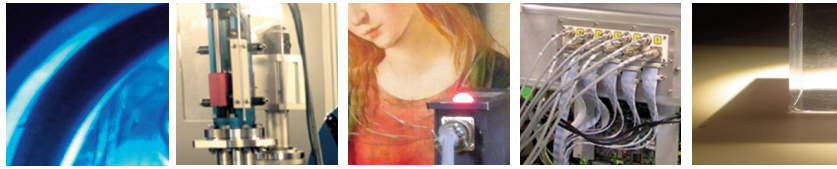
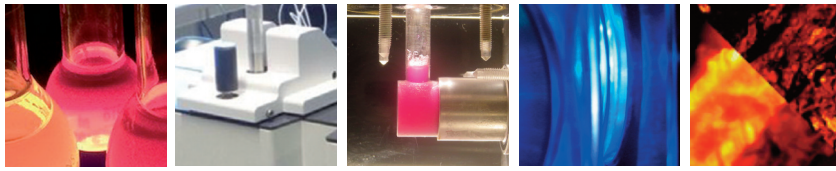
Department of
Basic and Applied Sciences for Engineering
SBAI



SBAI R&D

Applied sciences for growth and innovation



SAPIENZA
UNIVERSITÀ DI ROMA

SBAI
Dipartimento di Scienze di Base e Applicate per l'Ingegneria

SBAI, the Department of Basic and Applied Sciences for Engineering at Sapienza University of Rome conducts research primarily on issues of the Chemical, Physical and Mathematical disciplines exhibiting a significant applicative aspect. Such disciplines are a bridge between basic science and technological breakthroughs, using physical and chemical principles and mathematical methods to develop new technologies. Theoretical and experimental activities aimed at advancement of knowledge are also perfomed. They provide a fundamental stimulus to a scientific environment aiming to excellence based quality, and are an essential element of any innovation process.

In this leaflet, SBAI presents R&D projects and achievements in the following application areas:

- NANOPHOTONICS
- NANOMATERIALS FOR ENERGY AND THE ENVIRONMENT
- NANOMATERIALS
- NEW MOLECULES FOR ORGANIC ELECTRONICS
- PLASMONICS
- QUANTUM INFORMATION
- PARTICLE ACCELERATORS
- PLASMAS FOR NUCLEAR FUSION
- PARTICLE ACCELERATORS
- PARTICLE THERAPY
- ULTRASOUNDS FOR MEDICAL APPLICATIONS
- BIOPHOTONICS AND BIOSENSING
- MATHEMATICS AND THE BRAIN
- ENVIRONMENTAL MONITORING
- OPTICAL SYSTEMS FOR MEDICINE

