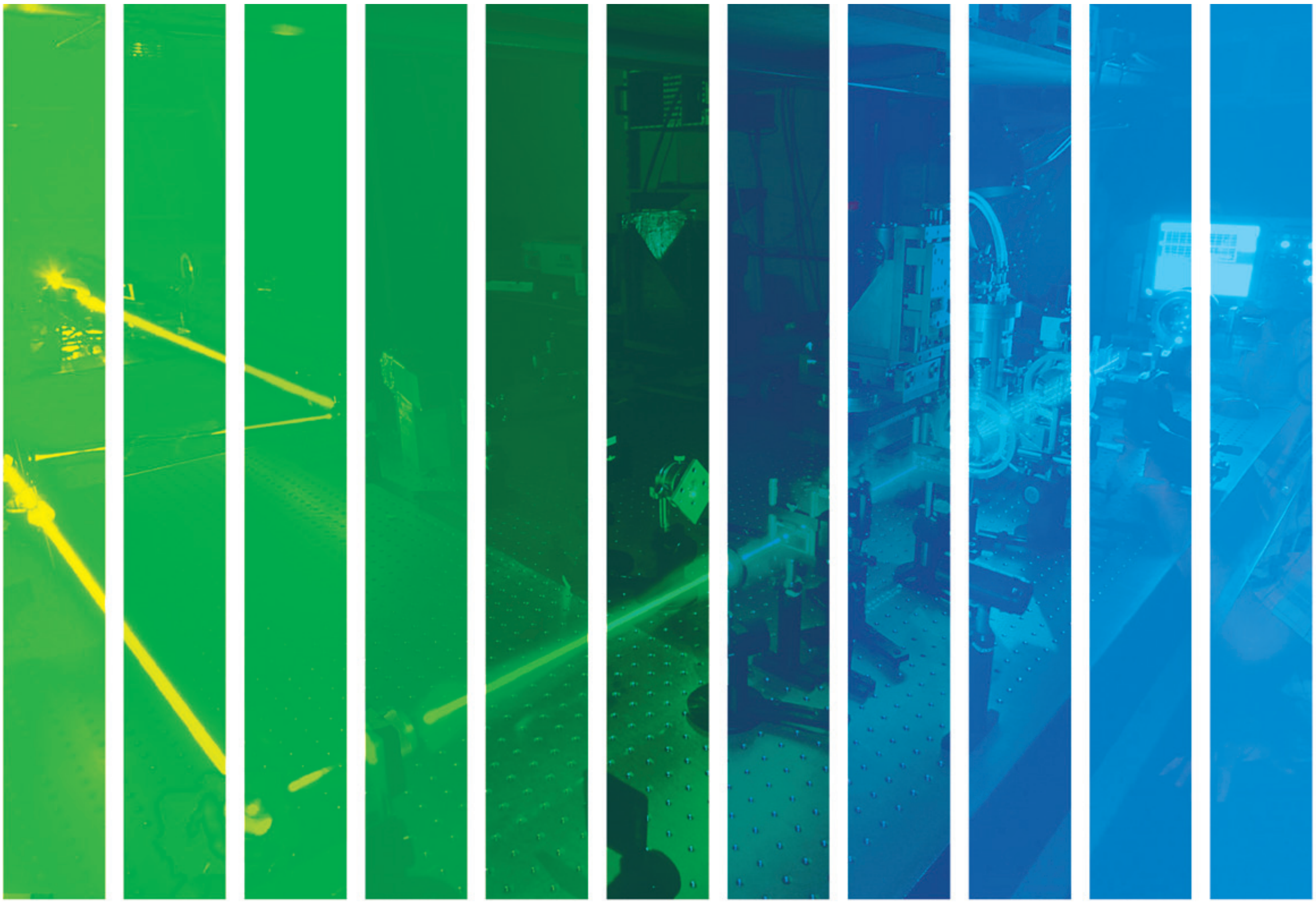

NANOPHOTONICS FOR ENERGY NETWORK OF EXCELLENCE

N4E

nanophotonics for energy efficiency

2010·2013

This project is funded by the European Commission's 7th Research Framework Programme

SEVENTH FRAMEWORK PROGRAMME

N4E

nanophotonics for energy efficiency

2010·2013

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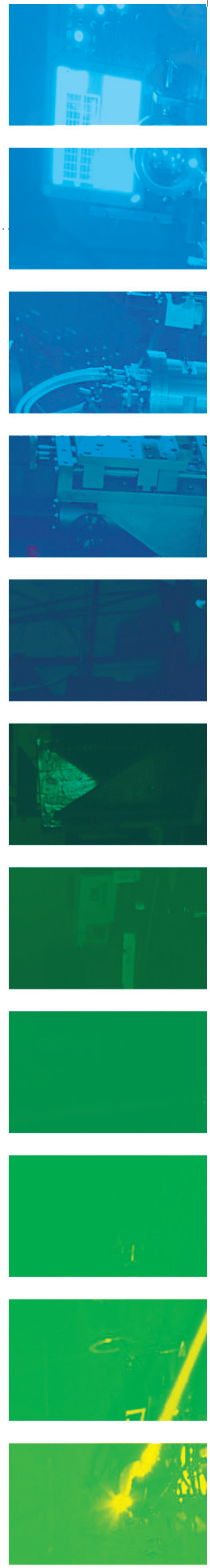
Artwork: **Tòfol Cruz**



Project Description

N4E

The Nanophotonics for Energy Efficiency Network of Excellence aims to re-orient and focus nanophotonics research towards the challenges in energy efficient applications. The network clusters nanophotonic laboratories and research groups in Europe, combining their expertise in the development of disruptive approaches to lighting and solar cell technology. The consortium consolidates know-how and resources of 9 different institutions in 6 European countries with complementary research and development expertise, integrating more than 130 scientists, engineers, technicians and managers in nanophotonics. Moreover, it is open to participation and collaborations with other stakeholders through two key instruments: Associate Membership and participation in the Seed Project scheme.

The project pursues a scientific bottom-up approach to ensure that novel ideas and scientific breakthroughs as well as established proof-of-concepts in academia are promoted along the value chain towards reaching their eventual goal of commercialization. Market and industrial relevance is ensured through the involvement of industry leaders in the Advisory Board. This approach complements the existing top-down, industry-driven projects.

The project intends to achieve the overall long-term integration goal by coordinating three main efforts:

a. Realising a strategy for successful integration: creation of new research community and a virtual laboratory network that will lead to the creation of a lasting entity that will exist beyond the duration of this Network of Excellence.

b. Establishing joint research: foster collaborations among the leading groups in nanophotonics for energy efficiency, interchanging knowledge and best practices, and paving the way towards the establishment of common research agendas.

c. Spreading knowledge: education and training specially geared towards young researchers and technicians – both on S&T issues as well as on complementary skills like communication, business, entrepreneurial or IPR skills – and dissemination towards the scientific community, industry, and the public in general.

If you are interested in the Network activities, becoming an Associate Partner, participating in Seed Projects, or in contacting any of the Network partners, please check **www.n4e.eu** or send us an email to **n4e-office@icfo.es**

Nanophotonics *for* Energy Efficiency

(nanophotonics4energy–N4E)

INTRODUCTION

Nanophotonics is the study of photons, the light, at the nanometre scale. There is an analogy between the terms of photonics, which deals with photons, and electronics, which deals with electrons. Photonics investigates the light generation, light manipulation, light control, light propagation, light modulation, light detection, light harvesting, etc., all of which can be most broadly considered as the light-matter interactions. Nanophotonics focuses on the study of these interactions at the nanometre scale. For example, nanophotonics explores nanomaterials that are structured to manipulate and control light at sub-wavelength scale. One of the critical motivations of nanophotonics is to develop and implement efficient materials, devices and systems for both light harvesting and light generation. In this respect, the N4E consortium, constituted by 9 different institutions, aims to create a Network for excellence in the field of nanophotonics to propose and implement innovative ideas for energy efficient photovoltaic and lighting applications in close connection with industry and all relevant stakeholders.

