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Marie Skłodowska-Curie Actions

Research and Innovation Staff Exchange (RISE)
Call:H2020-MSCA-RISE-2019

PART B

Proposal title:

BoSonic STimulation of AbsOrptioN of Light by Excitons

Proposal acronym

"STONE"

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2. EXCELLENCE

2.1 Quality and credibility of the research/innovation project; level of novelty and appropriate consideration of inter/multidisciplinary, intersectoral and gender aspects

2.1.1 STONE main and specific objectives and relevance of the proposed research and innovation action in relation to the state of art

STONE is a multidisciplinary research project, involving 13 partners from Europe and Third Countries, being at the interface between energy technology, basic research and photonic engineering. STONE proposes a new technology development based on the new areas of physics, new structures and new materials. The targeted scientific and technological outcome is a new generation of photocells with significantly improved quantum efficiency.

Development of renewable sources of energy is a strategic priority in Europe and for the entire world. The Paris Agreement, which went into force on 4th November 2016, has clearly pointed out the necessity to limit the maximum global average temperature rise as close as possible to 1.5°C. The burning of fossil fuels for energy purposes is still the largest source of the world's greenhouse gas (GHG) emissions, accounting for 68%. The current policies adopted to limit GHG emissions are still insufficient to keep the temperature rise below 2°C. Therefore, the decarbonisation of our energy supply is the most important component to achieve the target. During the G7 Environment, Energy and Ocean Ministerial in Halifax (Canada, September 2018) the members recognized the need to continue developing sustainable energy usage. In this framework, the advent of advanced renewable energy technologies will alleviate pollution, reduce carbon emission and provide energy savings.

Between the many forms of renewable energy, *photovoltaics (PV) is a key technology option that offers a huge global and European potential as a secure and sustainable energy system*, since it provides an alternative means of producing essential electric power from sunlight without further endangering the delicate balance of our fragile ecosystems. The latest edition of the *Joint Research Centre PV Status Report* [1] released during the Conference of the Parties (COP 24) in Katowice (Poland), gives an overview of current trends in the industry, in the context of the climate-related commitments, such as reaching a 32%-renewable energy target in 2030 in the EU. At the end of 2018, worldwide solar PV power is expected to have exceeded 500 GW capable of producing roughly 2.8 % of the worldwide electricity demand. According to market forecasts, the installed PV power capacity of 408 GW at the end of 2017 could triple by 2023. PV is one of the fastest growing industries in the world, and at present, the commercially available solar cells are based on silicon crystals and on thin films technology. The main production centres are located outside the EU and over the last 15 years, production volume of solar PV has been increasing with an annual growth rate of over 40 %. As indicated, in the report, in the last three years the developing economies have kept investing more in renewable energy capacity than the developed ones, being **China** the world leader manufacturing country for solar cells and modules followed by Taiwan and Malaysia while Europe is currently below 2% [1]. This is why China is one of the 3 Third Countries (TC) chosen to be part of this project, making possible to closely collaborate with European organisations and specific research units.

Concerning PV technologies, Europe in the last 10-15 years secured a leading position in the research on III generation (GEN) PV and more specifically on solar cells based on **O**rganic and **H**ybrid Organic/Inorganic **M**aterials (OHM) [2]. Several European academic and industrial R&D centres (some of them are partners in this proposal) are developing state of the art high efficiency PV cells and modules based on OHM. Recently, the advent of Hybrid Perovskites has revolutionized the field of solution process III-GEN PV reaching certified efficiency similar to those of silicon. The world record efficiency of a large area (> 50 cm^2) perovskite module, E_{ff}= 12.5%, has been indeed obtained by the CHOSE center of the MIFP partner [3].

OHM is widely discussed now as a valuable alternative to silicon but several obstacles such as the low efficiency and life-time, still block the full-scale development of organic photovoltaics. Unlike silicon, absorption of light in organics does not produce the free electron-hole pairs, but rather bound electrically neutral states known as Frenkel excitons. Frenkel excitons are characterised by a Bohr radius of less than 1 nm and the effective mass exceeding the free electron mass. They obey bosonic statistics and strongly couple to light, resulting in the appearance of Frenkel-exciton polaritons characterised by a much lighter effective mass. Frenkel-exciton polaritons are subject to the Bose-Einstein condensation in molecular crystal microcavities [5]. In a bulk-heterojunction organic cell, the dissociation of Frenkel excitons is realized at the junction between two different organic materials. The carriers are collected at the electrodes after traveling through the disordered organic material. The short lifetime of the exciton and reduced transport in the disordered media are responsible for the low efficiency of these cells [4]. Moreover, the metallic contacts used at present absorb light themselves which also reduces the quantum efficiency of photocells. Till now OHM have been used in almost conventional photovoltaic concepts by simply replacing silicon [6]. This means that the intrinsic properties of OHMs have never been exploited to identify new processes in order to boost the photovoltaic effect. The present proposal is aimed at the revolutionary improvement of the performance of OHM PV due to the use of new materials and new physical effects, belonging to different fields of physics and used in different areas of technology.

The starting idea [7] of STONE is to **take advantage of the bosonic properties of Frenkel excitons and use them to achieve the stimulated absorption of light.** [9-11] The groups composing the consortium are expert in the theoretical and experimental realization of light-energy conversion devices based on different types of devices [2-3,6-7]. Here **we propose to implement the accumulated knowledge of bosonic stimulation physics in inorganic materials for the realisation of organic photocells with record quantum efficiency**. The photocells based on stimulated absorption are expected to possess a dramatically enhanced quantum efficiency with respect to traditional photocells based on the spontaneous absorption of light. The expected difference is as huge as the difference between a light-emitting diode (LED) (producing light by spontaneous emission) and a laser source (producing light by stimulated emission) [12,13]. Furthermore, we take advantage of the experience accumulated in recent years to produce the optically transparent Ohmic contacts, based on diamond-like carbon (DLC) [14] with embedded carbon nanotubes [15] or 2D material layers [16-18] and to operate with the hybrid and organic microcavity with extremely high-quality factors (see the scheme in Figure 1.1, left). We emphasize the important role of photonic confinement in our photocells, which allows for resonant generation of a macroscopic number of Frenkel excitons in the same quantum state during the life-time of the corresponding photonic mode. In turn, having been created, the macroscopic population of Frenkel excitons reproduces itself by stimulated absorption of new solar photons (see the scheme in **Figure 1.1**, right-side).

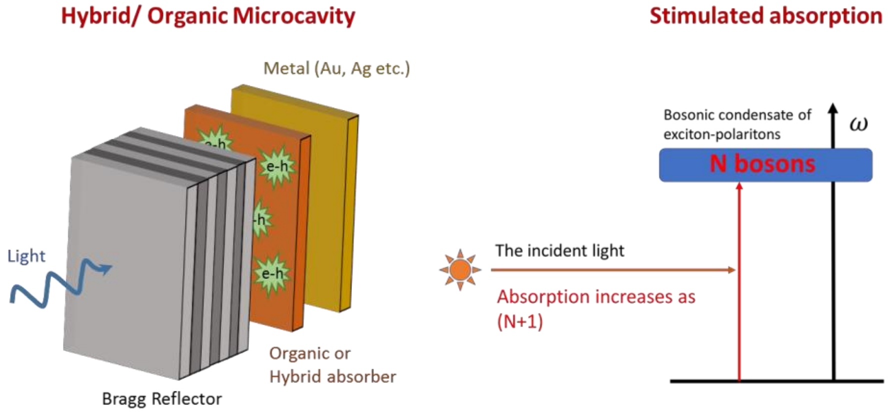

Figure 1.1. Tamm plasmon microcavity structure suitable for the stimulated absorption of light by bosonic condensates of exciton-polaritons (left); schematics for the stimulated absorption (right)

The qualitative analysis shows that the most important condition to be satisfied is to ensure that exciton states of interest are characterized by sufficiently long non- radiative lifetimes. Sufficiently long means about 100 ps according to our estimations [ref], based on the average intensity of the day-time light in the Mediterranean region. Such long-living excitons would form exciton-polariton condensates similar to those studied in polariton lasers under day-light optical pumping. Another important practical issue is linked with a necessity to have a significant absorption within the large frequency range of the visible and near ultraviolet light, in order to avoid losses of the solar energy. This is partly resolved because of the natural inhomogeneous broadening of Frenkel exciton resonances in the most part of OHM, which is of the order of several hundred meV, typically. In order to further extend the frequency range of efficient stimulated absorption and to control the life-time of the concerned exciton states we propose using the OHM cavity as a main element of the solar cell. It is well known that dielectric or semiconductor optical cavities are characterized by discrete optical spectra composed by a multitude of sharp resonances. These modes may have a quality factor (ratio of the mode frequency to its linewidth) of the order of 10^5-10^6, which ensures the photonic life-time of 100 ps or more. In the same time, the finesse of these modes (ratio of the frequency splitting between different modes to the linewidth of the mode) remains quite low (of the order of several units). This is why a cavity filled by an absorbing aggregate would absorb light at a huge multitude of discrete frequencies corresponding to these modes. The life-time of excitons coupled to each of these modes would be long enough to ensure stimulated absorption. Between these selected frequencies the absorption of light would be still spontaneous.

Given the state of art and the proposed research and innovation programme described above, we have set **specific and targeted objectives** to be fully reached during the running of the project:

1. Demonstration, for the first time, of the stimulated absorption of light in optical cavities with OHM (**WP2**);
2. Definition of a theoretical/simulative model of organic and hybrid organic-inorganic photocells based on novel structures and materials (**WP1**);
3. Optimisation of organic and hybrid structures for photovoltaic applications (**WP3**);
4. Reduction by more than 50% the content of Pb with respect to a conventional perovskite solar cell by using thin layer with stimulated absorption (**WPs 1-3**);
5. Final development of the **prototype of a photocell** based on stimulated absorption of light (**STONE solar cell)** with a quantum efficiency > 10**%** (**WP 3**);
6. Training and Transfer of knowledge among partners belonging to different communities of interests all over the world (**WP5**)

2.1.2 STONE methodological approach highlighting the types of research and innovation activities proposed, and their originality

The proposed **scientific and technological methodology will be divided into two main phases**. During the first one-year phase, we will focus on constructing reliable microscopic modelling and the signatures and demonstration of the stimulated absorption mediated by the Bose condensate of Frenkel excitons. At the same time, experimental partners will identify the most suitable materials and will fabricate model structures to test each part of the solar cell. In the second phase, we will exploit this knowledge to optimize the organic photocells based on the optical cavities and realize the first device prototype at the end (*see also Section 3.1 Work package description).*

Phase 1: The proof-of-concept demonstration device we aim for here is formed by an absorber in a microcavity. Two different types of structure will be considered, exploiting Frenkel exciton formation; namely an organic molecule-based microcavity and a hybrid organic/inorganic Perovskite microcavity. Hybrid Perovskite materials, such as $CH_3NH_3PbI_3$ have shown remarkable photovoltaic conversion [19] as well as polariton formation in microcavities [20], thus they are the ideal candidates for stimulated absorption of light investigated in the present project. We shall measure a photocurrent generated by an available laser as a function of the frequency and of the intensity of the laser light. A threshold-like superlinear dependence of the photocurrent as a function of the laser intensity at the discrete frequencies, corresponding to the cavity modes of the microcavity, would be a “smoking gun” for the stimulated absorption. Full numerical simulation of the generation of Frenkel excitons, their interaction with acoustic phonons, light emission and dissociation of excitons by the external electric field. Input from first principles microscopic calculations will be given by MIFP partners.