SBAI-RELATED SPIN-OFFS AND START-UPS

DINESTO
DRIVE THE INNOVATION IN ENERGY STORAGE

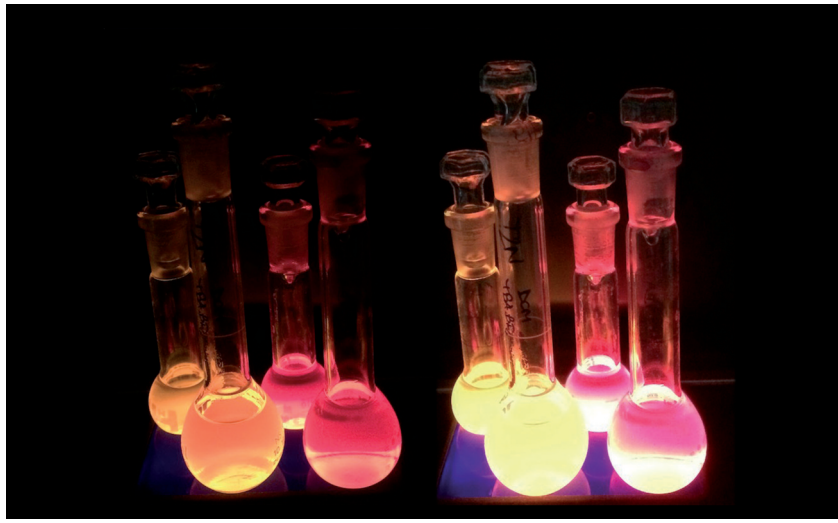
www.dinesto.com

NanoShare Srl
a start-up company for human technologies

www.nanoshare.eu

Sustainable energy for lighting and transportation

In the field of Chemical Technologies, SBAI researchers carry on research lines that have led to national and international patents. Efficient energy storage techniques have been developed in lithium batteries, which have produced patents and a spin-off related to sustainable mobility. Low-cost hydrogen production and storage techniques are also under investigation. Hydrogen, as "fuel of the future", has a fundamental role in the battle against atmospheric pollution.



New molecules for Organic Electronics

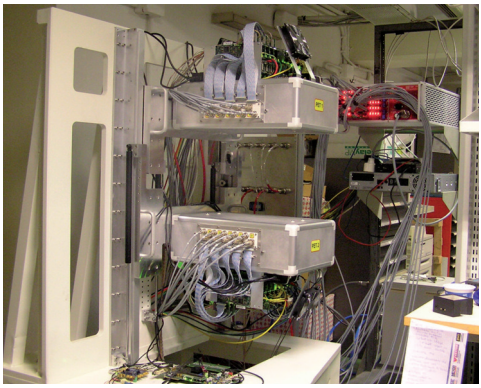
The laboratories also develop the so-called "Green Chemistry" where chemical reactions take place with minimum environmental impact. Electrochemical studies on organic compounds syntheses starting from carbon dioxide led to a scientific collaboration with Bayer Material Science (now Covestro Deutschland Ag).

New chemical compounds were also synthesized, usable both in the field of Organic Photovoltaics (environmental friendly low-cost solar cells) and in OLED devices (ultra-thin last-generation displays: TVs, cell phones, etc.). The synthesized compounds are the subjects of national and international patents, some of which have been acquired by Merck GmbH.

(Isabella Chiarotto, Marta Feroci, Leonardo Mattiello, Mauro Pasquali)

Particle Therapy: shooting at the tumor

A R&D activity of the department with direct biomedical applications is the research in Particle Therapy. This innovative technique for the treatment of cancer replaces the beams of X-rays, used in standard radiotherapy, with beams of protons or carbon ions.

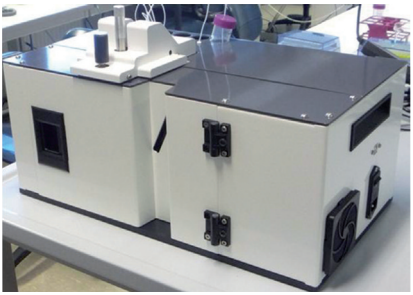


System for proton beam monitoring and Carbon ions in the adrotherapy

These particles have the property to release larger fraction of their energy at the end of their path. If these beams are sent to the patient with the necessary energy to precisely targeting the tumor, they preferentially kill cancer cells minimizing the damage for the surrounding healthy tissue.

The precision in the treatment depends on a lot of features (patient morphology, parameters of the machine that provides the beams), so it is crucial to monitor the actual path of the beam in the patient. At the moment there is no devices to perform such a control in clinical practice. In this landscape, the Department participates to the INSIDE project for the development of a device which monitor the adron beam position detecting the secondary radiation emitted by its interaction with the patient's tissues.

The project is a collaboration of researchers from INFN, the Fermi Center and the University of Pisa and Bari. The clinical end-user is the National Centre of Oncology Hadrontherapy (CNAO) of Pavia where the device will be installed in 2017.