Nanophotonics has the potential to address current gaps in the market (e.g., high cost and low performance) with next-generation photonics technologies. Possible contributions include quantum dots integrated on light emitting diodes (LEDs) for photometric performance; multiple exciton generation with inorganic nanocrystals in photovoltaic (PV) devices to overcome the theoretical efficiency limit of single exciton generation regime; nanostructure enhanced light extraction, and surface plasmon-enhanced

The Network provides a vibrant research hub and a creative environment to train young scientists light trapping and absorption in solar cells using less material. For instance, for light harvesting, the vision of the European Photovoltaic Industry Association (EPIA) is that by 2020, 6–12% of European electricity should be generated with PV systems. To achieve this goal, new developments with respect to material design and consumption, device design, reliability and production technologies, as well as new concepts to increase overall efficiency are required.

To address divergence in the field and potential contribution to energy topics, the N4E drives forward nanophotonics research for energy efficiency applications. The Network provides a vibrant research hub and a creative environment to train young scientists to identify and understand potential disruptive nanophotonics for future R&D developments. Dissemination is given utmost importance by the Network to create public awareness of research developments and their potential uses. The consortium offers and provides open access to knowledge, and state-of-the-art equipment and facilities. On top of these, the N4E Network puts effort to engage academic research with industrial companies for mutual gain where industrial relevance is ensured through the involvement of industry leaders in the Advisory Board of the Network.

Participation in the Nanophotonics for Energy Network of Excellence is open to all relevant stakeholders through its Associate Membership Scheme. Details are available at

www.n4e.eu

nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

BILKENT

The National Nanotechnology Research Center – UNAM

INTRODUCTION

The National Nanotechnology Research Center and Institute of Materials Science and Nanotechnology – UNAM at **BILKENT,** which consists of 15 dedicated faculty members and PIs, 30+ research associates/engineers, and 150+ graduate students, is currently the leading national institute of nanoscience/nanotechnology in Turkey, with its critical-mass of research groups and scientists, a wide range of expertise spanning from nanophotonics/nanoelectronics to nanomaterials synthesis/growth, and its MS-PhD DEGREE PROGRAM in nanotechnology. BILKENT is the first private university founded for research of excellence in Turkey. Presently, there are 1,200+ faculty members (from 40+ countries).

BILKENT attracts the top high school graduates and faculty in the fields of fundamental sciences and engineering in Turkey. BILKENT prides on well-established research infrastructure along with UNAM facilities and ranks among the top in terms of research outputs in science/engineering in Turkey. With over 60 separate labs, UNAM houses state-of-the-art nanofabrication and nanocharacterization tools including TEM, ESEM, SEM, EBX, XPS, XRD, NMR, EBL, and FIB. The Center runs large-scale National State-Planning projects (>30M€) and international projects, including EU-FP, ESF, EUROHORCS, COST and US-NIH projects, which have successfully led to spinoff companies and commercialization of nanotechnology-based products in Turkey and Europe.

HIGHLIGHTED RESEARCH

The DEMIR GROUP at THE NATIONAL NANOTECHNOLOGY RESEARCH CENTER – UNAM, EEE and PHYSICS led by Professor Hilmi Volkan Demir (ESF-EURYI), presently conduct research on the following topics relevant to the NoE:

For light generation

- Epitaxial growth and fabrication of InGaN/AlGaN/ZnO based LEDs, nano-structured LEDs;
- Nonradiative energy transfer (ET) based LEDs, and ET-controlled excitonics;
- Colloidal quantum dot (QD) optoelectronics (QD-LEDs, QD-nanophosphors);
- Theoretical/numerical studies and experiments of nanoplasmonic modification of emission kinetics for efficiency enhancement and polarization control;
- Physics and experimental realization of nanophotonic structures, complex constructs of multiple nanoparticle assemblies and functional nanocomposites.

For light harvesting

- Nonradiative ET-mediated light harvesting and photovoltaics;
- Self-assembly of quantum dots, and QD-integrated solar cells;
- Theoretical and numerical studies, fabrication and characterization of nano-plasmonic structure for absorption enhancement and photovoltaics; and
- Peptide optoelectronics.

Among many firsts and international accomplishments, the DEMIR GROUP also holds the records of the best photometric performance of white LEDs (OpticsLetters2010, APL2008), the strongest quantum-confined Stark effect in InGaN/GaN quantum heteroepitaxy (APL2008, APL2009), and the deepest in-body strain sensing by metamaterial-inspired wireless sensor implants (APL2009, APL2009, IEEE-JSTQE2010). The DEMIR GROUP is also very active in synergic entrepreneurship activities in Turkey, Europe, the US and Asia, based on high-technology prototypes the Group have developed and taking new ideas from the lab to the market. Demir is a co-founder and partner of two successful startup companies. Based on their joint research work and intellectual property, he first co-founded a nanotechnology based company, called InnovNano, which was then successfully turned into a joint venture, called InnovCoat, together with Materis, France. He also co-founded a startup for technology management in high-tech defense sector.

Relevant accomplishments include demonstrations of high-quality white light generating nanophosphors and nanocrystal scintillators for enhanced UV-detection and photovoltaics, invention and development of methods to increase optical efficiency in nanoparticle integrated systems for environmental self-cleaning, and invention and prototyping of wireless bio-implant sensors for real-time in-vivo fracture-healing assessment.

FACILITIES

THE NATIONAL NANOTECHNOLOGY RESEARCH CENTER provides extensive facilities and cleanroom environment for nanofabrication and nanocharacterization including: TEM,ESEM,SEM,EBX,XPS,XRD,NMR, e-beam lithography, focused ion beam (FIB), ICP-RIE (for GaN), ICP-RIE (for Si), e-beam evaporation, ALD, PECVD, LPCVD, sputter, thermal evaporators, organic thin-film evaporator, optical profilometer, ultramicrotome, PECS, PIPS, AFMs, UV-Vis-NIR spectrophotometers, fluorescence spectrophotometers, time-resolved fluorescence, circular dichroism system, ellipsometer (IR-WASE, EV-VASE), FSP spectrum analyzer, FTIR microscope, confocal microscope, Zeta potential/sizer), wire bonder.

nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

BILKENT

The National Nanotechnology Research Center – UNAM

INTRODUCTION

Bilkent University Nanotechnology Research Center (NANOTAM) is dedicated to research on applied nanoscience and nanotechnology with particular expertise in nanophotonics, nanoelectronics, nanoplasmonics, nanodevices, III-Nitride metal organic chemical vapor deposition (MOCVD) growth, in addition to design, fabrication and characterization of RF and optoelectronic devices. A group of 4 faculty members, 5 research associates and more than 35 research engineers and graduate students form the experienced and dynamic staff of Nanotam. The center houses 550 square meter of class-100 level clean room dedicated to nano-lithography and nanofabrication related projects. A wide arrangement of nanofabrication, microfabrication , material and device characterization equipments are installed alongside a MOCVD system which is being used for the epitaxial growth of GaN/AlGaN/InGaN material for ongoing projects. In addition to the clean rooms, the center also houses 16 separate research laboratories (with a total area of 1500 square meters) dedicated to various research projects funded through European Union and several Turkish institutions and organizations.

HIGHLIGHTED RESEARCH

Bilkent Nanotam group currently conducts research on the following topics relevant to the NoE:

- MOCVD growth of InGaN based solar cells.
- Fabrication of InGaN based solar cells.
- Theoretical and numerical studies of nanophotonic structure based enhancement in solar cells.
- Experimental realization of nanostructured solar cells.
- Blue and UV LED growth and fabrication.