Phase 2: Towards the device prototype. In this phase the optimized microcavities will be assembled with the metallic and semitransparent carbon or conductive oxide contacts. Charge extraction will be ensured by the presence of Charge (hole and electron) Transporting Layers (CTL). Spiro-OMeTAD or P3HT can be used as hole CTL while TiO2, SnO2, PCBM for electron CTM. We shall do the test photovoltaic measurements in order to optimize the fabrication technology. The numerical code will be extended to describe the current distribution in the microcavity and in the contacts (see Figure 1.2).

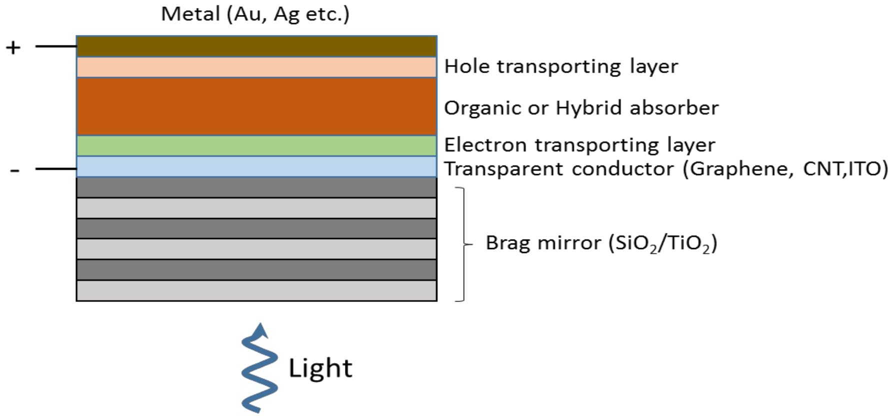

Figure 1.2. Scheme of the proposed photovoltaic device structure composed by an organic or hybrid organic inorganic microcavity, where the bosonic condensate of exciton polaritons will be created by resonant optical pumping, an upper metallic contact and a lower transparent carbon contact (or ITO). Dissociation of polaritons is achieved by the selective contact made by the hole and electron transporting layers.

Concerning **the peculiar properties of the novel mechanism** proposed for the photovoltaic technology we should consider that the stimulated absorption would permit to reduce enormously (by more than a factor of 10) the thickness of the absorbing layer. This would have several advantages: i) *the reduction of costs* and ii) *for perovskite solar technology it would allow decreasing (by more than 50%) the content of lead* (Pb) which is the major obstacle for the industrial exploitation of Perovskite solar cell.

We truly believe that a total duration of the project of **36 months** is realistic to reach the specific objectives that we have envisaged: the planned scientific activities of the consortium (i.e. *the two phases indicated above*) are grouped into **3 main research Work Packages (WP1 to WP3).** The overall workplan includes also a dedicated WP4 on "*Communication, dissemination and exploitation* of results", WP5 on "*Training and Transfer of knowledge*" and WP6 "*Project management*:

Table B1 – Work Package (WP) List

WP N	Work Package Title	Activity Type	Number of person-months involved	Lead beneficiary	Start month	End month
1	Theoretical and numerical modelling of light-matter coupling in novel structures and materials for stimulated absorption photocells	Research	58	WIAS	1	36
2	Technology and Fabrication of organic and hybrid photocells based on stimulated absorption	Research	55	UTV	8	36
3	Strong coupling in organic and hybrid organic-inorganic structures	Research	48	CNR	10	36
4	Communication, Dissemination and exploitation of results	Communication Dissemination	18	MIFP	1	36
5	Training and Transfer of Knowledge	Training	19	MIFP/UTV	3	36
6	Project Management	Management	21	UTV	1	36

.2.1.3 Inter/multidisciplinary types of aspects involved

STONE proposes *a revolutionary new concept of photovoltaic devices which is based on a combination of organic and inorganic materials and structures, and on the use of nanophysics technologies in combination with photonic engineering*. Each of these constituents is being developed in specific communities (PV, Polariton and stong- coupling, Bose-Condensation) but they have never been connected so far.

The multidisciplinary nature of this proposal served as a strong motivation for the design of the present consortium, which comprises experts from different areas and sectors of research, some of them already strongly collaborating. To achieve the project goals, a consortium enriched by experts from different

areas, and thus capable of solving both fundamental and applied problems, has been assembled. In fact, the main PIs involved are well recognized material scientists and engineers (e.g. Prof M. Scarselli, Prof. M. De Crescenzi), experts in nanoscience and nanotechnology (e.g. Prof. A. Di Carlo), theorists (as Profs A. Kavokin and O. Pulci), materials characterization (Prof. G. Pozina), Solar cell characterization (Dr. L. Cinà) and those with more expertise on Technology Transfer (Prof. G. Eramo). *(see also Tables B2.2. and B4.c*)
To sum up, this consortium will **tackle the multidisciplinary research topics necessary for fabricating a new generation of organic solar cells characterized by a record quantum efficiency working on the principle of stimulated absorption**.

2.1.4 Gender aspects

One of the latest reports of *EUROSTAT on Women in science and technology*[1] shows that still in 2016 from the 17 million scientists and engineers in the EU, 60% were men and 40% women. Of course the ratio of 40%, compared to oldest statistics, it is a good advancement so far, but much still needs to be done in terms of gender management and female par5tcipation in research. That is one of the reasons why we are particularly sensitive about gender issues and aware of the specific challenges that women meet when pursuing a scientific career. In our consortium we have chosen to delegate the coordination to a **female professor, Manuela Scarselli**, and we count a total of **9 female PIs**, dislocated in the 13 participating organisations' team of research *(see also Table 5*). We also have set an internal rule on secondments (that will be part of the signed Partnership Agreement) to try to keep the % of female researchers, and staff in general, involved in the secondments, to 40%. This makes our Consortium well balanced and guarantees attention and care towards gender issues.

2.2. Quality and appropriateness of knowledge sharing among the participating organisations in light of the research and innovation objectives

2.2.1 Approach and methodology to be used for knowledge sharing

Knowledge sharing will be done through the (1) **secondments (**in **WPs 1-3)**, (2) **networking**, in particular through **WP5** (training, seminars, schools, conference attendance, special workshops organized by the Consortium, etc.) and finally (3) through **the Project web site**.

(1) Research knowledge sharing:

- secondments within WP1: The seconded ERs and ESRs within WP1 will share their knowledge of theoretical modelling of light-matter coupling in novel structures and materials for organic/inorganic photocells, discuss and find optimal parameters for proposed structures such as quantum efficiency of photocells based on photonic cavities containing either organic or inorganic absorbents. The feedback from the experimental studies of the proposed structures in partners laboratories will help refining the modeling for further studies;

- secondments within WP2: The detached personnel will present knowledge sharing in fabrication of organic and hybrid organic/inorganic microcavities for stimulated absorption. The seconded ERs and ESRs will identify the most suitable materials (for contacts, CTL, absorber) and will make use of optimized design performed in WP1 to fabricate the first prototype of the project photocell.

- secondments within WP3: The seconded ERs and ESRs will share the knowledge of the photophysical experimental research and will work in the laboratories with high quality set-up world leading in the Bose condensation of exciton-polariton in microcavities.

Innovative knowledge sharing will be realized through the secondments within WP2-WP3. The new physics of energy transfer within hybrid organic-organic and organic- inorganic microcavities and possible polaritonic control of molecular transitions relevant to photoabsorption will be explored. This research will be completely innovative and will enable the experience and expertise of all project participants.

- secondments within **WP4** and **WP5**: WP5 will devoted to organizing the activities related to the transfer of the best skills and practices between partners, Seconded staff will get a proper Transfer Technology Coach to develop proper skill to exploit research results (WP5). Communication and Outreach activities will be performed to communicate research result in a wider context and enhance contacts with interested industries (WP4).

The project planned staff exchange is summarized in **Table B1.1** (*aggregate data as set in Forms A3 submitted on line*):

[1] Available at **https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20190211-1,** published in February 2018.

Table B1.1: Project planned secondments[2]

To: / From:	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	WIAS	GTU	LEPL	VLSU	PHON
UTV													
MIFP													
CNR													
CICCI													
LIU													
ALM													
INP													
BSU													
WIAS													
GTU													
LEPL													
VLSU													
PHON													

(2) Networking: besides secondments, a special emphasis will be put on the organization of project meetings (4 in total) with participation of the external experts, including industry experts, for the independent assessment of the project research program and the exploitation possibilities. The regular network meetings will take form of either the working meetings attended by the staff involved in the research program of the project, or open international conferences and schools. The experience of MIFP in organization of international conferences will play a positive role here and makes us confident that the new envisaged conferences will help dissemination of the results of the present project. (*see also sections 3.3.and 3.4 for details on project communication and dissemination)*

(3) The knowledge sharing between the partners of this consortium will be achieved through a number of specific measures including the creation and regular updating of the **project web-site**, which will serve also as a portal for the exchange of files and documents as well as the Web-forum.

The sharing of knowledge is assured by the exceptional quality of the scientific staff being exchanged. We underline that all group leaders will take an active part in the exchange program and engage themselves to spend their sabbatical years in the partner organizations. The massive participation of young researchers, technicians and some managers will make the collaboration full scale and the transfer of knowledge rapid and efficient.

2.3 Quality of the proposed interaction between the participating organisations

2.3.1 Contribution of each participant in the planned project activities

The justification of the present program of international staff exchanges comes from a complex and challenging subject of our research, which requires a highly coordinated effort from the experts in growth, fabrication, optical spectroscopy and theory. To this end, **STONE consortium is made up by a total of 13 participating organisations** coming from 2 EU Member States (Italy, Sweden), 2 EU Associated Countries (Israel and Georgia) and 3 Third Countries (China, Russia and Belarus), of which **3 non-academic organisations**. The majority of the partners have already scientific collaborations in place, while some other collaborations will be created thanks to this project (see **Figure 1.7**). Their joint human resources form a critical mass needed for the achievement of a major breakthrough in solar cells and the realization of the ambitious objectives of the project. The expertise of the participants and their contribution to STONE is briefly presented in **Table B1.2** below *(see also Part B2 Table 5 Participants' description)*

[2] The indicated are the secondments funded by the project; TC-TC and EC-EC same sector trips are also envisaged but not counted in the table and nor financed by the EC.