Testing tool for the detection of tumor markers

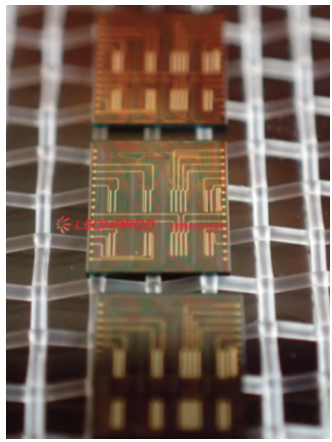
Furthermore, the SBAI Department coordinated the EU funded project Biloba (www.biloba-project.eu), which produced a point-of-care testing tool and an innovative disposable nanophotonic bio-chip for the detection of tumor markers.

In the first test on human plasma samples, the system succeeded to detect concentrations of pre-clinical interest.

(Adalberto Sciubba, Vincenzo Patera, Alessio Sarti, Francesco Michelotti)

Quantum information

Concreting Quantum Science in innovative products that can stimulate growth and create new jobs is undoubtedly a big challenge, which can only be won if the link between industrial production and scientific part is strengthened. In this context, in recent years there has developed a synergy between SBAI - Nonlinear Optic Laboratory (C.Sibilia) and Quantum Technologies Lab - LEONARDO (F.A. Bovino). LEONARDO's Quantum Technologies Lab holds a national / international leadership position, conducting advanced research in the fields of Quantum Information and Communication Technology, which led to the creation of the only two Italian products in the Quantum Cryptography field, the most recent of the which is the Q-KeyMaker®. The two devices have been developed under the projects funded by the Ministry of Defense (MD), namely: "QUCRYPT-D (" Quantum Advanced Encryption ") and" QUCRYPT-NET ". MD's interest in Quantum Technologies and applied security research has funded SBAI for a number of programs that have helped to build cooperation with Quantum Technologies Lab, such as the SORGENTI project ("Optical Source for Security "), the MARINE project (" Negative refractive index materials ") and recently the important COPERNIC project (" Quantum Computing and Advanced Sensor Chip in Near-Medium IR "). Quantum computing has attracted much interest in the last 15 years, mainly due to its ability to factorize large numbers in polynomial times and its efficiency in simulating the dynamics of complex quantum systems. COPERNICO project aim to design and developing circuits that use light for quantum information processing, based on a patent (F.A. Bovino EP3109803 - STRUCTURE AND METHOD FOR PROCESSING QUANTUM INFORMATION) already filed by LEONARDO. It is a revolutionary computing architecture that allows the creation of the so-called IntraSystem Entanglement. Entanglement is a key element for quantum information processing, and in this new architecture the correlation properties are not related to the internal degrees of freedom of the particles but are "in-printed" on an optical circuit. Thanks to this idea were realized "universal quantum logic gates", complex circuits such as Quantum Entangler shown in Figure, and quantum teleportation systems.



QUANTUM ENTANGLER
(courtesy of Quantum Technologies Lab - LEONARDO)

The race for the development of quantum computers is under way: NASA and GOOGLE already use the $ 10 million D-WAVE quantum calculator, cumbersome and working at temperatures close to zero. Our goal, following the example of Olivetti's 101 Program, is to realize QUANTIUM, the first quantum PC.

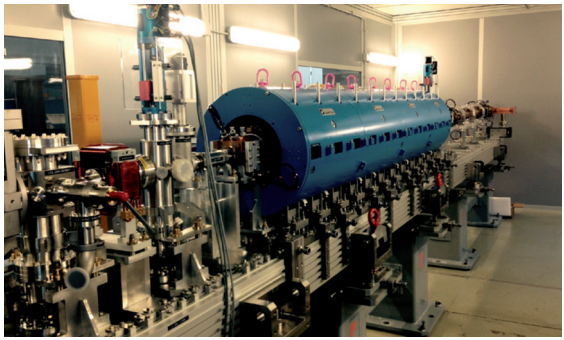
(Concita Sibilia - SBAI, Fabio Antonio Bovino - Quantum Tech. Lab-LEONARDO)

The energy of stars with particle accelerators and plasmas

While at Cern in Geneva, where the Higgs Boson was discovered, the Large Hadron Collider, which is the world largest particle accelerator, continues to work, scientists have begun to develop the accelerator of the future, an even bigger and more powerful accelerator, housed in a tunnel long about 100 km in the Geneva area.