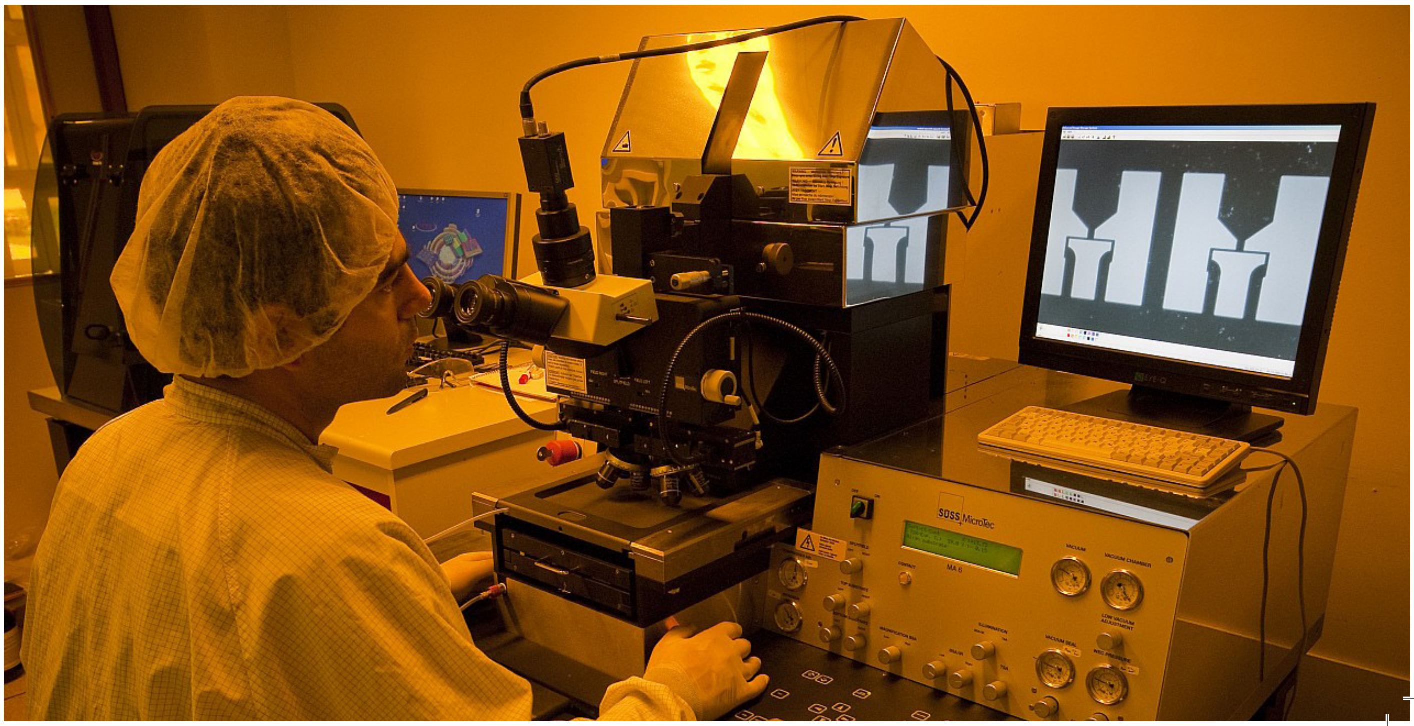
Nanotam group's relevant expertise is built by long lasting efforts in related research topics such as high performance photodetector design and fabrication, photonic crystals, metamaterials, and III-Nitride epitaxy and device fabrication.

A selection of Bilkent Nanotam's past international and national accomplishments in related topics can be listed as the demonstration of the smallest photonic crystal (PC) in the world in 1995, the first PC based waveguide in the world in 2000, world's smallest composite metamaterial (CMM) in 2005, first 3D metamaterial and smallest bulk CMM in 2006, as well as Turkey's first epitaxial growth of nitride based semiconductors in 2004 and the first blue LED grown and fabricated in Turkey in 2005.

FACILITIES

Bilkent Nanotam has a 550 square meter of class-100 level clean room dedicated to nano-lithography (RAITH E-Line e-beam lithography system) along with various nanofabrication equipments including ICP-RIE, PECVD, sputter and e-beam metal deposition systems. An AIXTRON RF200/4 RF-S MOCVD epitaxial growth system is installed for the growth of GaN and related materials.

Contact: volkan@stanfordalumni.org



nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

CEA-LETI

CEA-LETI

INTRODUCTION

CEA is a French research and technology public organisation, with activities in four main areas: energy, information technologies, healthcare technologies and defence and security. Within CEA, the **Laboratory for Electronics & Information Technology (CEA-Leti)** works with companies in order to increase their competitiveness through technological innovation and transfers. CEA-Leti is focused on micro and nanotechnologies and their applications, from wireless devices and systems, to biology and healthcare or photonics. Nanoelectronics and microsystems (MEMS) are at the core of its activities. As a major player in MINATEC campus, CEA-Leti operates 8.000-m² state-of-the-art clean rooms, on 24/7 mode, on 200mm and 300mm wafer standards. With 1.200 employees, CEA-Leti trains more than 150 Ph.D. students and hosts 200 assignees from partner companies. Strongly committed to the creation of value for the industry, CEA-Leti puts a strong emphasis on intellectual property and owns more than 1.500 patent families.

For more information, visit www.leti.fr.

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HIGHLIGHTED RESEARCH

The Nanophotonics Engineering Lab (LINA) is a dynamic team of researchers whose aim is to develop innovative concepts and techniques for optoelectronics components. A subsidiary of the CEA-LETI MINATEC Campus, the LINA belongs to the Optronics department, one of the biggest European nanotechnology center dedicated to imaging techniques and new photonics applications (approximately 200 people).

More precisely, the LINA lab. is specialized in plasmonic nanostructures applied to integrated optics for telecommunications and electromagnetic confinement for detectors which have been attracting the scientific community and optoelectronics industry for over a decade. However, the research areas do go further: they cover the fields of computational electromagnetism, metamaterials and optical nanostructures characterization.

LINA's mission is to promote the most advanced concepts of nanophotonics towards rapid and realistic prototyping, mandatory for an industrial transfer.
So, the laboratory has been developing fruitful collaborations with international level labs and optoelectronics majors in the fields of:

- Solid state lighting (nanowires light emitting diodes)
- Integrated optics for high speed datacoms
- Gas sensors
- Imaging sensors for visible and infrared light

Key Figures:

- 12 permanent researchers
- 5 Ph'D students
- 3 postdoctoral positions
- 10 international publications per year
- 10 patent per year

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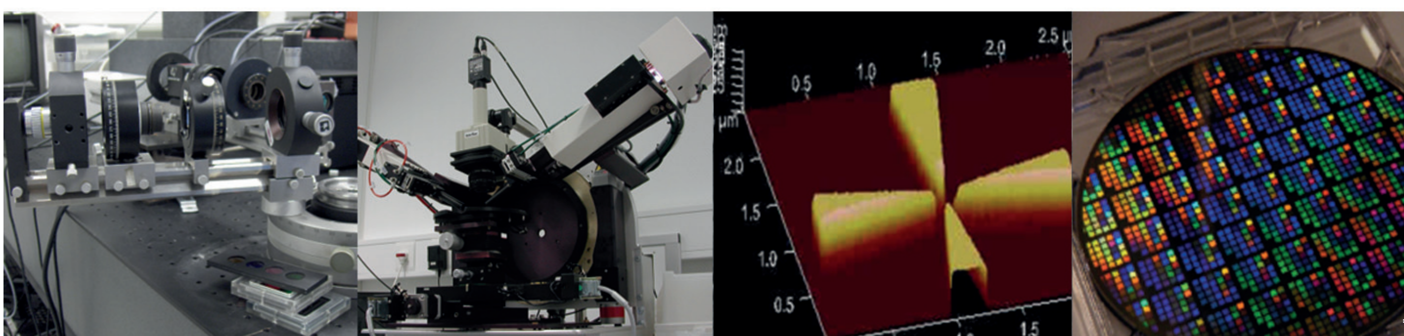
FACILITIES

- LETI: 200/300 mm nanotechnology platform

- LINA lab:
  - Localized (300 nm) photoluminescence et electroluminescence
  - Computational Electromagnetic software (finite-elements, finite-difference-time-domain, boundary elements method) and PC cluster
  - High precision spectroscopic photogoniometry (visible light + 325/540/633/1500/2150 nm lasers) in plane waves or SPR configuration, and spectroscopic angular ellipsometry (193-2500 nm range)



nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

CSIC

Consejo Superior de Investigaciones Científicas

INTRODUCTION

The Nanophotonics group at CSIC specializes in explaining and predicting new phenomena involving the interaction of light with nanostructures. We master theoretical methods in electromagnetism, quantum theory, and solid-state physics. Our group has extensive experience in the following areas:

- **Plasmonics**: We are a world leading group in the theoretical study of plasmons –the optical excitations at metal surfaces that are a hybrid of electromagnetic energy and collective oscillations of conduction electrons. Surface plasmons produce large confinement of electromagnetic energy that is currently used to achieve ultrasensitive bionalysis at the single-molecule level and improved nonlinearity at the nanoscale. Our group has produce seminal contributions in these fields and we are currently involved in studying plasmons in graphene and quantum aspects of these excitations (quantum plasmonics), as well as their application to quantum information technology and fundamental physics.

