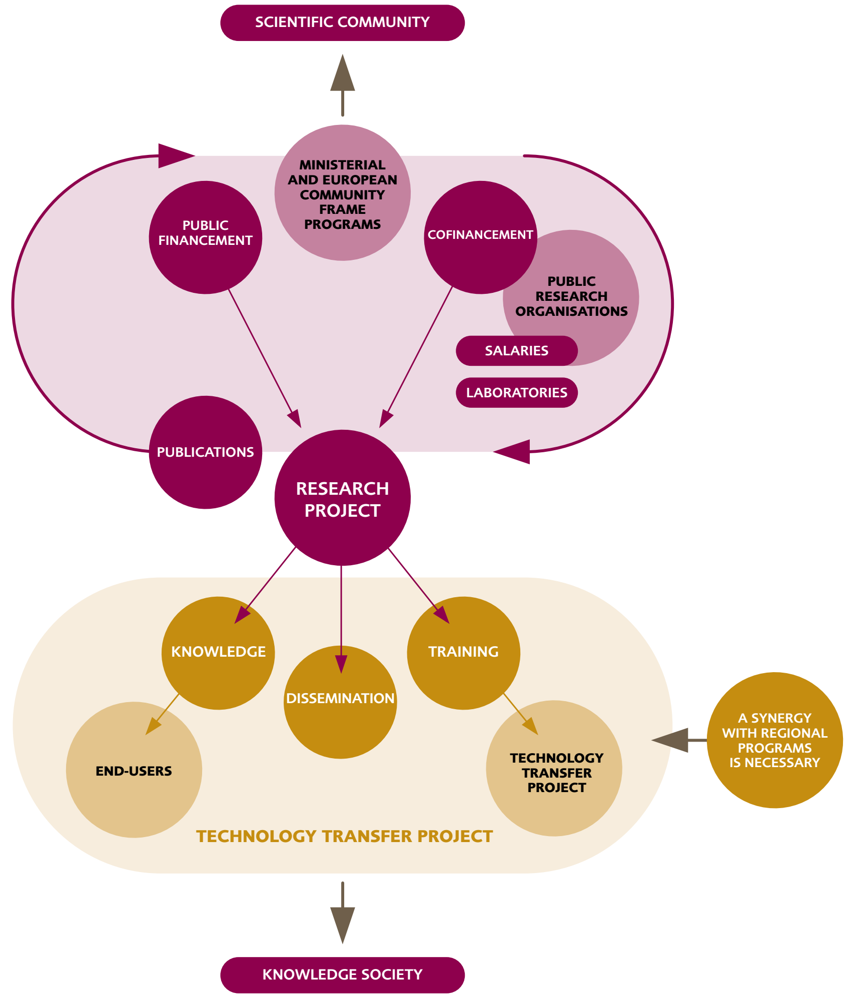
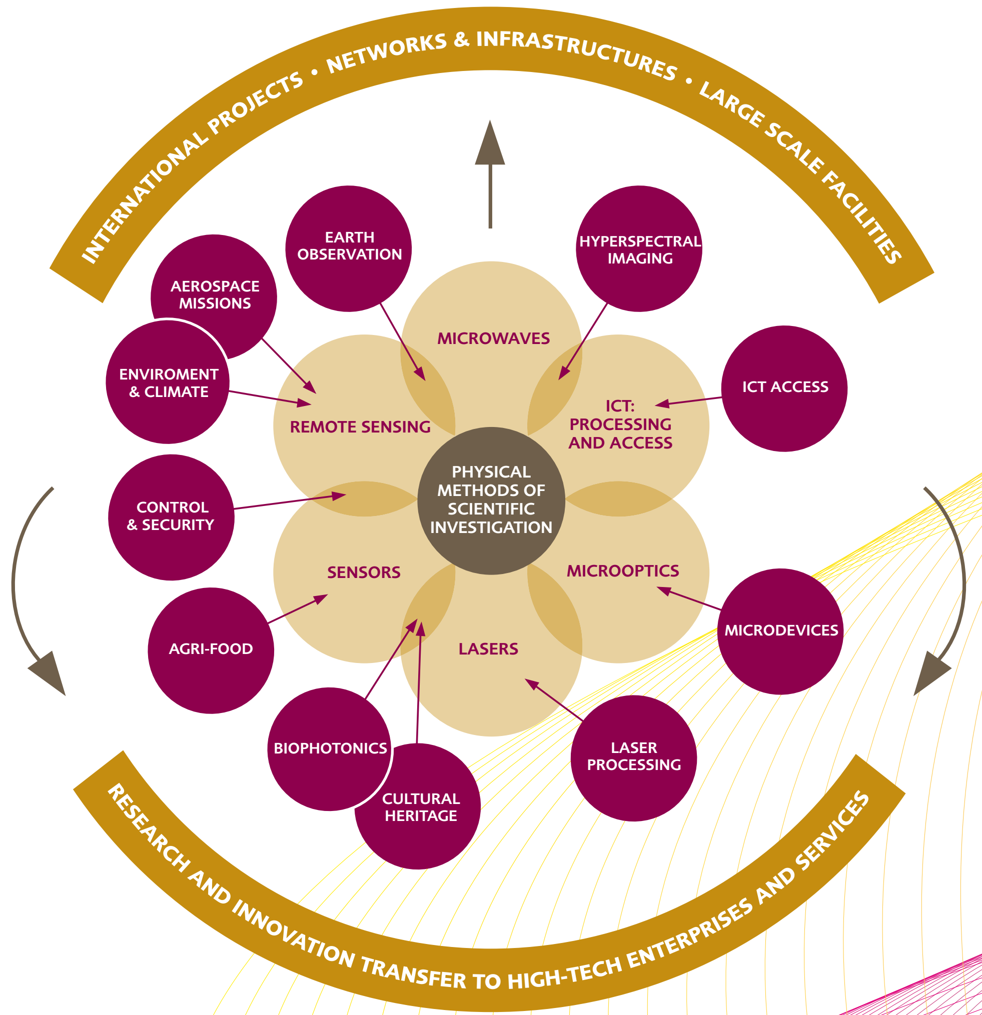
RESEARCH AND INNOVATION