Its name is Future Circular Collider (FCC). SBAI researchers, with experience in Physics and Technology of Particle Accelerators, participate in the project with roles of responsibility.

Particle accelerators are also used as sources of high energy radiation (X-rays, gamma-rays).



Electron Injector of the Gamma Ray Source in Romania

In fact, collisions between an electron beam and a laser beam may produce high energy gamma rays that penetrate matter, allowing (among other results) advanced studies of nuclei of atoms to understand what happens in the heart of the stars. The most ambitious gamma source in the world has been funded by the European Community and is under construction in Romania. The SBAI department is committed to implementing the project that will end in 2018.

SBAI researchers are also involved in nuclear fusion research. The process that feeds the stars is potentially a source of energy almost inexhaustible and with low environmental impact. To prove its feasibility on the earth, inertial confinement fusion uses very powerful laser light pulses, which irradiate submillimetric targets, transforming them - for a duration of billionths of a second - in plasma with densities, temperatures and pressures even higher than those in the centre of the sun.

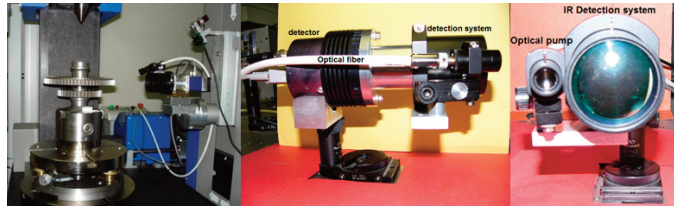
The SBAI department conducts research on inertial fusion by developing complex simulation models and diagnostic techniques of plasma. SBAI researchers join the experiments in laboratories of Luli (Ecole Polytechnique), Lle (Rochester) and Pals (Prague) with national and international groups: MIT, Los Alamos, CNRS, CEA, Bordeaux.

(Stefano Atzeni, Mauro Migliorati, Andrea Mostacci, Luigi Palumbo, Angelo Schiavi)

Nondestructive testing in industry by Photoacoustics & Photothermal Techniques

Non-destructive testing (NDT) of materials plays a key role in industry where products have to be tested to verify the integrity and compliance with the standards. Since 1990 the Photoacoustic and Photothermal laboratory (PA&PT lab) has been working to develop innovative instruments for NDT and quality control of materials in the area of civil and military technologies, in both automotive and aerospace industry, and recently in agrofood industry.
The following techniques have been implemented in the PA&PT lab: photothermal deflection and photoacoustic spectroscopy, infrared radiometry and thermography.
Basic applications refer to contactless measurements of thermal diffusivity and conductivity, optical absorption and scattering, and thermoelasticity of materials.

The main industrial applications are for NDE & NDT of materials: (1) the thickness measurement of coatings or paints; (2) the detection of subsurface cracks, adhesion defects, trace gas of pollutants; (3) the determination of the hardening depth profile in steels.
The methodology involves the excitation of thermal waves and the detection of the reflected/backscattered thermal waves from obstacles and/or inhomogeneities, in analogy to conventional ultrasonic technologies.



PTR o TWADAR infrared prototypes developed in the PA&PT lab at SBAI

Several IR devices have been realised (PTR and TWADAR) for leading companies in the field of aerospace (AVIOGROUP) and automotive (BIFRANGI), to measure the cementation in hardened steels, in gears, ball bearings etc, alternatively to Vicker or Brinell tests. The devices are portable and fully integrated on a robotic arm for the local NDT of materials (in collaboration with MDM Metrosoft). Other recent strategic partnerships are with the Chinese organization in Nanjing for the inspection and quality control of products (NQI).