- **Electron microscope spectroscopies**: Electron beams in electron microscopes provide the best combination of space and energy resolution that is currently available. Our group is a solid reference in the study of spectroscopies based upon electron beams, and in particular, electron energy-loss spectroscopy (EELS) and cathodoluminescence (CD). Besides, we are currently embarked in developing novel spectroscopies using quantum aspects of electron-plasmon interaction and energy gains suffered by the electrons upon external illumination.

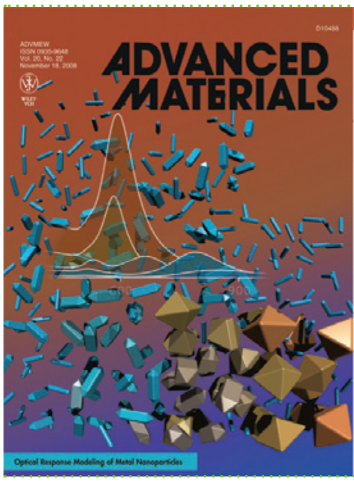
- **Quantum friction and radiative heat transfer**: As the cost of computing is now almost equally shared between the actual purchasing price of microchips and that of the electrical power that they consume during their active lifetime, energy saving and heat dissipation become issues of major relevance. In this context, we are studying radiative heat transfer, as well as quantum aspects associated to this process. Friction produced by the exchange of light quanta on moving nanoparticles has also attracted our attention in the recent past.

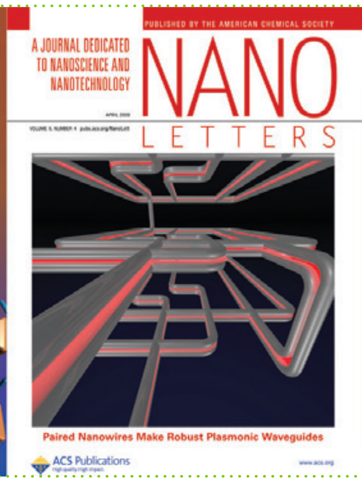
- **Other aspects of electromagnetic theory**: We have recently employed our versatile expertise to analyze different aspects of the interaction of light with matter, ranging from quantum phenomena (e.g., plasmon-molecule coupling, single-photon emission, etc.) to classical descriptions of optical forces (e.g., optical trapping) and light interaction with periodic structures.

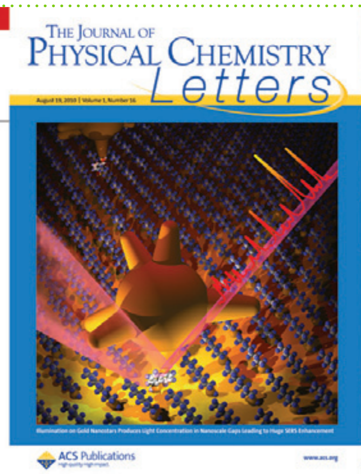
HIGHLIGHTED RESEARCH

The Nanophotonics group has produced pioneering works exemplified by the following papers and journal covers:

- Control of optical and plasmonic spectra of metal nanoparticles of varying size and morphology.
- Optical signal guiding in plasmonic waveguides with large integrability.
- Ultrasmall plasmonic cavity with record-high Purcell factor probed by CD.
- Vacuum and thermal friction of spinning nanoparticles, causing counterintuitive cooling of the particle (*Physical Review Letters*, 2010).
- Coherent control with a shaped light pulse used to tailor the distribution of near-field electromagnetic energy deposition (*Nature*, 2007).
- Record-high sensitivity in single-molecule detection using optical hotspots.
- New concept of single-photon source, tunable in the visible and NIR, driven by fast electrons, with 100% efficiency, and operating at room temperature (*Nano Letters,* 2011).
- Achievement of omnidirectional total absorption in engineered metal surfaces.







nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

ICMM·CSIC

The Materials Science Institute of Madrid (ICMM)

INTRODUCTION

The Materials Science Institute of Madrid (ICMM) belonging to the Spanish Research Council (**CSIC**) is a multidisciplinary materials science institute where more than 400 researchers work in several areas of physics and chemistry of materials such as photonics, functional materials, biomaterials, surfaces, theory, etc.

The ICMM is one among over one hundred of CSIC institutes and was founded in December 1986. It belongs to the Area of Science and Technology of Materials, one of the eight Areas in which the CSIC divides its research activities.

Its mission is to create new fundamental and applied knowledge in materials of high technological impact, their processing and their transfer to the productive sectors at local, national and European levels (the true value of materials is in their use), the training of new professionals, and the dissemination of the scientific knowledge. Therefore, its objective is to become an international reference Centre for Materials, contributing in an effective manner to the development of the Knowledge Society, a centre that promotes excellence for new professionals demanding training, and/or for established scientists requiring to broaden or update their knowledge. Simultaneously, the ICMM should be a national reference for the innovative industry, particularly at the nanometre scale and emergent fields.

The Photonic Crystals Group (luxrerum.org) comprises several senior researchers and PhD students working in the fabrication and optical studies of photonic crystals and photonic glasses by self-assembly. The group, with a background in optical properties of semiconductors, has accumulated over ten years' experience in the field and is renown at world level.

HIGHLIGHTED RESEARCH

We have designed a new photonic material called **"photonic glass"**. This is a three dimensional fully disordered solid arrangement of monodisperse dielectric spheres. Monodispersity will ensure single sphere optical resonances to be observed. Thin (correlated) disordered films can be grown too by vertical convective deposition and selective etching from binary colloidal suspensions. By fabricating large-area high quality Polystyrene opals and **ZnO** inverted opals by atomic layer deposition we can make photonic crystal lasers.

Random lasers are generally difficult to control: they emit in every direction at once and in many different colours. Now, exploiting a fundamental physical phenomenon, it is possible to select their colour using photonic glasses.

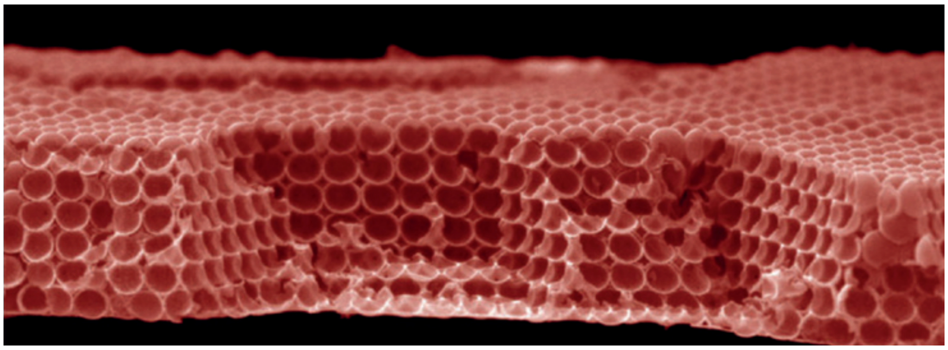
Infiltration and processing in two stages (magnesiothermic reduction and CVD) enabled us to obtain **Si spheres** in large quantities starting from ordinary state- of-the-art colloidal silica particles.

By means of combined silica and **silicon CVD** it is possible to build up multi-layered structures arranged in 3D with photonic crystal optical response. These structures are very open and can host other materials with additional functionalities. Bearing in mind the undeniable advantages brought about by polymer opals (and other polymeric structures) in terms of quality, ease of production and available range of sizes, the method demonstrated constitutes a great progress in the fabrication of photonic crystals. Novel topologies as silicon concentric layers surrounding spherical cavities are created with this fabrication process as an example.

Monolayers of dielectric spheres deposited on **metallic** substrates can strongly modify the emission of organic dyes contained in the spheres through coupling to hybrid plasmonic–photonic modes of the structure. Emission enhancement and polarization control are thus achieved.

FACILITIES

The ICMM group has laboratory facilities for a whole range of optical techniques such as optical absorption and transmission, photoluminescence, lasing, Raman, **nanosecond, picosecond** and **femtosecond** time resolved techniques such as time correlated single photon counting, streak camera, etc. and sample preparation techniques such as chemical synthesis, **chemical vapour deposition**, or **atomic layer deposition** are available. The ICMM group has significant expertise in **self-assembly** of passive and active photonic crystal and photonic glass, material characterisation and optical spectroscopy. Recently the group has acquired state-of-the-art expertise in light transport and emission from photonic nanostructures, both for light fluorescence control and for unconventional laser sources like photonic crystal lasers and **random lasers**.



nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

ICFO

The Institute of Photonic Sciences

INTRODUCTION

ICFO-The Institute of Photonic Sciences was created in 2002 by the government of Catalonia and the Technical University of Catalonia. ICFO is a center of research excellence devoted to the sciences and technologies of light. The Institute carries out frontier research and trains the next generation of scientists and technologists. ICFO actively collaborates with many leading research centers, universities, hospitals, and a range of private companies based locally and all over the world.

