as entanglement creation and distribution.
- Study coherence of nanophotonic quantum states such as surface plasmons, polaritons and excitons in a variety of different implementations.
- Elucidate the role of couplings in excitonic/electronic motion in molecular and solid-state environments with particular emphasis on the presence of long-lived vibrations/phonons in these processes. This will require new detection technologies that will be developed in the Action and promise to have an impact on our understanding of the function of biological systems going well beyond transport in photosynthesis including charges separation and the function of proteins.
- The development of new experimental methods, based on the possibility to enhance the spatio-temporal resolution with nanostructures, would allow the investigation of quantum transport phenomena in complex systems with unprecedented insight. For example, the investigation of these effects in natural and artificial light-harvesting complexes and accompanying reaction centres, which transform light into electric energy with highest efficiency.
- Development of new concepts for diamond-based sensors, with ground-breaking features for applications in environmental and biomedical optics. Nanophotonic structures will enhance the optical readout and boost the device sensitivity, e.g. by

combining nanodiamond with plasmonic structures. Explore new systems beyond the NV centre, which currently suffers from instability in single-digit diamond nanocrystals.

WG4: Cooperative effects, correlations and many-body physics tailored by strongly confined optical fields.

- Explore quantum regimes of light-matter interaction such as super radiance in nanostructured solid-state systems and surface plasmon lasing.
- Study polaritonic effects in nanostructures to attain quantum correlations between light and matter even in the presence of fast dephasing processes.
- Investigate transmitted photon quantum entanglement through nanostructured media, e.g. metallic hole arrays with a photon-plasmon-photon conversion process. A remarkable effect, which may have considerable applications in quantum-imaging technologies.
- Develop light induced self-organization of atoms in strongly confined light fields as nano-fibres and microresonators. Here single particles significantly act back on the light field, providing a new and efficient source of optical nonlinearity at the few photon – few atom level.

E. ORGANISATION

E.1 Coordination and organisation

The organization of the Action will conform to the “Rules and procedures for implementing COST Actions” (COST doc. 4112/13) and “COST Action Management” (COST doc. 4114/13) and to any new document amending or replacing them. A Management Committee (MC) will be established to represent the Parties and to implement, coordinate and supervise the Action. A Core Group (CG) will be introduced to support the MC. It will comprise the Action Chair, Vice-Chair, the WG Leaders, the Chair of the Editorial Board, the STSM Manager, the Advisory-Board Leaders, the Gender-Balance Advisor, and the ESR Advisor. The MC will appoint a Chair and a Vice-Chair for each WG. They will be responsible for the management and implementation of the scientific work plan under their respective WG. The Action among the MC members will appoint an Editorial Board that will assist the MC for all policies on publication and dissemination, including the preparation of an advanced book and a roadmap, a STSM Manager to promote, coordinate and monitor STSMs, and two Advisory Boards that will assist the MC for all policies on innovation &

technology transfer and education & training, respectively. The MC among its members will also appoint a Gender-Balance Advisor and an ESR Advisor, who will assist the MC for all policies on gender balance and on the promotion of ESRs, respectively. Gender balance will be supported within all these governance bodies. The Action coordination will be assisted by a website, which will be designed to contain up to date information about the Action members, activities and results.

E.2 Working Groups

The Action will be initially divided into four WGs, each for the research priorities outlined in section D. Each WG will be responsible for coordinating efforts in the assigned topic and it will take advantage of STSMs, Training Schools and WG meetings. Moreover, the WGs will establish connections among each other through joint events, starting from a Kick-Off Workshop. The Advisory Board on innovation & technology transfer will closely follow the scientific progress to advise on the innovation potential of the Action activities, promote the building up of intellectual property and facilitate the connection with industry. The Advisory Board on education & training will cooperate with the MC in order to select Training Schools and it will help defining curriculum development goals for Academia and lifelong learning programs for industry in the roadmap.

E.3 Liaison and interaction with other research programmes

The Action aims at developing close interactions with high-ranking national and international scientific institutions through the involvement of their members in its activities. In particular, the Action seeks to establish links and strategic partnerships with regional and national clusters of excellence, EU networks, COST Actions (e.g. Nanospectroscopy, Fundamental problems in quantum physics) and other relevant research centres worldwide. Moreover, it will involve industry as well as industry associations in its activities. To this end the Action will take advantage of the Industrial and Educational Advisory Boards.