(R. Li Voti, G. Leahu)

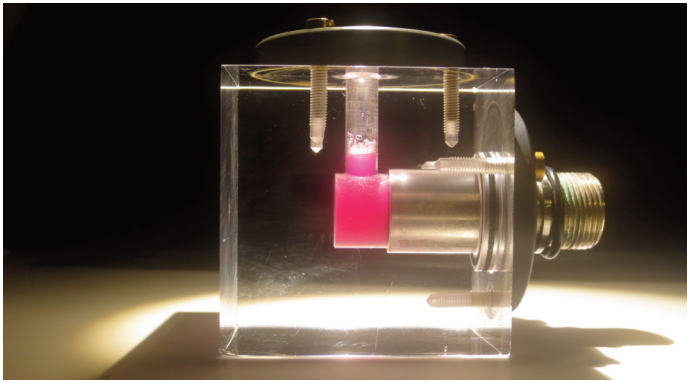
Ultrasound Enhancement Systems to help health-care management

Acoustic applications are wide ranging enough to encompass language and other forms of communications, the detection of danger, nondestructive evaluation of precision components and biomedical devices. The Physical Acoustics Lab at SBAI Department undertakes long-term, leading-edge researches on ultrasound innovations mainly to study new and improved biomedical applications of ultrasound. In particular the Lab is currently working on two separate projects for the development of ultrasound based health-care systems.

The purpose of the first project is the development of a small, novel, reliable, rugged and easy to use point-of-care (POC) sonodevice based on ultrasonic waves for real time measuring of blood viscoelasticity. At sound difference with common laboratory tests, the device will measure in real time blood viscoelasticity. The use of POC diagnostics may compensate for the methodological limitations of conventional coagulation testing as standard lab tests of blood coagulation yield only partial diagnostic information, and important coagulation defects remain undetected.

The second project is carried out in collaboration with the Department of Chemistry and Technology of Drugs, Sapienza University Rome. It deals with the development of lipid shell gas-filled nanobubbles (mean diameter 200 nanometers) to be used as a ultrasound contrast agent in ultrasound scan of vascular systems with small and very small vessels diameter and in small animals ultrasonography. The nanobubbles are also being designed for drug and gene delivery, as well as for theranostic applications (a combination of therapy and diagnostics in the same device).

(Andrea Bettucci)

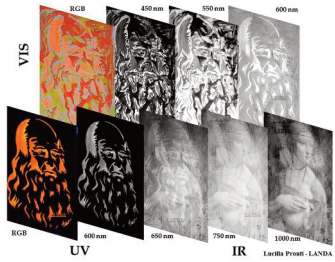


Experimental apparatus based on high frequency ultrasonic pulses for the characterization of nanobubbles used both as ultrasound contrast agent in ultrasound imaging systems and as a drug delivery vehicles

Laboratory for non destructive analyses and archaeometry - Landa "Sebastiano Sciuti"

Portable energy-dispersive X-ray fluorescence spectrometer (ED-XRF). When analyzing a painting it allows to identify the inorganic pigments used by the artist.

The Laboratory for nondestructive analyses and archaeometry – LANDA "Sebastiano Sciuti" has a long-lasting experience in the field of the archaeometric study of Cultural Heritages. By using nondestructive analytical methods mural and easel paintings, ceramics, metal and stone artifacts, manuscruptis books, etc. are analyzed in order to obtain information on the materials constituting the artifacts and on the techniques employed to realize them. These information are used to understand the provenance of the objects, to reconstruct ancient usage, to attribute a masterpiece to a specific artist, to attest the authenticity of an artwork or to identify the degradation processes that affect the integrity of an artifact. The techniques used by the researchers of the laboratory LANDA "Sebastiano Sciuti" are the energy-dispersive X-ray fluorescence spectroscopy (ED-XRF), Raman spectroscopy, reflectance spectroscopy in the UV-Vis-NIR range, UV induced fluorescence spectroscopy, and Multispectral Imaging. All the instruments are portable and this allows to perform in situ analyses in museums and archaeological sites. The main masterpieces studied are the "Lupa Capitolina", the Massenzio's Imperial insignia from Palatino, the Vallerano mirror (Museo Nazionale Romano), the Etruscan mirrors from the Gorga collection, Andrea Pozzo's wall paintings in the former Refectory of the Trinità dei Monti convent in Rome, the epitaph of Pope Hadrian I in Saint Peter's in the Vatican, metal artworks from Ebla (Syria), Mayadevi temple in Lumbini (Nepal) (UNESCO World Heritage) and paintings of Lorenzo Di Credi kept in the Galleria Borghese and the Accademia Nazionale di San Luca in Rome.