ICFO currently hosts 20 research groups working in more than 50 different laboratories. Available to them are a Nanophotonics Fabrication Lab, a Super-resolution Light Microscopy & Nanoscopy Lab, an Advanced Engineering Lab and a range of other support facilities. All research groups and facilities are located in a dedicated 10.000 m2 -building situated in the Mediterranean Technology Park in the metropolitan area of Barcelona.

Research at ICFO targets the forefront of science and technology based on light with a main focus in Health, Renewable Energies and Information Technologies and it is conducted in the framework of long-term and mid-term programs in a variety of topics, including quantum information technologies, solar cells, nanophotonic devices, remote sensing, optoelectronics, integrated optics, ultrafast optics, biophotonics and biomedical optics, among others. ICFO is currently expanding, thus by 2015 the institute will host some 350 researchers organized in 25 groups. ICFO performs cutting-edge research both in fundamental and applied fields. Spin-off creation by ICFO researchers is also encouraged and promoted. ICFO also hosts an active Corporate Liaison Program (CLP) which serves as a bridge between ICFO researchers and all kinds of industries and corporations.

HIGHLIGHTED RESEARCH

Photonics is at the core of all light-harvesting concepts and technologies, particularly in photovoltaics and solar cells, as well as in efficient illumination and lighting. ICFO has an active Light for Energy Program which targets the challenges in energy efficient applications, developing disruptive approaches to renewable energies.
Ongoing projects within the L4E Program include:

- Advanced micro and nano-structured materials to enhance the performance of organic photovoltaic materials.
- Novel nanomaterials and devices for renewable energy applications.
- Low-cost solar cells based on solution-processed materials of high abundance, low toxicity, and long-term stability.
- Transparent photonic approaches and ultrathin metal films.
- Low cost highly efficient transparent solar cells and smart windows.
- Efficient lighting applications, organic OLEDs and advanced displays.
- Advanced materials and optoelectronic devices for the photonics industry including micro- and nano-engineered electro-optic and acousto-optic modulators for low-power-consumption optical communication, photonic crystal fiber and nanowire sensors for environmental monitoring and aerospace applications, photoelectric, thermoelectric and electromechanical transducers, and energy efficient sensors amongst others.
- Nanophotonics: nano-structured materials, nano-cavities, nano-antennas, low cost material processed nano photonic devices and plasmonic enhanced light harvesting technologies and nanoscale light technologies to be exploited in sensing, nano imaging, optical circuitry and data storage applications

ICFO´s Light for Energy Program also focuses on establishing links and joint projects with local, national and international research institutions, which develop, use or think of using photonics for energy efficient applications in the future, organizing workshops and conferences as well as fostering spin-off creation, knowledge dissemination and outreach activities. ICFO collaborates with research centers, Universities and corporations worldwide, acting as a Green Photonics Hub.

FACILITIES

NanoPhotonics Lab (NPL@ICFO): a shared facility dedicated to the fabrication and characterization of nanostructured photonic devices. Post-Processing Lab (PPL@ICFO): designed to support the processing, fabrication, and characterization of optical materials and components for fundamental and industrial research projects. Advanced Engineering Lab (AEL@ICFO): brings the most advanced technologies in electronics and precision mechanical engineering to researchers providing state-of-the-art tools for electronic design, assembly, and characterization as well as for micromechanical engineering.

nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

KTH

The Royal Institute of Technology

INTRODUCTION

The Royal Institute of Technology (Kungliga Tekniska Högskolan), KTH, is responsible for one-third of Sweden's capacity for engineering studies and research. The main campus of KTH is in central Stockholm; other campuses are located in Kista, Haninge, Flemingsberg and Södertälje. KTH conducts top-notch education and research of a broad spectrum - from natural science to all branches of technology. Apart from research performed at our departments, a large number of national Centres of Excellence are located at KTH and we contribute to another three national ones.

The school of Information and communication technology (ICT) is at campus Kista– in the center of one of the world's leading ICT clusters and the activities span the entire field of information technology in its widest sense from technical solutions to systems. The research and education (undergraduate to PhD levels) is predominantly in the fields of nanoelectronics, photonics, electronics and computer systems, software technology, communication and cognitive sciences.
The ICT school also houses the Electrum lab operated by KTH together with Acreo, a research institute. The Electrum lab is an outstanding resource for fabrication and characterization in the nano and micro scale supporting the whole chain from education, research and development to prototyping and production.

Detailed information about KTH is available at www.kth.se

HIGHLIGHTED RESEARCH

In the field of electronics and photonics, the divisions at the School of information and Communication Technology at KTH are engaged in research in several areas such as material science, lasers, integrated optics, micro-mechanics, photonic crystals, meta-materials, plasmonics, magneto-optics, photovoltaics, thermoelectric, quantum optics, optical networks, high speed electronics, high power electronics and spintronics, to name a few. In line with these areas, the school has strong research programs on synthesis of a wide range of materials including fundamental material physics, nano- and micro- fabrication techniques, chemical synthesis of nano-materials and characterization of materials and devices.

The division of semiconductor materials participating in the Nanophotonics4energy network has extensive expertise on photonic Integration, III-V nano-structures and nano-structured materials, covering physics, technology and applications. The division specializes on high speed devices for telecom applications, novel solutions for optical interconnects, high temperature quantum cascade lasers for sensing applications, photonic crystals, nanofabrication, low-dimensional semiconductor structures, high resolution material characterization tools and technology for solar cells. The division has pioneered epitaxial solutions such as selective area growth, epitaxial lateral overgrowth and heteroepitaxy. Specific expertises include selective area growth of III-Vs on planar and non-planar substrates for discrete and integrated components; heteroepitaxy for Si-photonics and for large size III-V layers on Si for applications such as solar cells. The division is a pioneer in deep-etching of photonic crystals in InP-based structures and has demonstrated several devices or device-concepts such as lasers, filters, and negative-refraction. Processing of nanopillars including low-cost approaches is currently an important activity for solar cells, LEDs and second harmonic generation The division has also made significant contributions on the understanding of the physical mechanisms in nanofabrication of semiconductors. The methodology and application of Atomic force microscopy based electrical characterization techniques have been established for 2D mapping of the electrical properties of materials and devices, including low dimensional structures containing QWs/Q-dots, with nanoscale spatial resolution.

FACILITIES

The Electrum laboratory accommodates a comprehensive infrastructure comprising of nano and micro fabrication, material and device characterization facilities for electronic, photonic, and micromechanic components and systems.

Electrum Laboratory identifies three state-of-the-art profile processes where we maintain a leading competence:

- Epitaxy and other synthesis methods for a wide range of materials.
- Stepper lithography for submicron patterning with high alignment accuracy and reproducibly.
- Precision dry etching - state-of-the-art etch processes for a wide range of materials.
- Detailed information is available at www.electrumlaboratoriet.se

nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

LENS

The European Laboratory for Non-linear Spectroscopy

INTRODUCTION

The European Laboratory for Non-linear Spectroscopy (LENS) is the largest interdisciplinary laser and photonics institute in Italy, and is part of the European Network of large scale facilities, Laserlab-Europe. In addition, LENS is associated with the University of Florence and the National Institute of Optics of the CNR. The LENS laboratory is by its nature a place which welcomes many visitors from within and outside Europe, both for short term research projects, as well as postdoc and senior researchers. The institute is organized to conduct research in atomic and molecular physics, in physics and chemistry of condensed matter and in optics and photonics. LENS is consistently ranked within the top three research institutions in Italy in terms of amount and quality of publications, patents, and number of citations.

Within LENS, the micro and nano photonics group (http://www.lens.unifi.it/cs) focuses its work on exploring new photonics materials, in particular strongly scattering photonic structures and photonic crystals, thereby covering both the synthesis of new materials, their experimental characterization, and the development of theoretical models. In addition, the group is active in the new emerging field of photonic-fluidics in which nano fluidics is combined with photonics, with the aim of making new materials in which an optical trigger can change a (nano scale) liquid flow or induce auto-propulsion (swimming) on a micro/nano scale.