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 Gender-Balance Advisor and the ESR Advisor will specifically establish and coordinate monitoring of related data and a mentoring programme. This may include coaching activities, summer internships, student awards, career advice, and satellite events at workshops and conferences. The Action will support the career development of ESRs by organizing mentoring activities related to Marie Curie Actions (for mobility) and ERC Starting Grants (for independence) through the involvement of its senior members within training events. An advanced book will address scientists and engineers, but also graduate students and post-docs, who want to be actively involved in research on NQO. The Action will encourage female scientists and ESRs to take concrete responsibilities and duties, including a significant participation to committees, the organization of ESR Workshops and visits to research centres and companies. The Action will elaborate and disseminate a set of principles that define a women-friendly environment. These will follow from well-tested programmes such as the Athens SWAN Charter for Women in Science and the more discipline specific Institute of Physics Project. Best practice within institutions will be awarded and funding will be assigned for the dissemination of its equal-opportunity programme. Special care will be taken of the accessibility of meeting venues and availabilities of childcare services at the hotel to make it easier for participants with children to attend. Moreover, the Action will organize a workshop “Women in photonics and quantum optics: academia or industry?” to exchange experience, discuss about career opportunities for women working in these topics and disseminate the monitoring activity on the involvement of female scientists in the COST Action Nanoscale Quantum Optics. Participation of female scientists and ESRs to STSMs, WGs meetings, conferences organized by the Action and related international events will be monitored, and data will be periodically analysed and published. Attention will be given to promote role models relevant to female scientists at all career stages within the Action. The Action will significantly target the participation of young female scientists, by dissemination of the Action aims among ESRs, where a higher percentage of female scientists is present.

F. TIMETABLE

The Action activities and milestones (M) are scheduled for the duration of four years.

Year 1	**Year 2**
(M) Nanoscale Quantum Optics website online, Linkedin, Twitter and Facebook accounts active	STSM and internship proposals evaluated, funds allocated
(M) Kick-Off Workshop	(M) ESR exchange visit and Training School
STSM and internship proposals evaluated, funds	(M) Nanoscale Quantum Optics Workshop with

allocated	disruptive technology satellite event
Action members, industry contacts and non-COST institutions expanded	Action members, industry contacts and non-COST institutions consolidated
(M) ESR Workshop and training for Marie Curie and ERC starting grants	(M) Book and roadmap proposal submitted
(M) Monthly e-mail digest and quarterly newsletter activated	(M) Female-friendly environment institution evaluation started
WG and MC meeting reported / website updated	WG and MC meeting reported / website updated
Year 3	**Year 4**
STSM and internship proposals evaluated, funds allocated	STSM and internship proposals evaluated, funds allocated
(M) Book chapters and roadmap allocated	(M) ESR exchange visit and Training School
(M) ESR Workshop and training for Marie Curie and ERC starting grants	(M) Nanoscale Quantum Optics Workshop with disruptive technology satellite event
(M) Women in photonics and quantum optics: academia or industry? / Best-practice female-friendly environment awarded	(M) Book and roadmap in the press
WG and MC meeting reported / website updated	WG and MC meeting reported / website updated

G. ECONOMIC DIMENSION

The following COST countries have actively participated in the preparation of the Action or otherwise indicated their interest: AT, BE, CH, CZ, DE, DK, EL, ES, FI, FR, IE, IS, IT, LT, NL, PL, RO, RS, SE, SK, TR, UK. On the basis of national estimates, the economic dimension of the activities to be carried out under the Action has been estimated at 88 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?

Researchers working in NQO and related fields from academia and industry are a major target group, being the most direct user of the Action's results. In this regard the Action will adopt means to ensure visibility and create awareness of its achievements in NQO as outlined in sections H.2 and H.3. Students and ESRs represent another major target group. Their education, training and involvement in the field of NQO is crucial: on the one hand it will ensure the future success of NQO in academia and industry, on the other hand it will give students and ERSs the opportunity to develop skills and be trained in a topic with high scientific and innovation potential. The early involvement of industry may be more effective if besides research staff the Action will find appropriate channels to outreach technical management and human resources. The involvement of female scientists and engineers will be proactively encouraged by the Action also in the dissemination plan, as described in sections H.2 and H.3. Regional and national photonics clusters are decisive in the assimilation of the Action's results within local communities, where typically more distinctive interventions to support research, innovation and education in strategic directions are undertaken. The general public, including industry associations, academic bodies responsible for educational programs, and policy makers represent the broader circle of stakeholders. Dissemination to this target group is relevant, because positive awareness of the Action's activity may generate a large consensus and support to the field of NQO at many different levels.