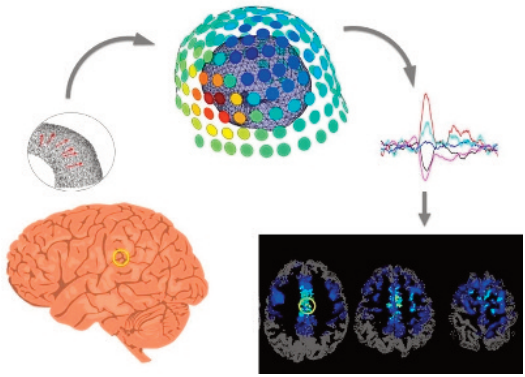
Multispectral images. When analyzing a painting they allow to highlight the spatial distribution of different materials that constitute the artifact or to discover the presence of preparatory drawings or "pentimenti".

The researchers of the laboratory collaborate with archaeologists and art historians of several universities and research centres (University of Roma "La Sapienza", Catholic University of Milano, IULM - Milano, ISCIMA – CNR), with museums (Museo Nazionale d'Arte Orientale 'Giuseppe Tucci' – Roma, Galleria Borghese – Roma, Accademia Nazionale di San Luca), Superintendence and Italian financial Police.
The laboratory has performed several in situ analyses campaigns during archaeological excavations, some of which abroad (Mayadevi temple in Lumbini - Nepal (UNESCO World Heritage), Ebla – Syria, Banbhore – Pakistan, Estakhr – Iran)

(Anna Candida Felici)

Math & Brain

The Applied Math research group - Dept. SBAI - is involved in the development of numerical and probabilistic methods for the solution of various mathematical problems arising in the modeling of real-world phenomena.
A relevant research project is in the field of neuroimaging, and specifically in the reconstruction of the neuronal activity generated in the working brain using Electroencephalography (EEG) and Magnetoencephalography (MEG) signals. These non-invasive techniques measure the electric potential difference on the scalp and the magnetic field outside the head due to neuronal activations.
The brain areas activated during stimulus detection, cognitive processing or simply at rest can be inferred by electric and/or magnetic measurements. Thus, by using E/MEG it is possible to study non-invasively the brain at work and to diagnose possible pathologies such as, e.g., epilepsy.



Reconstruction of the brain activity map by MEG signals

From the mathematical point of view, to reconstruct the brain activity map from EEG and MEG data we need to solve a highly ill-posed and ill-conditioned inverse problem that requires cutting edge mathematical inversion methods.
The research group of Dep. SBAI, in cooperation with researchers in the Institute for Advanced Biomedical Technologies of "G d'Annunzio" University in Chieti-Pescara (Italy) and in the Dept. of Mathematics, Applied Mathematics and Statistics of Case Western Reserve University in Cleveland (Ohio, USA), have implemented an efficient algorithm that is able to reconstruct accurately the electric activity map in the brain by MEG signals.