For more information see: www.lens.unifi.it and www.complexphotonics.org.

HIGHLIGHTED RESEARCH

The micro and nano photonics group at LENS has a long standing experience in the optical properties of complex photonics materials, ranging from photonic crystals to quasi-crystals and, in particular, photonic materials with varying degree of disorder. Transport of light in disorder photonic structures is a fascinating research area, both regarding the related fundamental physics as well as for its potential applications. Interference effects play an important role also in disordered structures and can lead to dramatic trapping effects like Anderson localization. The group recently found a way to implement disorder in thin film solar cells, and use Anderson localization effects to trap and therefore strongly absorb light waves (patent pending).

Both the LENS laboratory in general and the micro and nano photonics research line in particular have an excellent international reputation and have been at the forefront of several important discoveries in the field of photonics. Amongst these are the observation of Anderson localization of light in strongly scattering materials (Nature cover story, 1997), the observation of optical necklaces states in disordered systems, the observation of several analogies between light and electron transport (optical Bloch oscillations, weak localization, optical Zener tunnelling), and the observation of Lévy flights (superdiffusion) of photons (cover story Nature, 2008). The group is also a pioneer in the field of amplifying random media and random lasers (see e.g. review paper Nature Physics, 2008).

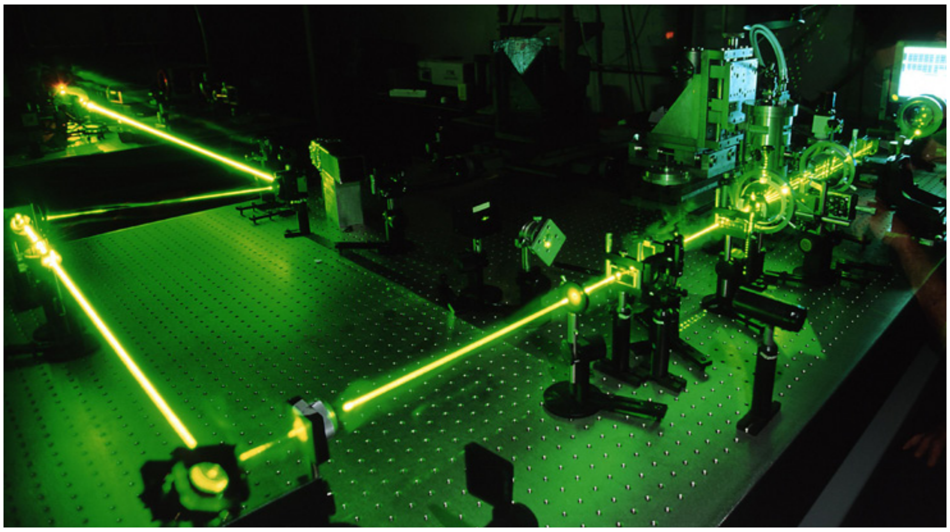
FACILITIES

- Facility to realize 2D and 3D photonic structures using direct laser writing in polymers. The technique allows to realize photonic crystals, quasi-crystals, disordered structures, or any other point-wise defined structure.

- In addition, the group has developed a local infiltration technique that allows to address individual pores of 2D photonic membranes, and infiltrate them with liquids of choice.

- Several experimental techniques to characterize light transport in photonic materials, including a system to monitor the temporal evolution of a fast (150 fs) light pulse in transmission (both direct and diffuse), a system to measure coherent backscattering, and a near-field and confocal optical microscope.

- Theoretical modeling tools, including fully 3D FDTD calculations, finite-element methods, and self-consistent multiple scattering theory (based on diagrammatic expansion).



nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

TUD

Technische Universität Dresden

INTRODUCTION Founded in 1828, **Technische Universität Dresden** (TUD) is a full-scale university with 14 faculties, covering a wide range of fields in science and engineering, humanities, social sciences and medicine. The university emphasizes interdisciplinary cooperation, and in both teaching and research its students participate early on in research. More specifically: interdisciplinary cooperation among various fields is a strength of the TUD, whose researchers also benefit from collaborations with the region's numerous science institutions - including Fraunhofer institutes, Max Planck institutes and institutes belonging to the Gottfried Wilhelm Leibniz society. The Department of Physical Chemistry consists of research groups dealing with theoretical chemistry, physical chemistry of polymers, colloidal chemistry, electrochemistry and physical chemistry of nanocrystals.

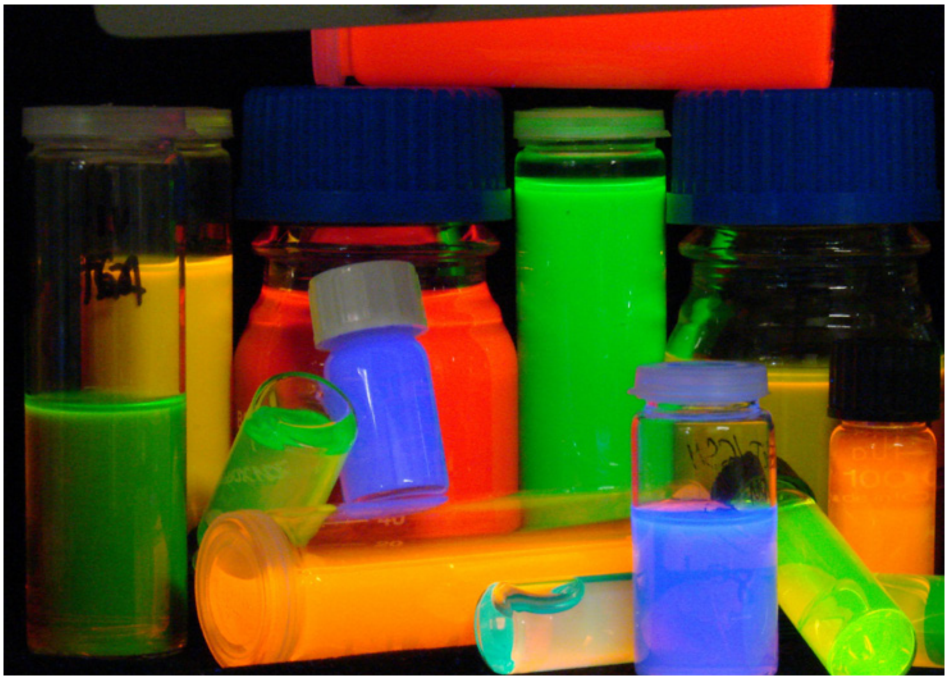
HIGHLIGHTED RESEARCH

The TUD group has a long lasting expertise in modeling, synthesis, characterisation, functionalisation and assembling of colloidal semiconductor and metal nanocrystals (NCs). Semiconductor nanocrystals have attracted considerable attention because of their appealing optical properties such as strong, narrow, and tuneable (quantum confinement) photoluminescence with quantum yields in the region of 30-85% and full-width-half-maximums (FWHM) of 20-50 nm. Amongst other attractive properties of NCs are their high extinction coefficients (at least an order of magnitude higher than organic dyes), stability (common for inorganic materials), and variable surface functionalities which determine their processability. Metal nanocrystals possess pronounced surface plasmon resonances which are size-dependent and remarkably sensitive to the chemical composition of the nanocrystal surface.

The combination of all these properties makes both metal and semiconductor NCs very promising for a variety of active applications in nanophotonics and optoelectronics, including LEDs, solar cells, lasing, optical sensors, colour conversion layers, bioimaging, etc. Assembly approaches are considered as important tools for nanotechnology allowing a predictable and reproducible handling and addressing of nanoobjects. The TUD group is an expert in the layer-by-layer electrostatic assembly, solvent-controlled precipitation, covalent linking, gelation, 1D assembling by oriented attachment, nanoparticle self-assembly, etc. These methods being applied to the variety of available nanocrystals allow the fabrication of functional composites possessing desirable properties as demanded by the particular nanophotonic and optoelectronic application.

FACILITIES

- Chemical laboratories, equipped with Schlenk lines and gloveboxes for the synthesis of semiconductor and metal nanocrystals under inert atmosphere.
- UV-Vis-NIR spectrofluorimeter Fluorolog 3 equipped for static and time-resolved fluorescence spectroscopy with sub-nanosecond resolution. Spectral region: 300 – 1700 nm.
- UV-Vis-NIR spectrometer Cary 5000 (Varian), equipped with mirror reflection and integrated sphere setups. Spectral region: 200 – 2500 nm.