Since the early origin of the Microwave Centre, the scientific identity of IFAC has unwaveringly pursued the objective of producing both research at an international level and innovation for the national economic system. To this end, the Institute draws up its research plans on two interacting planes: that of a competitive comparison at an international level, and that of a strong interaction with both public institutions and private companies at a local level.
IFAC works on these two levels by proposing advanced research projects capable of producing original results and technological development. It also plans technology transfer projects that extend and enhance their results by means of direct collaboration with high-tech enterprises that are capable of producing innovative products, and with public or private organisations that function as end-users. It is thanks to the interaction of these three elements (research, high-tech producers, end-users) that novel knowledge can become innovation and thus develop new products, update professional skills, and generate a related economy.
This method of proposing or contributing to projects with different dimensions and aims constitutes the most effective sequence for completing a pathway between a research idea and a technology transfer that may become a product or a process innovation.
In order for this mechanism to work, it is obviously necessary that all three of these components contribute with appropriate interest and motivation. The accompanying outline shows the sequence of a research project possibly addressed to produce an iterate increase in knowledge within the limited sphere of the scientific community, followed by a technology transfer project that employs that knowledge in a different way by forwarding it to other professional spheres, by means of training and joint experimentation.
Among other fundamental conditions for the success of this mechanism, the role of the Tuscany Region is in our case synergic and crucial, thanks to policies and resources made available for research, innovation, and the economic development of the territory.
This is the model for innovation pursued by IFAC, which hosts joint laboratories with private enterprises, and has made a considerable number of formal agreements in targeted associations (>200) which have been signed during the past 5 years with enterprises that are active in various manufacturing sectors.