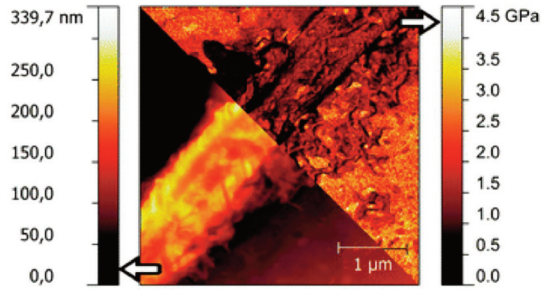
The algorithm learns from the data the main features of the neural sources responsible for the measured magnetic field and is particularly suitable for the characterization of the activity of deep brain sources and, thus, useful both in clinical diagnosis and in neuroscience study targeted at subcortical brain areas.

(Francesca Pitolli, Barbara Vantaggi)

Nanometrology: measuring the nano-world

Technological progress based on the use of nanotechnologies to realize innovative materials and devices requires the availability of methodologies for the study and characterization of the chemical and physical properties of nanomaterials, nanostructures, and nanocomposites. The main challenge in this field is represented by conceiving and developing new measurement techniques and standards which meet the next-generation fabrication and failure-analysis needs. EMINA (Electron MIcroscopies and NAnoscopies) lab is committed with the development of nanometer scale measurements techniques and methodologies, based on the combined and synergistic use of electron microscopies and diffractions and atomic force microscopies (AFM). The latter use a nano-tip to "touch/see", which allows one not only to reconstruct the sample topography but also to measure its local physical properties, e.g., mechanical, magnetic, electric, or thermal properties. EMINA has developed techniques able to study and map mechanical properties of materials in a wide range of elastic moduli, from soft polymers and biological samples to stiff coatings and gemstones, with a particular focus on inhomogeneous samples like nanocomposites and nanosctructured materials.

Recently, in consideration of the technological interest toward nanomagnetisms, EMINA has developed a magnetic force microscopy based innovative methodology for the study of nanoscale magnetic properties, capable to study magnetic properties of single isolated nanoparticles.



Topography of a nanocomposite polymeric fiber reinforced with nanodiamond particles (left) and corresponding elastic modulus map (right).

In this context, in the framework of research projects and contracts in collaboration with research institutes, other universities and high-technology industries, R&D activities are currently ongoing aiming at the technological transfer of these techniques and methodologies in the production processes which require the control of properties at sub-micron scale.

(Marco Rossi)

SBAI Department is actively engaged in the so-called third mission, namely the practical appication of its expertise, through technology transfer from academia to industry.

SBAI R&D is performed at the following laboratories:

- Accelerators
  Prof. Andrea Mostacci (andrea.mostacci@uniroma1.it)
- Applied Electrochemistry
  Prof. Mauro Pasquali (mauro.pasquali@uniroma1.it)
- EMINA - Electron MIcroscopies and NAnoscopies
  Prof. Marco Rossi (marco.rossi@uniroma1.it)
- Physical Acoustics
  Prof. Andrea Bettucci (andrea.bettucci@uniroma1.it)
- Molecular photonics
  Prof. Francesco Michelotti (francesco.michelotti@uniroma1.it)
- UPho Lab - Ultra-fast Photonics, Lasers and Optical Sensors
  Prof. Eugenio Fazio (eugenio.fazio@uniroma1.it)
- InBay - Inverse Problems and Bayesian Inference
  Prof.ssa Francesca Pitolli (francesca.pitolli@sbai.uniroma1.it)
- LANDA - Laboratory of Archeometry and Non-destructive Analysis
  Prof.ssa Anna Candida Felici (annac.felici@uniroma1.it)
- LEOS - Lab of Electrochemistry and Organic Syntheses
  Prof. Leonardo Mattiello (leonardo.mattiello@uniroma1.it)
- Nonlinear Photonics
  Prof.ssa Concita Sibilia (concita.sibilia@uniroma1.it)
- SBAM - Basic Sciences for Medicine
  Prof. Vincenzo Patera (vincenzo.patera@uniroma1.it)
- GAPS - Advanced Plasma Simulation
  Prof. Stefano Atzeni (stefano.atzeni@uniroma1.it)

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