Table B1.2 Participating organisations' expertise and their contribution to STONE

N.	Name	Main expertise	Main PI unique expertise to be used in STONE	Contribution to STONE
1	UTV	UTV The activities of the UTV node belonging to the Physics Department are both experimental and theoretical. The Theory group belongs to the European Theoretical Spectroscopy Facility (ETSF, www.etsf.eu) and are experts of first principles calculations, based on DFT and Many-Body approaches, of excitations in complex systems. The experimental activity ranges from the synthesis, characterization and applications of carbon nanomaterials as well as novel 2D materials. Since 2006 UTV has established the "Centre for Hybrid and Organic Solar Energy" (CHOSE). The centre develops organic and hybrid organic-inorganic technologies both at research and industrialization level.	**Dr. Manuela Scarselli,** Senior researcher, Head of UTV node and project scientific coordinator. She is an expert of the growth of nanostructured materials applied in the realization of organic devices and their structural, electronic and optical characterization. She will coordinate the theoretical and research activity of the unit.	UTV in collaboration with LIU, SO, BSU, MIFP will develop the new solar cell based on stimulated absorption of the light with organic molecules and hybrid perovskites. The CHOSE laboratory will contribute to the design, development and characterization of nanostructured and organic semiconductor devices. UTV will be also involved in the theoretical and numerical activity by using Density Functional Theory and the Multiscale software TiberCAD that can model electronic and optoelectronic devices.
2	MIFP	MIFP is an international research institute including currently 207 members with an institute h-factor of 153 (Web of Science, 2017).	**Dr. Giuseppe Eramo** is the President of the Mediterranean Institute of Fundamental Physics. He is a permanent Organising committee chair of the series of international conferences on the Physics of Light-Matter Coupling in Nanostructures organized every year since 2000 in different countries of the world. He also organizes yearly International Nanophotonics & photovoltaic schools, Terametanano conference and the international workshop on 2 dimensional cristal, March meetings of the MIFP.	MIFP will contribute to the definition of the theoretical model and the comparison between theory and experiment. Based on the large experience in scientific event organization, MIFP will be responsible for the dissemination activities and the organization of project/network workshops.
3	CNR	A multidisciplinary centre for research and technology development at the nanoscale.	**Dr. Daniele Sanvitto** is the senior scientist leading the group of *Advanced Photonics* at CNR NANOTEC. He is an expert of advanced studies in photonics and ultrafast spectroscopy. He is author of more than 200 papers which received more than 5000 citations (h-index 40). He was awarded an ERC StG (POLAFLOW) and an ERC POC (ElecOpteR).	The Advanced Photonics Lab. will study light matter phenomena related to the strong coupling regime (polaritons) thank you the numerous facilities for ultrafast photoluminescence measurements with high spatial and temporal resolution. The research unti is also expert in the study of the optical and optoelectronic properties of semiconductor nanostructures, hybrid perovskites for nanophotonic devices.
4	CICCI	CICCI is a company involved all-in-one measurement platform for mesoscopic solar cells and equipment for cell fabrication.	**Lucio Cinà, PhD** CEO of Cicci Research, has 8 years of experience in characterization and process automation for mesoscopic photovoltaic devices. Creator of a fully programmable and modular testing platform *(Arkeo)* for optoelectronic devices. His expertise area is the design and fabrication of advanced characterization tools.	CICCI will be involved in the photocell fabrication and characterization. CICCI will participate to the team for Technology Transfer coaching and will contribute to the exploitation plan.

5	LIU	LIU has strong experience in the field of novel applications based on advanced material nanotechnology with great expertise in development of strategic materials for energy saving such as GaN and SiC. LIU has well equipped laboratories with advanced optical, structural and electrical characterization.	**Prof. G. Pozina** has great expertise in the development of strategic materials for energy saving such as GaN and SiC. She has experience from both academia and industry. She has coordinated many European research projects.	LIU will contribute to the fabrication of the project photocell and its characterization using optical and electrical probes. LIU will be also involved in the photophysical characterization of strong coupling in organic and hybrid microcavity
6	ALM	ALM has experience in research and innovation in energy and environmental materials based on silicon carbide and graphene.	**Dr. Mikael Syväjärvi** has experience in research and innovations in energy and environmental materials based on silicon carbide and graphene. He develops materials production process of 3C-SiC for power devices. He was one of co-founder of Graphensic AB which applies a High Temperature Graphene Process to produce high quality large area epitaxial graphene on silicon carbide wafers.	ALM will produce high quality large area epitaxial graphene for the composite photocells.
7	INP	BSU expertise is in materials and for opto- and microelectronics applications	**Prof. Sergey Maksimenko** is principal researcher in the NanoElectroMagnetics lab at the INP. He is an expert in theoretical electrodynamics of low-dimensional materials, and their low-frequency, microwave and THz experimental probing.	INP node will provide unique transparent conducting electrode for the fabrication of the photocells
8	BSU	It is involved in the study of optical, chemical properties of the organic and hybrid organic/inorganic materials.	**Dr. Mikhail Tivanov)** is Dean of the Faculty of Physics at the BSU.is an expert in semiconductor materials fabrication and characterization for solar energy devices.	BSU will characterize the organic/inorganic materials constituting the photocells and their photoresponse.
9	WIAS	WIAS is a non-profit Chinese research institute that is dedicated to the advancement of natural sciences and the frontiers of engineering disciplines	**Prof. Alexey Kavokin**, h=53 (Web of Science), h=63 (Google scholar) is a world leading theoretical physicist, expert in Polaritonics. Field of expertise is physics of light-matter coupling and solid-state physics, both theoretical and experimental.	Research activity and key contributions are in many-body quantum physics of excitons and exciton-polaritons. The research group will be involved in the theoretical investigation of the light-matter coupling and solid-state physics, both theoretical and experimental
10	GTU	GTU is one of the largest educational and scientific engineering institutions in South Caucasian region. GTU has extensive experience in design of semiconductor optical and microelectronic devices, modern technology methods of their production, in the research field of electro-physical and optical properties of advanced materials. It has experience in sensory techniques and their design as well as their using in different sensor systems	Prof. **David Tavkhelidze,** Head of Research Management Department has extensive experience in design of semiconductor optical and microelectronic devices, modern technology methods of their production, in the field of researches in electrical-physical and optical properties of the contemporary materials.	Their expertise will be exploited for the fabrication of the photocell components and their electrical characterization
11	LEPL	The LEPL “Optics” Institute can synthesize nanomaterials with enhanced physical properties, including high-quality catalysts, nanoparticles with magnetic properties.	**Dr. Zaur Berishvili** is the head of the research group of OPTCA Institute. The research activity is mainly devoted to Semiconductor technology and electronic equipment materials.	The research unit is capable of applying planar magnetron sputtering in a vacuum for obtaining dielectric optical coatings, as well as metallic layers, that can will be tested in the different solar cell prototypes..
12	VLSU	Vladimir state university named after (VlSU) is the leading institution of higher education in the Vladimir region. The main	**Prof. Sergey M. Arakelyan,**Head of the department of Physics and Applied Mathematics. He has a wide range of scientific interests in	It will supply nanoscale materials (semiconductor, metal-carbon compounds, colloidal nanoparticles) and characterize the morphology of

		direction of research of the VISU team is the synthesis of nanoscale materials (semiconductor, metal-carbon compounds, the formation of colloidal nanoparticles) and the study of their optical-physical properties.	the field of nanostructure physics and laser interaction with the substance	the device interfaces related to the optical-physical properties of the prototypes.
13	PHO	It is a startup company of Israel Center of Advanced Diamond Technology (ICDAT).	Dr. Joseph Kaplun is CTO and co-founder of Phononics Technology, has 35 years of experience in Si, compound and wide band semiconductors processes and devices development and transfer to production, including synthetic based on chemical vapor deposition (CVD) of diamond films for electronics applications.	The company will study the thermal losses of the porotypes and suggest innovative solutions for overheating prevention. In addition, it will also test diamond or other thin insulating materials for cells encapsulation.

2.3.2 Justification of the main networking activities

Many members of the Consortium know each other well already and have had numerous opportunities to meet in various scientific conferences. The present consortium has been carefully composed in order to combine the efforts of world leading theoreticians with the experimental research on the forefront of modern solid-state physics together with SME involved in Technology Transfer Activities as well on equipment for solar cell production. The complementarity of theoretical, experimental and Technology Transfer groups is key to the success of the present program. Basically, each specific task of the project will be developed by several groups following the cycle: theoretical prediction – design of the samples – growth and fabrication – experimental study – analysis of the data – corrections to the model parameters – feedback to the growers (see **Figure 1.3**). The synergies between partners will strongly contribute to the success of this proposal requiring the joint forces in one the most rapidly developing research fields in physics.

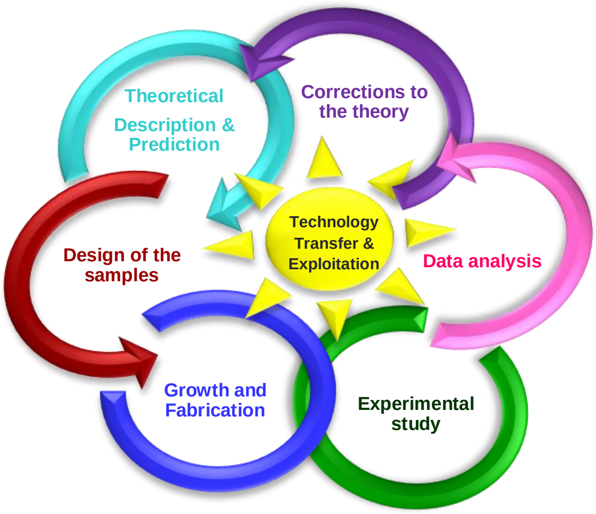

Figure 1. 3: Research cycle of the project: from theoretical prediction to optimized sample design

3. IMPACT

3.1 Enhancing the potential and future career perspectives of the staff members

The main expected impact of the STONE will be to develop a **highly skilled pool of *young and experienced researchers*** capable of performing internationally competitive research in one of the most rapidly developing areas of modern science and technology.

Each **staff member** involved in the exchange programme of this project will therefore have the opportunity to:

- Receive the best possible training in their main domain of expertise;
- Receive a strong inter-disciplinary training through secondments, training visits and network events;
- Enjoy personal contact with some of the best international level scientists active in the field.

As an **immediate benefit** for young researchers, the network will generate a large number of **new collaboration links** between groups, which were previously either competing between each other or working on similar subjects in physics but with different materials and structures. It will also bring together **experienced researchers and technicians** from groups working on different realisations of photovoltaic cells and create a scientific community, which **would not exist otherwise**. The career perspectives of the project's young researchers will be strongly improved by a rapid expansion of the new research area where they will have received the highest quality of training. Providing generic skills, thus improving significantly the employability (including industrial focus) of the young researchers, trained by the proposed Network,

is one of the central goals of our training programme.
The project will also assist **young researchers to find a permanent job in either the academic or industrial sectors.** In this context we shall emphasize the training in entrepreneurship among other complementary skills offered by the designed training programme: the entrepreneurial mindset of our staff developed via the staff exchange programme will help shape the Optoelectronics industry in the next 5-10 years.