H.2 What?

Peer-review scientific publications in international and high-impact journals and presentations at European and other international conferences will be disseminated to researchers working in NQO and related fields. In addition, the Action members will benefit from dedicated workshops and exchange opportunities. The Action will join forces in the WGs to publish a coherent advanced book on NQO. The involvement ESRs will be supported with individual conference grants, hands-on training events and internships in public and private research laboratories. Moreover, ERSs will organize an ERSs Workshop and visits to relevant research infrastructures, companies and research centres. Specific attention will be devoted to ESR and female scientists with a dedicated section in the website and the newsletter on where to find relevant information about training and summer schools, starting and mobility grants, and the activities available within and outside the Action. The early-involvement of industry will be promoted through direct interaction within Action members from industry and academia, a dedicated section in the website and the newsletter highlighting scientific results with a high potential for generating disruptive technologies, and disruptive technology satellite events will be collocated with the Nanoscale Quantum Optics Workshop to discuss key questions about the innovation potential of NQO with respect to state-of-the-art technology. Furthermore, the Action will prepare a research and development roadmap with the aim of prioritizing future research, training and education on topics identified to be of high scientific and technological impact. A website and a newsletter will also be set up and maintained active to disseminate the Action’s result also to national and regional photonics clusters and to the general public.

H.3 How?

The Action will effectively encourage joint-publications in peer-reviewed international scientific journals by covering part of the publication fee in open access journals and for high-impact journals it may support the free-to-read option. The Action will organize two workshops or symposia on NQO, either individually or in conjunction with existing conferences. Travel support will be made available by the Action to member participants upon application. WGs will be also encouraged to organize specialized sessions at recognized international conferences and to apply for additional funding to make this possible. Furthermore, the Action will establish connections with photonics and quantum physics research centres through the involvement of non-COST country institutions to benefit from expertise beyond the European Research Area.

Travel grants for Short-Term Scientific Missions or Summer Internships will be provided following submission of an application to the MC. Summer Internships will be possible for students who want to spend an experience on a new research topic and a number of fellowships will be made available every year. ESRs will organize an ESR Workshop nearby a partner institution, such that the attendees may visit labs and facilities. The workshops may be organized in conjunction with other associations of ESRs which may provide additional funding to invite prominent speakers from oversea, e.g. through Traveling lecturer programs. Moreover, people from industry and academia who started up companies will be invited to share their experience with ESRs.

A website will display information about the Action activities and results, such as meetings, conferences and publications. In addition, a database will be created and continuously updated to facilitate monitoring and reporting of the Action’s activities, e.g. ESR involvement, gender balance, publications, and the analysed results will be published in the website. The website will have specialized sections with dissemination material tailored for each target audience, e.g. scientific publications, projects, job openings, breaking news, conferences, educational material, etc.

A monthly e-mail digest will target the Action members and other subscribers with information on recent publications, job offers, conferences and workshops. A quarterly newsletter will summarize and showcase the Action activities (new memberships, research and technical highlights, prizes and awards, especially for ESRs and female scientists, news from meetings and conferences). The newsletter will reach a broader audience, including national and regional photonics clusters, technical managers, directors of research centres and other relevant stakeholders through e-mail and regular post (for selected contacts).

For each COST country involved in the Action, the MC members will be encouraged to promote the Action in cooperation with national and regional photonics clusters identified by Photonics 21. The Action will regularly invite external experts from academia, industry and public agencies to the plenary meetings to enhance the exchange of results and ideas, learn about progress in other fields that are nearby NQO, establish partnerships with other key players in NQO. The Action will also communicate its activities through Linkedin, Twitter and Facebook accounts. The latter may be an effective instrument to attract the interest of young students.