SEVENTH FRAMEWORK PROGRAMME

UPC

The Technical University of Catalunya

INTRODUCTION

The Technical University of Catalunya (UPC) with near 30000 students is the main technological university at the north east of Spain. Located in the Barcelona area, offers graduated and master studies in all areas of engineering: civil, telecommunications, informatics, electronics, chemistry, enegy...

The Micro and Nano Technologies research group (MNT) of the Technical University of Catalunya (UPC) is formed by faculty members, researchers, PhD students and technical personnel doing research about materials, technologies and devices. The focus being oriented in semiconductors at the micro and nano scale. MNT staff share research facilities where micro and nano fabrication facilities are available together with specialized characterization and measurement equipment and simulation and modelling tools. The facilities include a clean room with main silicon processing equipment, material deposition, photo and e-beam lithography, surface and bulk micromachining and advanced characterization facilities: Focussed Ion Beam, XPS, DRX, UHV-SPM, UHV-AFM, AFM's

HIGHLIGHTED RESEARCH

One of the main research lines is on photovoltaic devices. Three different options are considered a) Crystalline Silicon solar cells. b) Organic solar cells and c) Thermophotovoltaic.

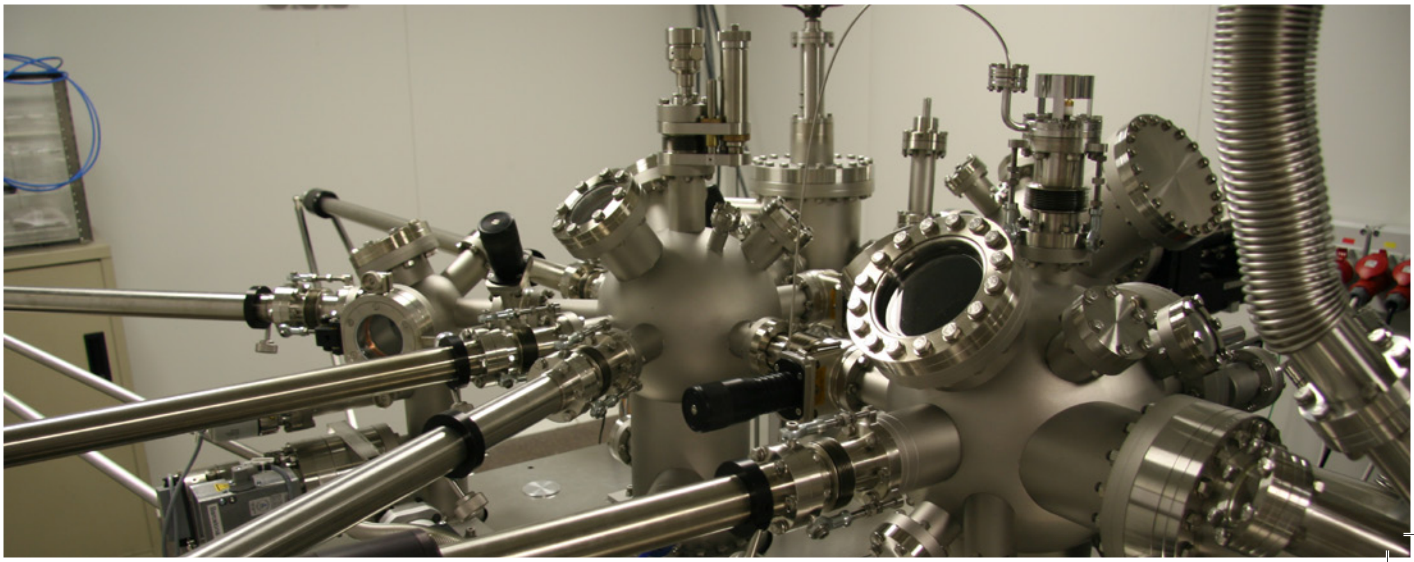
a. **Crystalline Silicon solar cells**. Our research in this area is focussed in laser processing and passivation. As Silicon solar cells are getting thinner back surface passivation becomes mandatory, at the same time the use of Lasers either for contacting or fabricating local emitters opens new possibilities of improving industrial solar cell efficiencies. We have developed a technology of PERC cells (Passivated Emitter and Rear Cell) with efficiencies over 20%. With this background we can analyse the effect of different passivation layers (SiCx, SiNx, Al_2O_3) on real operating devices. Also beginning from an operating PERC cell we substitute usual contacts by laser processed ones without loose efficiency.

b. **Organic solar cells**: As it is well known in organic solar cells we can find those fabricated from polymers usually by spin-coating or a related process and those fabricated from small molecules usually by evaporation. In our group we have developed both technologies and research is being done in optimization of the fabrication technology: inclusion of intermediate layers, annealing, molecules, surface treatment, etc.

c. **Thermophotovoltaic** attempts to obtain electrical power from a solar cell but instead of light the cell transforms heat (long wavelength electromagnetic radiation) into electrical power. In principle the overall efficiencies can be very high. An important part of these systems are the selective emitters. A selective emitter when heated emits radiation at, ideally, a single wavelength. For doing so we have developed a Silicon based technology for 3D photonic crystals.

FACILITIES

- Clean Room: Equipped with: Diffusion and oxidation furnaces, optical lithography, PECVD, sputtering, evaporator.
- Organic solar cell fabrication set-up: Glove-box, metal evaporator and organic evaporator.
- Nanofabrication and nanocharacterization facility: FIB, UHV-AFM, UHV-SPM, XPS...



nanophotonics for energy efficiency

SEVENTH FRAMEWORK PROGRAMME

US

University of Southampton

INTRODUCTION

The University of Southampton has a distinguished heritage that can be traced back to the creation of the Hartley Institution in 1862, following a bequest to the Corporation of Southampton by Henry Robertson Hartley, the son of a local wine merchant.
The Hartley Institution became a university college in 1902. It was renamed Hartley University College, and subsequently University College Southampton. In 1952, the Queen granted the University of Southampton a Royal Charter to award degrees in its own right, conferring full university status. Back in 1952, there were around 900 students at Highfield and today we have over 22,000.
For more details about our history, see www.soton.ac.uk/about/historyofuni/.

The University today

Today, the University of Southampton is a forward-thinking institution that aspires to change the world for the better. Through education, research, innovation and enterprise, we provide opportunities that transform the lives of our students, our community, society and the economy.

With over 22,000 students, around 5,000 staff, and an annual turnover well in excess of £400 million, the University of Southampton is one of the UK's top institutions for engineering, computer science and medicine. We combine academic excellence with an innovative and entrepreneurial approach to research, supporting a culture that engages and challenges students and staff in their pursuit of learning. As a founder member of the Russell Group, a prestigious association of 20 major research-intensive universities of the UK, we offer a high-calibre study environment. With a global reputation for linking fundamental research with real-world applications, Southampton is home to cutting-edge research centres and facilities in nanophotonics.