3.2 Developing new and lasting research collaborations, achieving transfer of knowledge between participating organisations and contribution to improving research and innovation potential at the European and global levels

3.2.1 STONE contribution to the improvement of the research and innovation potential

As a **longer-term benefit** of this network, a **breakthrough in optoelectronics manifested by appearance of new devices on the market will create a great number of new jobs**. Special attention will be also given to new generation of experts in photovoltaics. One of the project objectives is to create **a highly skilled pool of young researchers** capable of internationally competitive research in one of the most quickly developing areas of modern science and technology. The multidisciplinary nature of the project and a close collaboration between academic and industrial partners will help to develop its employees a set of transferable skills which can be applied to a wide range of different jobs at photovoltaic market. The project specific knowledge obtained by the employees will increase their employability at photovoltaic market[3]. Hitherto non-silicon photovoltaic market has been underdeveloped because of several technological issues (such as the low efficiency and life-time of the solar cell components) which are the main objectives of the proposed project. However, a constant growth of this market is envisaged as efficiency of organic and hybrid ortanic\inorganic solar cells increases. This will inevitably increase demand for specialists understanding the basic principles of such device operation. In this context, we shall emphasize the training in entrepreneurship among other complementary skills offered by the proposed programme,

3.2.2 Self-sustainability of the partnership after the end of the project

The common training background and personal contacts developed within the network will ensure long lasting co-operation between participating organisations. Many of the present partners have a significant experience of scientific collaboration and multiple joint publications. These collaborations will last beyond the end of this project and will necessarily involve new partners as the subject of the present network is of a high interest for the optoelectronics industry worldwide. *The project will create a critical mass needed for a major breakthrough in photovoltaics.* The progress in this area is instrumental for development of alternative energy sources and is of a high interest for the society. **Figure 1.4** below clearly represents the networking and collaboration activities already in place among partners and those (i.e. organisations from Georgia, Russia and Israel) that will be strengthen during and after the running of the project:

Moreover, the research links established during this project would make it possible to move the research in photocells towards the realisation of the first practical photocell based on stimulated absorption of light. This in turn would secure further funding for this research from the photovoltaic industry (for example from EPM and ISA in Medellín-Colombia, which are enterprises involved in generations and transport of energy, 3SUN in Italy, Trina Solar in Switzerland, EDF (Photowatt) in France, AZUR Space Solar Power in Germany etc). Such developments would ensure the lasting collaboration, and further development of the links between the four partners and the two EU academic institutions beyond the end of the project. The research collaborations of the consortium will further expand also across the whole nanophotonics and PV community in the EU through our association with the Nanophotonics for Energy Efficiency Network of Excellence.[4]

[3] *Global Market Outlook For Solar Power 2017-2021, SolarPower Europe* http://www.solarpowereurope.org).
[4] https://cordis.europa.eu/project/rcn/93819_en.html, https://www.facebook.com/NanoPhotonics4Energy/.

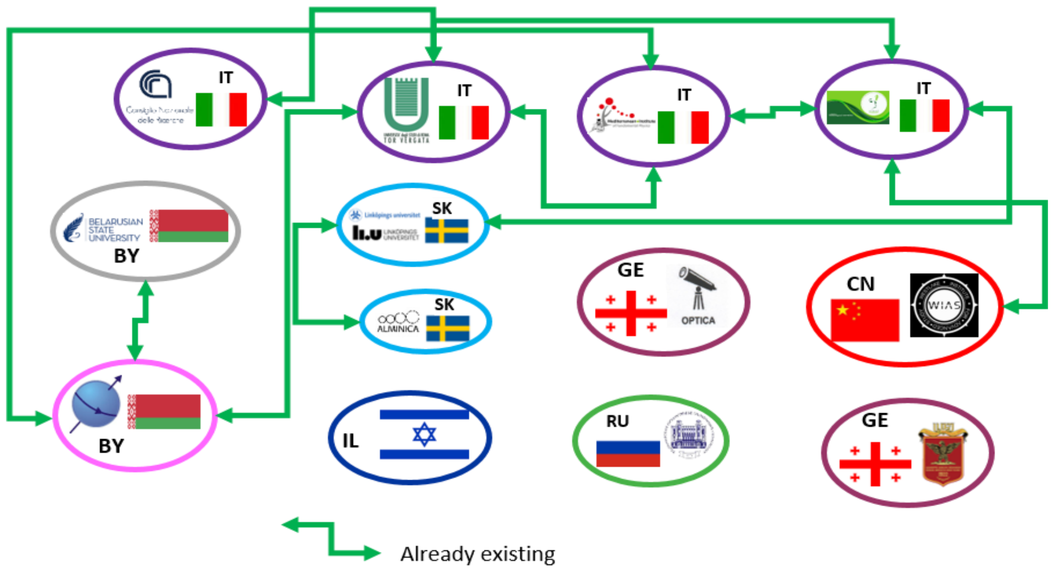

Figure 1.4 Sketch of networking activities (thick green arrows: already existing scientific collaborations)

3.3 Quality of the proposed measures to exploit and disseminate the project results

3.3.1 STONE Dissemination Strategy

STONE has a defined strategy for the dissemination of the results (see D 4.1) to be run systematically and timely by all beneficiaries and partners of the project. The strategy will fully entail the channels, tools and target audiences with a predication of impact factor as well.. It will be finalised during the first project meetings (at KoM in M1) and the implementation and quality of the activities monitored by the WP4 Leader (MIFP). It will entail the types of events to be actively present for dissemination purposes, the publication of results (which journals and how many articles per year) and the organisation of the project dissemination events, with clear target groups.

The main dissemination activities will be performed through the participation to a series of **International Conferences** on the Physics of Light-Matter Coupling in Nanostructures (PLMCN) organised yearly. Prof. Alexey Kavokin (MIFP) is a permanent Chairman of this conference series, and other members of the consortium are directly involved in the organizing committees. We shall also disseminate the results of this project at the major external conferences (IEEE, APS, SPIE and MRS meetings and ICPS, EP2DS and OECS conferences)).

The *organisation of the network events will be the responsibility of the organizing committees specifically created for each event*, and will typically include the Coordinator, the relevant node leader, and local financial and administrative staff. For example, MIFP is in charge of organizing highly-popular **annual International School on Nanophotonics Photovoltaics** (ISNP). The latest ISNP took place in Cefalu, Sicily, in September 2016, with all organization provided by MIFP. These meetings will be added to the conferences (PLMCN, OECS) in 2020 and 2021 where sessions will be devoted to topics related to our project. Moreover, STONE will allow all participants to take part in OECS-conferences and other meetings, organized outside the consortium.

The publication of results will be done at conferences and in journals with high impact factors. The project commits *to publish at least **15 articles** in peer reviewed journals and conference proceedings*.

3.3.2 How results will be taken up and used: STONE Exploitation Strategy

STONE will opt for **Open access journals**. The reliable publishers following the principles of transparency and best practice in scholarly publishing will be identified with the help of Directory of Open Access Journals (DOAJ https://doaj.org/). DOAJ is a community-curated online directory that indexes and provides access to high quality, open access, peer-reviewed journals.

Many publisher's policies allow self-archiving by the authors at their personal and institutional web pages. Thus, for the dissemination of the project results the preference will be given to the "green" and "blue" publishers as per RoMEO color categories (http://www.sherpa.ac.uk/romeoinfo.html). However, paper copies uploaded to authors' own webpages are less stable and harder to find than documents uploaded to well-indexed repositories. Therefore, in addition to the self-archiving on personal and institutional web pages, we will make our papers freely available online in the open access repositories.

We will use **Dissemination services** that helps to find those published papers which comply with the green open access policy and allows one an easy submission of the found papers to well-indexed freely accessible online repositories. Where it is possible and does not contradict the publishers' policy, the results of the published research originating from this project will be uploaded to open repositories. In this way the data generated by consortium will be made available to stakeholders for a suitable period beyond the life of the project. This will also increase the awareness of the general public and stakeholders of the cutting edge scientific results.

3.3.3 Expected impact of the proposed measures

The Call MSCA-RISE-2019 sets among its targets: (1) enhancing cooperation and transfer of knowledge between disciplines; (2) increasing employability of the staff both in and outside academia; (3) development of the knowledge-based economy and society; (4) increase in international, interdisciplinary and intersectoral mobility of researchers in Europe etc.

These are all goals that STONE foresees to achieve thought the dedicated dissemination strategy and plan to be finalized and agreed upon by all participating project organisations that are all fully involved in the foreseen activities. The consortium commitment to open access policy will urge cooperation and transfer of knowledge between industry and academia as well as between physics, material science and engineering disciplines. The training and outreach activity planned within the project will contribute towards awareness of the general public and specialists in a new area of the organic photovoltaic thereby contributing to the development of the knowledge-based society and economy in EU and increase of the attractiveness of its R&I.

The diverse measures to exploit and disseminate the project results are carefully designed to develop a set of transferable skills of the involved staff members which will lead to their improved employability and career prospects both in and outside academia. It should be also pointed out that the above described dissemination strategy will require international and interdisciplinary mobility of researchers which will foster international and intersectoral collaborative networks.

The high visibility of the project results and of the researchers involved will serve the final goal -- visibility towards commercialization and start-up companies oriented on solar cells. *This will certainly work towards a European industrial competitiveness and growth.*

3.3.4 Intellectual property rights aspects

Care will be taken regarding intellectual property by setting up a special task force in the Project Board in order to follow the formal procedures. This task force will work closely within the Project Board (PB), see also section 4.2.

Confidentiality: Each partner will treat information from other partners as confidential and not disclose it to third parties unless it is obvious that the information is already publically available.

Ownership of Knowledge: Knowledge is owned by the partners who carried out the work generating the knowledge. If such a piece of knowledge is jointly generated, it will be jointly owned, unless the concerned contractors agree on a different solution. If a partner wishes to assign any knowledge to a third party, he should inform the other partners and request their consent, which should not unreasonably be withheld.

Patents: When knowledge developed within the project is capable of industrial or commercial application, it will be protected. Partners are encouraged to make applications for patent or similar form of protection.

Access Rights: Partners grant to each of the other partners royalty-free access right to knowledge generated in the project to the extent needed to successfully perform the project. Access rights to a partners pre-existing knowledge for use outside the project is, when needed and only to the extent necessary to make use of the project result, given on preferential conditions to the other partners.

IPR will be also dealt in the duly signed Partnership Agreement under the articles 9 to 12 (sees section 4.2 for more details).

3.4 Quality of the proposed measures to communicate the project activities to different target audiences

3.4.1 STONE Communication Strategy

The project Communication strategy**,** to be finalized in M1 at the KoM (D 4.1) will be dedicated to the public at large at national and international level: the project participants will be active in this area by producing, for example, non-technical brochures, newspaper articles and providing television presentations. Newsletters, which are targeted especially to the industry will be used more extensively and should contain clear statements of '*what we can do to help your business'*. To create awareness among the general public about the research work performed and its implications for citizens, as well as general understanding about the implication of science in society, **STONE** communication will be based on a solid communication strategy which action plan will be continuously revised by the task leader (WP4, Task leader MIFP) and fully involves the project participants at all levels

In particular, the project will have **two main press releases**, one at the beginning and one at the end, drafted by the professional PR office of MIFP. We also plan to arrange additional press releases for any major breakthroughs. The **project website** will be structured in order to provide access to the collected knowledge, the most important highlights of current research activities, etc. and at the same time will be easily accessible for potential end-users. The project website will have a page summarizing major results. It will be in a written in terms that will be understood by a reader with a science or engineering background, but one lying outside the immediate specialism, and will provide an overview of the carried out research, of its objectives and of its originality. It will be linked to other projects and networks related to this action, such as XX. The website will also entail an intranet solution to be available to all beneficiaries/partners for an easy and rapid communication from M3 (see D 4.2).

3.4.2 How STONE will be targeting multiple audience

We are excited about the potential for public engagement that this project will bring, and we will use **press releases** for any major breakthroughs. Press releases will be developed and circulated by using the partners own networks and mailing lists. Research on renewable energy is a hot topic after the COP Paris 2015 agreement and for this reason public engagement is strategic!

Perovskite-based photonics and hybrid photovoltaics bring quantum physics out of the laboratory. As such, it frequently attracts press coverage, interest from the general public, and provides a possibility to build demonstration experiments that can be used in outreach activities. We will involve **research and management staff members** in public engagement activities by first asking them to undertake public communications training (available without charge from the partner universities) and then mentoring them in applying the training at events such as the International Mobile Learning Week, Italian Festival of Science. We will achieve wide impact by encouraging students and postdocs working on the project to use social media to gain visibility for our work within this action. This will communicate our work at a very different level to an entirely new audience. This direct engagement with the public will help researchers to better understand public interest in priorities for science and technology and also the public's concerns.

We plan to disseminate the motivation of research based in scholar systems of each participant country. The popularization of science and research carried out within the action as the project matures will be communicated through synergy by organizing, as part of the Inspiring Science education projects, visionary workshops for participants from different communities - the scientific research community, the educational community and local government units. Indeed the technical and scientific progress is ensured only if we are able to attract future generations of students to work and study in science. In addition, seminars and public lectures in schools and community organizations, newspapers and news magazines will be a regular part of the project. Every group will have the responsibility to communicate and disseminate related-news among the general public in their own environment at least twice a year (seminars in schools and community organizations, newspapers and news magazines and other non-academic means).

Moreover, **the Principal and Co-Investigators in this programme lead, or are active in, many networks with academic colleagues, industry, professional academies, and policy makers**. All Investigators are committed advocates for science and engineering and engage regularly with the press through broadcast and popular articles, public science events and the trade press. We will use the image of Liquid Light composed by exciton-polaritons as a vehicle to improve public's understanding of science and technology in general and photonics in particular.We will engage with local politicians, MPs and MSPs to explain. Engage with politicians through Learned Societies and provide written evidence on relevant topics to select committees.

3.4.3 STONE channels to be used to inform and reach out to society

The **network-wide communication and public engagement activities defined in the strategy (D4.1). will be combined with those at a local/node level.** MIFP will be responsible for organising the network **open days** associated with the network meetings. It will coordinate organisation of STONE Open Days by the participants and supervise the activity of the **project nominated <u>Marie Skłodowska-Curie Ambassadors</u>**: the staff members who will be encouraged to visit schools and local communities and promote the research they are doing in the local press. A special **Award** for the most efficient Ambassador will be established. This Award will be given on a yearly basis to the champion chosen by the group leaders based on the supervisors' recommendations.

3.4.4 The expected impact of the proposed communication activities

One of the main expected impacts of the proposed measures will be *a high visibility of the EU-led collaboration between the researchers from the international countries and regions, which historically have relatively weak collaborative links with the European researcher community*. Highly-visible joint publications and jointly organised knowledge exchange events will provide an ideal showcase leading to establishing new scientific links between these countries and the European Union.

4. QUALITY AND EFFICIENCY OF THE IMPLEMENTATION

4.1 Coherence and effectiveness of the work plan

A detailed work plan has been considered to ensure the effectiveness of the entire project (see Table B1). BUBLES activities are organized into 6 main Work Packages (WPs), of which 3 dedicated to the research part WP1 to WP3) and where secondments will be set for, and 3 WPs dedicated more to the administrative and management part of the project. Each WP has a nominated WP leader and a set of Task Leaders, and for each task the collaborative organisations (i.e. those taking part to the Task) has been also identified in order to best set the secondments. Scheduled milestones will be recorded internally including semester tasks status. Thus, corrective actions shall be taken on time in case that normal delays arise (see also section 4.2 Project Management).

Table B2 Work Package Description

Work Package Number	**1**										**Month: 1-36**		
Work Package Title	Theoretical and numerical modelling of light-matter coupling in novel structures and materials for stimulated absorption photocells												
Lead Beneficiary	**WIAS**												
Participant Short Name	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	**WIAS**	GTU	LEPL	VLSU	PHO
Person-months per Participant:	10	15	1	1	1	0	10	1	**15**	11	1		1

Objectives

To optimize the design of organic inorganic photocells based on the strong light- matter coupling in icrocavities. This work package will develop the models and the numerical tools to describe strong coupling in microcavities containing organic or hybrid organic/inorganic absorber. Particular emphasis will be devoted to the calculation of the quantum efficiencies of stimulated absorption. The developed models/numerical tool will be used to optimize experimental realization of the POLAR ENERGY photocell. On the other hand, the feedback from experimental studies of these structures in partner laboratories will be used to improve the quality of ab-initio modelling and phenomenological models.

Description of Work and Role of Specific Beneficiaries / Partner Organisations

Task 1.1 Development of theoretical models for stimulated absorption (UTV, MIFP, WIAS, INP); The model will account for strong coupling of light in microcavity and organic/hybrid materials. DFT calculation of optical properties of OHM.

Task 1.2 Realization of a numerical simulation tool for POLAR ENERGY photocell design and analyses (UTV, MIFP, WIAS); A master equation approach will permit to describe formation of the Bose condensate induced by the stimulated absorption and the coupling between the Bose condensate and the external transport materials for charge collection at the electrodes.

Task 1.3 Optimisation of the project photocell (MIFP, UTV, BSU, CICCI). The theoretical model and the numerical software will be used to design the project photocell that will be then used by the experimental group.

Task 1.4 Comparison with experimental results (WIAS, ALL). The theoretical and numerical tool will be use to assist the design of the project photocell and the analyses of the results. Moreover, experimental data will be used to refine the models.

Description of Deliverables

D1.1 Theoretical model for stimulated absorption with organic molecules and hybrid organic/inorganic perovskites. (M12)

D1.2 Computer code for the design of the stimulated absorption photocell (M12)

D1.3 Theoretical/numerical design of optimized photocell (M18)

D1.4 Comparison between theoretical/numerical prediction and experimental data (M36)

Milestones

M 1.1. Theoretical model for stimulated absorption explain experimental results (M)

M 1.2 The numerical simulator properly describe the project photocell (M)

Work Package Number	**2**										**Month: 8- 36**		
Work Package Title	Technology and Fabrication of organic and hybrid photocells based on stimulated absorption												
Lead Beneficiary	**UTV**												
Participant Short Name	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	WIAS	GTU	LEPL	VLSU	PHO
Person-months per Participant:	**10**	6	4	2	8	5	6	6	1	3	3	3	3

Objectives Realisation and optimisation of organic photocells based on the Frenkel exciton coupling with microcavity modes

Description of Work and Role of Specific Beneficiaries / Partner Organisations
Samples with organic molecules and hybrid perovskites in the microcavity formed by a metallic contact and a Bragg reflector will be fabricated. The feasibility study of using different contacts (graphene, carbon nanotubes, or other planar contact) will be performed. The samples obtained will be thoroughly tested in the experimental laboratories. The results of tests will be communicated to all partners for optimisation of the sample design and modeling.

Task 2.1 Realisation of microcavities based on the organic molecules, hybrid perovskites or other organic molecules (UTV, LIU, INP, CICCI, MIFP).

Task 2.2 Installations of transparent organic and other contacts (LIU, INP, MIFP, ALM, UTV, LEPL, VLSU, PHO). This will permit the use of the solar cells with light coming from the metal contact avoiding possible reflection induced by the Bragg reflector side. Studies of the structural and electronic properties of the interfaces.

Task 2.3 Experimental testing of the quantum efficiency of POLAR ENERGY Photocell. (CNR, CICCI, BSU, UTV,ALM, INP)

Optical time-resolved studies and determination of the quantum efficiency of the devices.

Description of Deliverables

D2.1 Report on microcavities for stimulated absorption based on organic molecules and hybrid perovskites (M18) (

D2.2 Report on the graphene transparent electrode for the project photocell (M24)

D2.3 Publication on the quantum efficiency and other parameters of the new photocells (M36)

Milestones
M 2.1 Graphene transparent contact optimized for photocell; (M18)
M2.2 Demonstration of the stimulated emission (M36)

Work Package Number	**3**									**Month: 10- 36**			
Work Package Title	Strong coupling in organic and hybrid organic-inorganic structures												
Lead Beneficiary	**CNR**												
Participant Short Name	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	WIAS	GTU	LEPL	VLSU	PHO
Person-months per Participant:	5	1	**12**	0	8	4	4	4	1	4	4	1	0

Objectives Experimental investigation and demonstration of stimulated absorption in microcavities formed by organic of hybrid organic-inorganic perovskite absorbers

Description of Work and Role of Specific Beneficiaries / Partner Organisations
In this WP photophysical characterizations of organic and hybrid organic-inorganic microcavities will be performed together with a study how polaritons could be used to control molecular transitions relevant to photoabsorption. We will couple hybrid excitations of inorganic or organic semiconductors through a photonic resonance of a microcavity in which both materials are embedded. Achieving the strong coupling, understanding the physics of these states and how to exploit them in devices will be the major focus of this workpackage.

Task 3.1 Characterization of photophysical properties of absorbers. Both organic and inorganic perovskite absorbers will be characterised via photonic probes (PL, TRPL etc.) and the relevant photophysical quantities will be determined and used in WP1 for the design of project photocells made in WP2 (**CNR**, UTV, ALM, BSU,).

Task 3.2 Experimental demonstration of the strong coupling of Frenkel excitons and modes of the microcavity. Specific microcavity will be used to demonstrate the strong coupling of Frenkel exciton of organic and hybrid perovskites.
(**LIU,** CNR, LEPL, UTV)
Task 3.3 Experimental investigation of stimulated absorption. The stimulated absorption will be investigate in the configuration of microcavity with organic and hybrid absorber and compared with theoretical prediction (**LIU,** C N R ; I N P , BSU, U T V , MIFP).