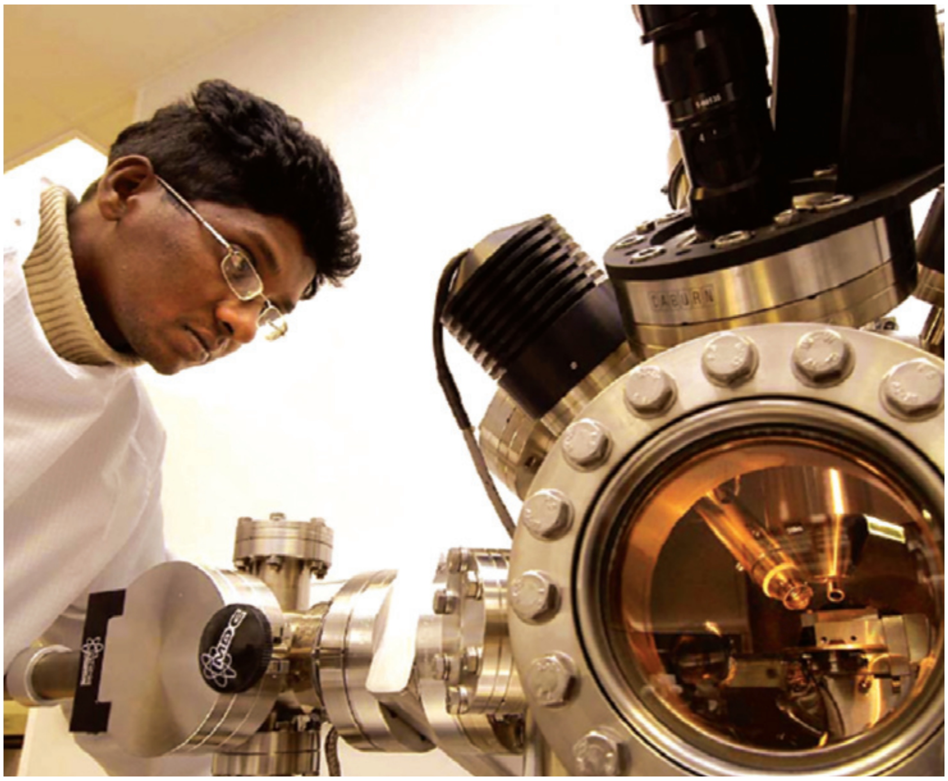
HIGHLIGHTED RESEARCH

Innovative hybrid systems are inspired by naturally-occurring biological-nanostructures that use energy transfer and recycling to transform light into chemical energy. At Southampton we explore alternative ways of removing carriers from efficient light absorbing materials such as organic semiconductors and nanocrystal quantum dots (QDs) and transferring them into single crystal inorganic semiconductors with high carrier mobility. Such phenomena are yet to be observed and will pave the way for a completely new generation of hybrid optoelectronic devices.

Using ultrafast spectroscopic techniques we investigate alternative ways of removing carriers from efficient light absorbing materials of low carrier mobility, such as organic semiconductors and nanocrystal quantum dots, and transferring them into single crystal inorganic semiconductors with high carrier mobility. We recently demonstrated record exciton transfer efficiency of 65% and by implementing novel technologies developed in our group in excitonic solar cells we have achieved a threefold enhancement of the photocurrent conversion efficiency of a single junction photovoltaic device. Visit www.hybrid.soton.ac.uk for a more recent update.

FACILITIES

Multi-color ultrafast spectroscopy, Caliber SPM, Multimode SPM, Multiview 4000, Cryoview 2000, Mask aligner: LI07 EVG 620T, LI01 EVG 6200 Infinity, SEMME15 Zeiss EVO, ME01 Zeiss Orion, EL02 FEG-SEM, DLSME11 Zetasizer Nano, FIBME02 Zeiss NVision40, Dry EtchDP01 RIE80+, DP06 RIE80+, DP07 ICP380 Oxide, DP02 ICP380 Metal, DP05 Ionfab300Plus, DP03 STS Pegasus, PECVDPT08 OIPT Nanofab, PT03 OIPT System 100 LS, PT05 OIPT FlexAl ALD, PT04 OIPT Poly System 100, PT04 OIPT System 100 Si/Ge, EpitaxyPT02 ASM Epsilon 2000, Vapour Phase EtchWE21 HF Vapour Phase Etcher, Resist ProcessingLI08 EVG 150 Resist Processing Station



Advisory Board Members

**in alphabetical order*

BASF SE, GVC/E

JAEHYUNG HWANG | Lab leader

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"At the "Joint Innovation Lab - Organic Electronics", experts from BASF are pursuing research together with their cooperation partners from industrial companies, prestigious universities and research institutes. The researchers at JIL are currently focusing on the areas organic light emitting diodes and organic photovoltaics. Dr. Jaehyung Hwang is leading part of the organic photovoltaic team, whose ultimate purpose is to develop organic molecules to replace the silicon in solar cells and make them more cost effective."

CENTROTHERM THERMAL SOLUTIONS GMBH & CO. KG

WILFRIED LERCH | Director Technology

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Centrotherm is delivering manufacturing equipment for the PV industry and additionally equipment for the semiconductor industry. Especially here we are in the business for high temperature SiC processing (e.g. vertical furnace annealing up to 1900 °C). These SiC based chips are very often used in the DC/AC converter for the PV industry. Furthermore we are producing equipment for LED production.

ENI S.P.A.

Studies & Research – DISRI Research Center for Non-Conventional Energies Istituto Eni Donegani

ROBERTO FUSCO | Technical Leader

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Eni, a world leading firm in the energy sector, and among the majors in oil extraction and distribution, recently devoted its research institute- Istituto eni Donegani- to the exploration of new perspectives offered by renewable energy sources.The topics under investigation, including capture, conversion and storage, are developed in a range of projects envisioning innovative photovoltaic solar cells, hydrogen production by water photosplitting, spectral converters, luminescent concentrators.Aimed at obtaining increasingly more efficient solar devices, eni moved its attention towards the exploitation of nanostructured materials and innovative molecular systems.

IBM

DR. SOLOMON ASSEFA | IBM Research, Research Staff Member

sassefa@us.ibm.com

Dr. Solomon Assefa is a member of the Integrated Silicon Nanophotonics group at IBM. His research activities include silicon nanophotonics integration with CMOS for optical communications, ultra-fast and ultra-low power avalanche photodetectors, and low-power broadband optical switches. Moreover, he has been performing research on electrically-activated photonic-crystal devices and slow-light engineering for buffering application. He has also explored magnetic random access memory (MRAM) and spin-torque memory device integration.

ROYAL PHILIPS ELECTRONICS – PHILIPS LIGHTING

BRUNO SMETS | Director External Relations

b.smets@philips.com

Philips Lighting at present is the global leader in general illumination. It is its ambition to become the number one in LED lighting, combining solid state lighting with sensors and actuators. The major remaining challenge with SSL is no longer to generate photons in an efficient way, but to extract the photons from the device. Nanostructred materials are seen as one of the preferred options to reach the overall system efficiency required in general illumination.

HELIATEK GMBH

DR. ANDREAS RÜCKEMANN | CEO

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Heliatek is engaged in the development and production of organic photovoltaic solar cells. The company is applying the extensive research and development work of its founders by leveraging organic materials to improve the cost-efficiency characteristics of solar cells for large area applications. Heliatek is developing a new proprietary material that displays unprecedented power efficiency, transport and contact properties as well as extended life-time characteristics. Heliatek's proprietary technology relies on the vacuum deposition of so-called small molecules, a technology proven successful in OLEDs. The company will bring to market its first generation of modules in 2012. After first test markets, the company is targeting volume markets including OPV in the industrial roof top and Building Integration sector. Based on both technology and strategy, Heliatek nicely fits into the Network of Excellence "Nanophotonics for energy efficiency". It is thus an honour to serve as advisor in its board.

T-SOLAR GLOBAL S.A.

DR. JORDI ANDREU | CTO

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TSolar Group is a vertically integrated holding with activities on photovoltaic electricity generation (more than 160 MW installed) and thin film silicon photovoltaic module fabrication. T-Solar Global S.A. is the manufacturing company of T-Solar Group, with a production capacity of 50 MW/yr and a production efficiency above 7 %. Our main target markets are large ground mounted PV plants and roof PV systems on industrial and commercial buildings. The TSolar R&D department is focused on internal development and on identification of external developments suitable to be transferred to large scale industrial production. The main area of work for this improvement is the development of optical technologies that help to improve the optical absorption in the active layer of the device and most of the technologies developed within the network are suitable for this purpose. TSolar is willing to serve as advisor to the board providing a vision close to the photovoltaic market.

UNIVERSITY OF EXETER
SCHOOL OF PHYSICS AND ASTRONOMY

Bill Barnes | Professor

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Our research focus is on the interaction between light and matter, where we have a particularly strong interest in the fundamental study of electromagnetic materials that incorporate structure from the nanometre to centimetre scale.

UNIVERSITÉ TOULOUSE 3 · LAPLACE

GEORGES ZISSIS | Professor

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The Light & Matter research team of LAPLACE laboratory is dealing with Light Sources and Lighting Systems Science and Technology. Discharge lamps, Solid State Lighting and more especially Organic Light Emitting Diodes are in the heart of our activities. Our team, composed of 7 permanent staff members and 10 PhD students, is working since 40 years on both experiment and modelling and we participate to large industrial scale demonstrations. Finally, our team has an important activity on standardization issues for Light sources.

Project Partners

9 different institutions in 6 European countries...
More than 130 scientists, engineers, technicians in Nanophotonics.
The project partners are:

www.bilkent.edu.tr	www.leti.fr	www.csic.es
www.icfo.es	www.kth.se	www.lens.unifi.it
tu-dresden.de	www.upc.edu	www.soton.ac.uk

nanophotonics
for energy efficiency

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