Description of Deliverables

D3.1 Report on the photophysical characterization of absorbers (M18) (

D3.2 Publication on the strong light-exciton coupling in hybrid microcavities (M24) (

D3.3 Report on stimulated absorption in organic and hybrid microcavities. (M30)

Milestones

M 3.1 Experimental demonstration of the strong coupling with perovskites (M30)

Work Package Number	**4**	**Start/End Month**	M1/M36
Work Package Title	**Communication, Dissemination and Exploitation of results**		

Lead Beneficiary[5]	MIFP											
Participating organisation Short	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	WIAS	GTU	LEPL	VLSU	PH
Total Person Months per Participating	1	**6**	1	1	1	1	1	1	1	1	1	1	1

Objectives:

To promote the dissemination of the project activities and results at the scientific and popular level with publications, workshops and dedicated outreach activities. To define and run the communication and dissemination/exploitation plan of the project

Description of Work and Role of Specific Beneficiaries / Partner Organisations

Task 4.1 Communication and Dissemination Plan (MIFP)

Definition of a Communication, Dissemination and Exploitation Plan (Task leader: MIFP, All). STONE will take a very thorough approach to dissemination and promotion of the project's objectives, activities and results. In order to ensure the dissemination and promotion activities are well defined, organised and correctly implemented, a dissemination and promotion plan will be produced at the start of the project. The plan will account for publications, conferences, schools etc., and will be regularly monitored though the yearly internal progress reports (see D 6.2)

Task 4.2 STONE Website (MIFP, All)

One of the key tools for project visibility will be the project **website** shining the light on its activity**.** It will be developed at the beginning of the project and on line by M4, maintained and administrated for the whole duration of this project, and beyond. The website will take advantage of new technologies like wiki, podcasting and webcasting, and also entails an intranet solution for internal communication, sharing of project documents and reports among participating organisations.(MIFP)

Task 4.3 Outreach activities (MIFP, All).

Outreach activities will be promoted for public engagement that this project will bring. Some of the outreach will be performed via the dedicated **website**. We will involve the appointed seconded researchers, and staff in general, in public engagement activities by first asking them to undertake public communications training (available without charge from the partner universities) and then mentoring them in applying the training at events such as the International Mobile Learning Week,", the Italian Festival of Science, and the EU Researchers Nights that will be organised in the participating organisations countries..

Task 4.4 Exploitation Plan (CICCI, All). (Definition of a final exploitation plan including, GEN-III PV market analysis, technology transfer policy, and business strategy drafting

Description of Deliverables:

D4.1 Dissemination and communication plan (M1)

D4.2 Project Website (M4) (**MIFP**)

D4.3 Final Report on outreach activities (M36)

D4.4 Exploitation Plan (M35) (

Milestones:

M 4.1 Project website on line and fully running (M4)

M 4.2 Final dissemination conference (M36)

Work Package Number	5									Start/End		M3/M36	
Work Package Title	Training and Transfer of Knowledge												
Lead Beneficiaries	**MIFP/UTV**												
Participating organisation Short Name**	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	WIAS	GTU	LEPL	VLSU	PHO
Total Person Months per Participating	3	5	1	1	1	1	1	1	1	1	1	1	1

Objectives:

To overlook the network trainings activities and monitor the transfer of knowledge arising from the secondments. To support entrepreneurship in EU/TC organisations via a Transfer Technology Coaching.

Description of Work and Role of Specific Beneficiaries / Partner Organisations broken down and listed into numbered tasks including the following details:

This WP will be led by MIFP, in strong collaboration with UTV (the coordinator), whose PIs have strict exiting collaborations with all participating organisations and better know the needs for the networking training and ToK. The activities here foreseen of course require the strong collaboration of all project partners. The management staff between EU and TC partners will help sharing the best practices between partners.

Task 5.1 Organisation and monitoring of secondments (UTV, MIFP, All). e coordinator (UTV) will provide the overall management of the project secondments, support the partners in their organisations during the whole duration of the project and provide timely progress reports as from D 6.2. A worksheet (excel) on secondments wil be produced and timely updated. A special emphasize will be on hosting the researchers coming with their families for secondments. The child-care services and language courses for the family members will be organized in each partner institution with an overall coordination by MIFP. Together with the Project Management Board it will also monitor the quality of the transfer of knowledge and propose corrective actions if needed (see section 4.2).

Task 5.2 Technology Transfer Coaching (CICCI). A pool of experts selected among MIFP, CICCI and LIU members will be established a coaching support for technology transfer with the aim to properly exploit the results of the project. This will include i) Detect the project's strengths/weaknesses, skills and knowledge gaps to be filled with customised support, ii) Translate the identified gaps into well-defined, integrated and timely delivered support packages (engaging both the coach and qualified experts), iii) Develop a straightforward business/exploitation plan to be shared and endorsed by the research team which streamlines the areas of intervention, the roles of the research team and coach/experts as well as the expected contributions, the mechanisms for delivering the services, milestones, timing, resources, as well as the outputs required for the success of the project.

Task 5.3 Local training and organisation of a summer school on stimulated absorption (MIFP, All) Local/in-house trainings will be organised by the participating organisations, when seconded staff is also in place, and the overall quality of the sessions will be monitored by MIFP, who will also organize and host a summer school on stimulated absorption in M18.

Description of Deliverables:

D5.1 Secondments' list (M2, updated until M36)

D5.2 Report on Technology Transfer Coaching (M30)

Milestones:

M5.1 Secondments started (M4)
M 5.2 Summer school on stimulated absorption (M18)
M 5.3 Strategies for effective exploitation for the new technology (M30)

Work Package Number	6									Start/End	M1/M36
Work Package Title	Project Management										
Lead Beneficiary	**UTV**										
Participating organisation Short Name**	UTV	MIFP	CNR	CICCI	LIU	ALM	INP	BSU	WIAS	GTU	VLSU PHO
Total Person Months per Participating	10	1	1	1	1	1	1	1	1	1	1 1

Objectives:

To technically and financially manage the project and the network.

Description of Work and Role of Specific Beneficiaries / Partner Organisations broken down and listed into numbered tasks including the following details:
WP6 will be led by UTV (the coordinator), which possesses significant experience in EU project management. This WP is of course strictly interlinked with WP5 Training and Transfer of Knowledge and will foresee a strong collaboration with MIFP. UTV and MIFP will organize a total of 4 project meetings starting from the kick-off meeting in Rome (M1) and including subsequent meetings in Minsk, XXx and XXX, this latest in accordance with the final dissemination conference (M36). WP6 also deals with the technical and financial EC/REA reporting and with the overall management of the network.
Task 6.1 Project meetings (UTV, MIFP)
Organisation of four project meetings: a kick-off at the very beginning (M1), to be held in Rome hosted by UTV and MIFP, and then 1 meeting at the beginning of each year, with last one taking place together with the final conference at the end of year 3 (M36) (**MIFP**, UTV).
Task 6.2 EC Reporting. Producing official reports/deliverables (UTV, All)
Task 6.3 Consortium agreement and Partnership agreement (UTV, All). Drafting and finalization of the project CA and PA, to be signed by all participating organisations at KoM in M1

Description of Deliverables:

D6.1 Report on Project meetings (M1, M12, M24, M36)

D6.2 Yearly progress reports (M12, M24)

D6.3 EC intermediate and final financial and technical reporting (M18, M36)

Milestones:
M 6.1 KoM (M1)

Table B3.a Deliverables List

Scientific Deliverables						
N	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Disseminati o n Level**	**Due Date**
D1.1	Theoretical model for stimulated absorption with organic molecules and hybrid organic/inorganic perovskites	1	MIFP	R	CO	M12
D1.2	Computer code for the design of the stimulated absorption photocell	1	UTV	R	CO	M12
D1.3	Theoretical/numerical design of optimized photocell	1	BSU	R	CO	M18
D1.4	Comparison between theoretical/numerical prediction and experimental data	1	UTV	R	PU	M36
D2.1	Report on organic microcavities based on organic molecules and on hybrid perovskites.	2	UTV	R	PU	M18
D2.2	Report on the graphene transparent electrode for the project photocell	2	LIU	R	PU	M24
D2.3	Publication on the quantum efficiency and other parameters of the new photocells	2	LIU	PDE	PU	M36
D3.1	Report on the photophysical characterization of absorbers	3	CNR	R	PU	M18
D3.2	Publication on the strong light- exciton coupling in hybrid microcavities	3	LIU/CNR	PDE	PU	M24
D3.3	Report on stimulated absorption in organic and hybrid microcavities	3	LIU	R	CO	M30
Management, Training, and Dissemination Deliverables						
N	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Disseminati on Level**	**Due Date**

D4.1	Dissemination and Communication Plan	4	MIFP	R	PU	1
D4.2	Project Website	4	MIFP	PDE	PU	4
D4.3	Final Report on outreach activities	4	MIFP	R	PU	36
D4.4	Exploitation Plan	4	CICCI	R	PU	35
D4.5	Report on Technology Transfer Coaching	4	CICCI	PDE	CO	36
D5.1	Secondments' list report	5	UTV	OTHER	CO	M2 until M36
D5.2	Report on Technology Transfer Coaching	5	CICCI	OTHER	CO	32
D 6.1	Reports on Project meetings	6	MIFP	R	CO	M1 to M36
D6.2	Yearly progress reports	6	UTV	R	CO	M12, M24, M36
D6.3	**EC** intermediate and final financial and technical reporting	6	UTV	R	RE	M18, M36

Table B3.b Milestone List

N.	Title	Related Work Package(s)	Lead Beneficiary	Due Da	Means of Verification
M1.1	Theoretical model for stimulated absorption explain experimental results	WP1	MIFP	18	Comparison between theoretical prediction and experimental results
M1.2	The numerical simulator properly describe the project photocell	WP1	UTV	30	Comparison between numerical simulation and experimental results
M2.1	Graphene transparent contact optimized for photocell	WP2	LIU	18	The organic/hybrid cell with graphene contact should perform similarly to the conventional one with no transparent contact
M2.2	Demonstration of the stimulated emission in prototype photocell	WP2	UTV	36	Measurement of the quantum efficiency of the Project photocell
M3.1	Experimental demonstration of the strong coupling with perovskites	WP3	CNR/LIU	30	The results are published
M4.1	Project website on line	WP4	**MIFP**	4	STONE website fully running and the intranet fully used by participating organisations also for ToK
M4.2	Organisation of the final conference	WP4	**UTV**	36	The conference has been organized and delivered, with an expectation of more than 150 participants
M5.1	Secondments started	WP5	**UTV**	**4**	The first secondments have been organized and successfully started.
M 5.2	Organisation of summer school on stimulated absorption	WP5	MIFP	18	The school has been delivered and a webinar has been produced
M5.3	Strategies for effective exploitation for the new technology	WP4	CICCI	30	A report on possible exploitation strategies is submitted
M6.1	KoM	WP6	UTV	1	The project meetings associated with the KoM have been successfully implemented and all the foreseen project activities fully agreed by all partcipating partners, also via the signing of the CA and PA.,
M6.2	Intermediate EC reporting	**WP6**	**UTV**	**18**	The go ahead given by the EC after acceptance of the reporting.

4.2 Appropriateness of the management structures and procedures, including quality management and risk management

4.2.1 Project management structure

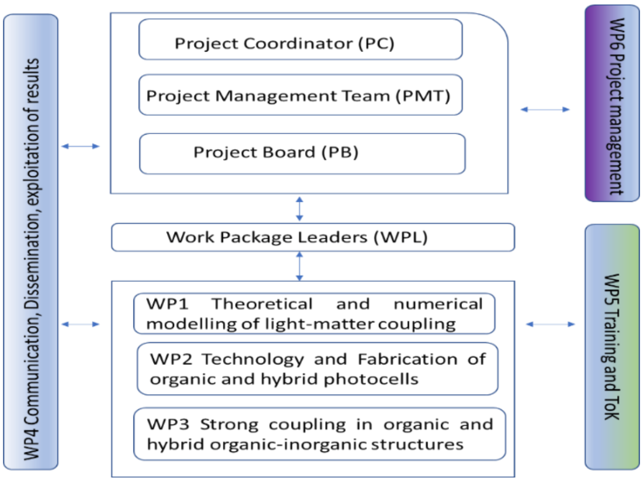

Figure 1.6 *Project management structure*

The management structure will be organised in a coherent manner to support all aspects of the project financial and scientific management and for a smooth administration of the visits and secondments of the involved staff.

The overall project management will be conducted by the **Project Coordinator** (**PC**), supported by a **Project Management Team (PMT)** based at its premises, in accordance with the **Project Board (PB),** this latest composed by the PC and by 1 member per participating organisation, for **a total of 13 members,** as graphically shown in **Figure 1.6**.

The project will be coordinated by **Tor Vergata University** (UTV), Italy. UTV has long experience in managing EU funded projects (*see Table 5).* The UTV team is led by **Prof. Manuela Scarselli** (**Project Coordinator**), a senior researcher at the university. Graduated at the University of Rome "Sapienza" in 1991, after spending some research activity at the National Research Council (CNR) Institute of Struttura della Materia of Frascati (Italy) she joined the Physics Department of the "Tor Vergata" Univerisity in 1996. Her research activity focuses on materials science. In particular, she is an expert on synthesis and applications of carbon nanostructures. She has published more than 100 peer-reviewed journal papers, review articles and one patent.

The PC will manage the network, the project financial assets and also communicate with the REA starting from the GaP up to the final technical and financial reporting, with the help and the support of a dedicated **Project Management Team (PMT),** based at the coordinator premises, composed by 3 staff members who will help with day-to-day monitoring of the project activities.

The **Project Board** (**PB**) is the body responsible for taking the decisions regarding the actual implementation of the project activities and will also be in charge to deal with the project risks mitigation actions (*see section 4.2.3 below*) while ensuring the quality of the implementation of the overall submitted programme. It will also oversee the overall scientific management of the project. The decisions taken by the PB are based on the consensus principle, including the implementation of the planned exchange visits and project meetings. It is composed by one representative per participating organisation, including the PC, for a total of 13 members.

To better monitor the progress of the project activities, members of the PB will be in permanent contact by e-mail and telephone on daily basis. Special attention will be paid to the organization of regular Project meetings starting from the Kick-off meeting in Rome.

In fact, they will meet for the first time during the project meetings organised at KoM (Month 1) during which a first final planning for the implementation of the planned exchange visits and project meetings will be discussed and approved, in order to kick off the secondments and exchange of knowledge project activities. Four project meetings (a kick-off meeting, and 1 meeting at the beginning of each year of the project) will be organized by UTV, in accordance and strict collaboration with MIFP, in order to check closely the advance of the research and discuss eventual problems and correction strategies. Each meeting will have its web-page on the project maintained by the administration of MIFP. Care will be taken regarding intellectual property setting up a special task force in order to follow the formal procedures.

The project implementation will be followed by the **Work package Leaders (WPL**) that will report on regular basis to the PC by means of regular contact via e-mail and internet teleconferences.

4.2.2 Network and financial management

The network will be formalised through a **Partnership Agreement (PA)** to be signed by all project participants (beneficiaries and partnering organisations in Third Countries) right at the beginning of the project (M1). The draft PA will be circulated among participants for approval already during the Grant Agreement Preparation phase (GaP) so that it can be smoothly signed in M1. The PA will detail the organisation of work, intellectual property management, budget and resource allocation, liability, conflict resolution, scientific misconduct, and the future exploitation and dissemination of results.

In particular, under art. 6 and art. 7 of the PA the distribution of funding among participants and the methods of payments will be dealt with. The Project Coordinator will ensure that the allocation of resources and funding within the Consortium is carried out in a transparent, fair manner, with the objective of directing funding appropriately to ensure efficient delivery of the Programme, for training and research of the staff during their secondments. As per the PA, the PC will notify all participants of the distribution of funds within 30 days of receipt of the EC funds. The PC will also distribute directly the funding to TC organisations according to their submitted secondments/involvement, in accordance with the distribution adopted for all other participants/beneficiaries and to the articles of the signed GA.

4.2.3 Quality management in support of the day-to-day management of the project

All participants will fully adhere to the *main principles of the European Charter for Researchers and Code of Conduct for the Recruitment of Researchers promoting attractive working conditions.* In this respect, *f*or **what concerns the secondments**, each incoming staff member will be assigned a personal tutor in the host organization who will be in charge of her/his installation, administrative and logistic details of her/his secondment and will be the reference person for all every-day questions.

As a rule, the hosts will provide the exchanged scientists with free language courses, organise the child care and help with finding suitable and affordable accommodation. The detached personal will receive the full salary from their sending institutions and will fully benefit from social programs of his/her country of origin.

4.2.4 Risks and contingency plans

Feasibility of the project has been looked up attentively considering several **risk** scenarios. We have taken into account the impact of each WP as well as likely events that may disturb the progress of each task within correspondent WP. In order to reduce the effects of risk events and to ensure the feasibility of the project, mitigate tasks have already been defined allowing a speed up for minor, moderate and major decisions. From a scientific and technological point of view, STONE risks can be divided and summarised into the two main methodological phases presented in section 2.1:

Risk, phase 1: We have already commenced fabrication and measurements of a first series of the organic microcavities. This research goes along with an intense numerical modelling aimed at optimization of the fabrication technique. We have already obtained the main characteristics of the future organic photocell numerically. This stage is challenging as there is no direct evidence for stimulated absorption of light reported in literature up to now, to the best of our knowledge. We are confident that such direct evidence can be obtained within the first phase of the project in agreement with our theoretical predictions.

Risk, phase 2: We rely on the existing know-how of making the transparent carbon contacts playing a role of the conductive transparent to collect the current without screening solar light (see Fig.2). The fabrication technique for these contacts has been developed and patented by one of our partner laboratories. Mitigation plan consist in the use of conventional Indium Thin Oxide. The second stage of the project will involve comparison of the main characteristics of the organic/hybrid photocells we develop with those which are developed by other laboratories. We plan to organize an international

workshop on organic photovoltaics in order to facilitate the transfer of knowledge between the groups involved in this research program and other world- leading groups in this area. The main risk at this stage is linked with the proposed discharge mechanism for the microcavities which has not yet been tested experimentally. The consortium will assure the maximum flexibility in designing the contacts and is ready to modify the work plan if needed to allow more time for this stage, provided that the stimulated absorption is demonstrated quickly after the beginning of the project. As discussed above, a way to mitigate this risk is the use of the bulk heterojunction concept.

From a managerial point of view, few risks are foreseen regarding the management of the secondments and transfer of knowledge, mainly due to the fact that staff might change in the course of the running of the project or risks related to better exploit the project networking (R 4 and 5 below).

Table B3c. Risks and contingency plans

No	Description of Risk	WP No	Proposed mitigation measures
R 1	Failure to achieve agreement between theory and experiment.	1	We have a large set of theoretical tools ranging from ab-initio calculations to phenomenological models with several adjustable parameters. If one approach fails we shall switch to the alternative one.
R 2	Failure to achieve high quantum efficiency in photocells	2	We shall optimise the organic or hybrid material to be used an the design of the cell. 2D perovskite with enhanced exciton binding could be used.
R 3	Failure to achieve the strong coupling in hybrid microcavities	3	Our plan "B" allows for realisation of photocells operating in th weak coupling regime. Corresponding adjustments to the model will be introduced.
R 4	Organisation of project meetings and sedondmnets/visits due to, for example, to any delay in receiving EU funding.	6	We have experience of organisation of many conferences and in managing EU project. In case of delay, if institutionally not available, we shall apply for supplementary funding from national funding agencies and industry to secure the future meetings financially.
R5	Changing of involved staff	ALL	Given the size of the partnership, and the numerous staff involved as PI or for secondments, it is clear that some changes in the staff originally involved might occur, due for example of changing of jobs, retirement, sickness, others. In case of such events, all organisations composing the partnership have the right expertise to quickly adapt to any change, and nominate new staff if necessary.

4.2.5 Gender aspects in the planning of the activities.

Gender equality will be carefully pursued. The project has a **female coordinator, Dr. Manuela Scarselli**, and counts a total of **9 female PIs** based at the 13 participating organisation research teams. Of course the PIs does not constitute all the staff that will be involved in the project/secondments. As already stated in section 1, for the seconded staff we will try to keep the percentage of 40% female participation.

Special attention will be paid to the needs of female staff in general (clearly underrepresented in the research field of our proposal) when organizing the project events, research, and secondments. In particular, **babysitting** will be organized during the project meeting; seconded researchers will have help in finding a kinder garden or a school for the children during longer stays. In general, we plan organizing long secondments of female researchers during school summer holidays, and fractional secondments (1-2 weeks multiple trips in order to fulfil the RISE rules of integer months/research) during school terms. As a matter of fact, RISE schemes, being based on staff exchange for long periods, do not allow an easy participation of young mothers. Part of the EC funding will be used to help both female and male researchers to travel with their under-age children. All consortium members are committed to the policy of equality and diversity and constantly working on developing the equal opportunities environment.

4.3 Appropriateness of the institutional environment

4.3.1 The expertise and human resources to carry out the proposed research action

The project is based in the world leading experience of project partners on theoretical and experimental aspects of exciton-polariton Bose Condensation and on the fabrication and characterization of Organic and Perovskite solar cells. Thus, even if the project is very ambitious and would introduce a revolutionary concept for solar cell energy harvesting, it is at the same time feasible and all the knowledge acquired by the partners will contribute to reach the project goals.

This is facilitated by the thorough secondments, which will foster the multidisciplinary and intersectorial activity presented in the tasks of the project. This project is very ambitious but has solid grounds. In fact, partners have a profound knowledge of stimulated emission, strong light-matter coupling and Frenkel and Wannier exciton physics as confirmed by a large number of publications in leading international physics journals. This competence will be exploited to achieve the goals of the project which are in the same physical context applied to stimulated absorption instead of stimulated emission. The demonstration of these new phenomena, which have been proposed theoretically [7], will result in a breakthrough in the photovoltaic field.

Being many of the partners working at Academic Institutions, we have a reservoir of students and young researchers which guarantees the necessary work power during and after the project. All partners are leaders in their research field, which is confirmed by publications in Nature, Science, Physical Review Letters, Applied Physics Letters, Nano Letters, ACS Nano, Nanoscale and other prestigious international journals. This certifies the expertise of the human resources involved in this project.

The successful fabrication and characterization of the new solar cell presented in the project is achievable if several skillful teams combine their effort. The teams present in this project have been selected because they provide specific excellence to reach the project goals. To name few examples of the main competencies bought to the project (*see also Table B2.1 for a brief summary of the main PIs expertise*), **UTV** via the CHOSE lab **(MIFP)** has a strong experience on conventional organic solar cell fabrication. The coordinator of the project, **Dr. Manuela Scarselli (female)**, Senior researcher, is expert in nanomaterials design and growth, x-ray spectroscopy and scanning probe microscopy. She will be responsible of the growth of carbon nanostructured materials applied in the realization of organic devices and their structural, electronic and optical characterization. **Prof. Olivia Pulci (female)**, Associate Professor in Theoretical Solid State Physics be responsible for the ab-initio theoretical description of the optical response of the nanostructured solar cells. **Maurizio De Crescenzi (male)**, Full Professor in experimental Solid State Physics. The development of new cell architecture will be supported by the knowledge on innovative TCO layer provided by **LIU** and the engineering skills on organic materials provided by **BSU and BSU2**. All these three group however need the profound expertise in strong-coupling and light-matter interaction to enter in this new mechanism of light-harvesting. The experimental activity will be supported by a multiscale modelling approach where ab-initio expertise of **MIFP**, supported by the know-how on synthesis, numerical models and procedure of **BSU**, will provide important parameters to the microscopic models. The unique expertise of the experimental part of the **WIAF, CNR and other Teams** t, in carbon-based flexible electronics will engage in the search of alternative materials for transparent contacts.

4.3.2 The necessary infrastructures and any major items of technical equipment available

In terms of the infrastructure and equipment to be used during the running of the project, **Table B4** below provides a clear summary (*also see section 5*):

Table B4 Infrastructures and equipment available for STONE

N.	Name	Infrastructures and equipment available
1	UTV	UTV is one of the best equipped laboratories in the area of organic and hybrid photovoltaics worldwide. It has a leadership in Numerical device simulation (software TiberCAD) and in photovoltaic devices with the Center for Hybrid and Organic Solar Energy (CHOSE). CHOSE has the state-of-art fabrication facilities for small and large area organic and hybrid solar cells. The Centre has a 250 sqm clean room with screen printers, spray coating and bled coating equipment and a three section glove-box equipped with organic and metals thermal evaporators for small molecule/polymer solar cells. Characterization instruments include micro-Raman, micro-photoconductance, spectrometers, Sun simulators, IPCE, confocal microscope, impedance spectroscopies and light soaking machine. Growth of carbon nanomaterials will be carried out at the Physics department and characterization of hybrid and organic solar cells will also be carried out at the Physic department of University of Tor Vergata, with a laboratory fully equipped with CVD chamber, STM, and AFM.
2	MIFP	Based on the large experience in scientific event organization, MIFP will be responsible for the dissemination activities and the organization of project workshops. Profs. Misha Portnoi and Aldo Di Carlo will be involved, with UTV in the theoretical/numerical model for what concerns the exciton formation in organic and hybrid organic inorganic materials.
3	CNR	The Advanced Photonics Lab. has many facilities for ultrafast photoluminescence studies with high spatial and temporal resolution.
4	CICCI	It offers competencies in fully automated solutions regarding the realization process and analytical equipment especially suited for mesoscopic solar cells. Cicci research s.r.l. can provide advice on photovoltaic harvesting solutions focused on mesoscopic technology. The company is partner of the COST Action MP1307 (StableNextSol): a working group on stability issue for mesoscopic photovoltaic technology. A laboratory of 80 sqm is available for ES and ERS activities
5	LIU	LIU will contribute to the fabrication of POLAR ENERGYPOLAR ENERGY photocell and its characterization using optical and electrical probes. LIU will be also involved in the photophysical characterization of strong coupling in organic and hybrid microcavity.
6	ALM	The research group has long expertise in the production of 3C-SiC for power devices (which can be used in electric cars), high temperature solar cells, and it can provide high quality large area epitaxial graphene on silicon carbide wafers that can be tested in the hybrid microcavity.
7	BSU	BSU experimental capabilities include close-cycled refrigerator Cryogenics Limited for the measurements of electrical and magnetotransport properties in the temperature range 2-300 K and in the magnetic field range 0-8 T, LCRmeters Agilent for carrying out AC-conductivity measurements in the frequency range 20 Hz-30 MHz, scanning electron microscopy SEM, Raman spectroscopy and atomic force microscope (AFM), laboratory made vacuum chamber for thermo vacuum deposition and vacuum studies, TEM LEO 604, spectrofluorimeter, XRD, spectrophotometer
8	INP	It possesses a high-quality Nanofinder-HE confocal spectrometer equipped with cells for measurements at cryogenic (down to 25 K) and elevated (up to 800 K) temperatures, as well as a set of equipment for measurement of optic and electric parameters (UV-Vis-IR spectrometers, DC source-meters, LCR-meters, etc.). The research unit will use the laser beam of confocal spectrometer (i) for the excitation of Raman and photoluminescence (PL) spectra; (ii) for local measurement of photoelectric parameters of solar cells (short-circuit current, open-circuit voltage); (iii) as a source of local photodegradation for unveiling the dynamics of properties under illumination. In addition, the registration system of spectrometer can be used to record electroluminescence (EL) spectra under continuous current flow through the sample from an external source. The presence of a 3D-piezoscanner allows mapping of spectral and photoelectric parameters, which is important for revealing the spatial homogeneity of samples.
9	WIAS	The International Center for Polaritonics (Prof. Alexey Kavokin) is the world-first research center that implements a new class of physical systems for quantum technology applications. The experimental labs of the Polaritonics center include a space for the MBE and lithography growth of nanostructures, laser ablation systems, an optical part for exciton and exciton-polariton observation and a modern diagnostic laboratory with unique devices. For instance, the LT NANOPROBE device is a dedicated to the non-destructive multipoint measurements at low temperatures ($T<5K$) providing four independent STM probe modules combined with the high resolution SEM imaging.
10	GTU	It hosts Advanced Research Centre for Microscopy and Structural Studies equipped with modern devices: transmission microscopes Auger spectrometry, electron scanning probe microscopes, and X-ray structural and optical spectrometer. This equipment will be available to partners for photocell components characterization. In addition, GTU has different modern equipment for fabrication of microelecronic materials metal and dielectric films, chemical and photographic processes.
11	LEPL	It has a material-technical base and intellectual environment, which is directly related to developing innovative structures and constructive documentation of solar magnetic emission. The Institute is equpied with devices for development of methods of magnetic emission in the vacuum are used to obtain layers of optical lenses and structures of solar magnetic emission.
12	VLSU	The laboratory is equipped with Atomic force microscope, scanning electron microscope, spectrophotomet laser systems: CW and QCW at a wavelength of 1.06 μm; femtosecond laser systems at a wavelength of 8 nm and 1.03 μm, Raman microscope with excitation of wavelengths at 473 nm and 632.8 nm. The unit will ap their consolidated expertise in materials fabrication and characterization to study the morphology and optic properties of the OHM cavities materials.
13	PHON	It develops synthetic CVD diamond and selected semiconductor device layer for passive devices cooling. In the project, the company will test the deposition of passive layers on the hybrid cavities.

4.4 Competencies, experience and complementarity of the PIs of the participating *organisations and their commitment to the project*

As shown in Table **B1.2** the competencies of the PIs of the nodes show a high level of complementarity (*see also Part B2 Table 5 Participants' description)* These are also graphically summarized in **Figure 1.7** below that schematically shows how the complementary skills of the 13 different groups involved will allow the successful realisation of such a large-scale interdisciplinary research program. The ambitious goals of the project require tight collaboration between the partners which will be assured by regular staff exchanges.

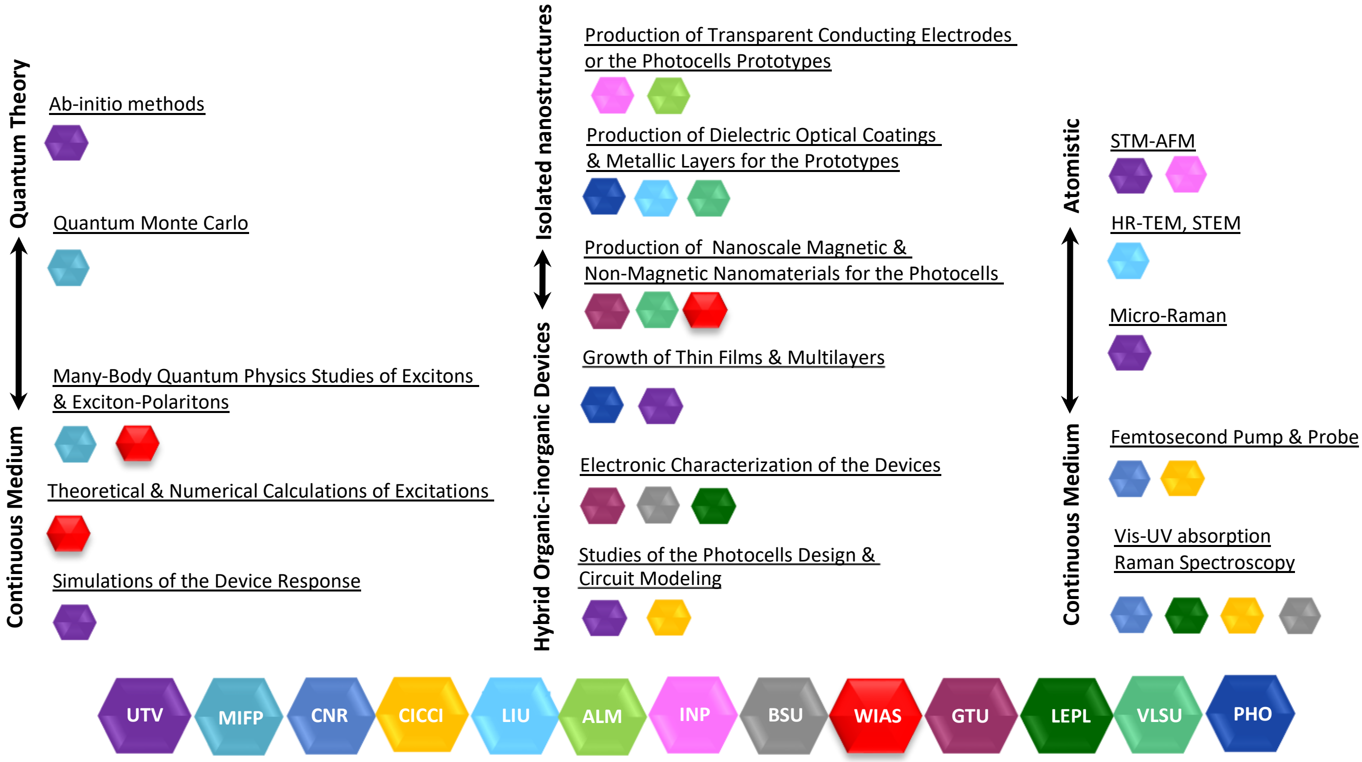

Fig.1.7 Illustrative chart of the methods, techniques, and expertise available in the consortium. Not all of them are referred to in the proposal but all contribute to the knowhow of the partners. For each item, the colored hexagons *displayed at the bottom of the figure* refer to the involved partners according to the code used *in the B1.2 on page 9*