RESEARCH ACTIVITIES



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INSTITUTE OF APPLIED PHYSICS NELLO CARRARA

THE INSTITUTE

The "Nello Carrara" Institute of Applied Physics (IFAC) is part of the National Research Council (CNR), which is the main public organisation pursuing research and innovation in Italy.
IFAC was founded in 2002, but it actually originated much earlier: in 1946, it was known as the "Microwave Centre", thanks to Nello Carrara, a pioneer in the field of microwave science. During this period of time, the scientific interest of the institute in various branches of physics grew, due to the scientific contributions of other scientists such as Giuliano Toraldo Di Francia. They involved optoelectronics, quantum electronics, Earth science, and information science.
In 2002, a CNR reform established the conditions for merging the Institute of Research on Electromagnetic Waves (IROE) with the Institute of Quantum Electronics (IEQ), both of which had evolved from the earlier Microwave Centre, into the present-day "Nello Carrara" Institute of Applied Physics. The merger followed the aggregation process of small-size institutes in the direction of larger institutes of a more suitable size.

At present, IFAC's main aim is to carry out frontier research at an international level and, at the same time, to develop new technologies and methodologies that could be effectively transferred to the economic system. The approaches involved are theoretical, experimental and applied research, with a firm determination to develop new techniques and to build prototypes of instruments. The illustrative outline shows the main research lines around the inner core of physical methods of scientific investigations. These pertain to the general fields of optoelectronics, spectroscopy, and ICT. The main lines of research are Lasers, Bio-photonics, Micro-optics, Sensors, Remote Sensing, Microwaves, and ICT. These physical methods are then employed to investigate novel applications in several branches of interdisciplinary sciences, such as photonic devices for telecommunications, space, balloon and airborne instrumentation for observations of the Earth, digital solutions for information access, bio-photonics for therapy and surgery, laser processing for industrial production, optical sensors for environmental control, laser techniques and diagnostic methods for archaeometry and the conservation of the cultural heritage.

IFAC also contributes to cosmological studies together with the National Institute of Nuclear Physics of Italy, such as the BOOMERANG project on the cosmic microwave background and the PAMELA project on astrophysical research in anti-matter and dark matter.
IFAC has also been involved in the ALISEO, MORFEO and NOWCASTING projects of the Italian Space Agency, in the MIPAS, LEIMON, BISTATIC, GPS-SIDS, DOMEX and COREH2O projects of the European Space Agency, and in the FLEX, KLIMA, CAMELOT, MARSCHALS projects of the European Community Frame Programs, which focused on the problems of climate, with the development of payloads, data analysis and elaboration.
In FP6, IFAC has contributed to several projects, such as NEMO, ENOC, EFONGA on the development of micro-optics, CLINICIP and CAREMAN on biosensors for health care, AUTHENTICO on authentication methods of metal artefacts, and DfA@e-inclusion for ICT access for all.
In FP7, IFAC coordinates the E-Dean network, which deals with information access, and contributes to projects such as Photonics4Life on bio-photonics and POP ART on the subject of the conservation of modern art. It is a partner in the European Research Infrastructure on Cultural Heritage CHARISMA, which involves a study of laser techniques as applied to conservation.
IFAC also contributes to research and innovation programs at national and regional (i.e. Tuscany) levels, with the coordination of many projects concerning optoelectronic and photonic technologies transferred to industries and SMEs active in the sectors of biomedical products, aerospace instruments, manufacturing, and art conservation.
By accomplishing all this, IFAC fulfils its objectives of contributing effectively to the needs of a knowledge-based society while developing significant innovations in various technological sectors.

LASERS

The main research activity deals with promising new solid-state laser systems developed in cooperation with INFM-NEST of Pisa for the growth of the active medium. In a recent MIUR project, we developed Ce3+ lasers that emit tunable radiation in the near ultraviolet (290-315 nm). The result of this research has found an application in molecular biology.
At present, our interest is centred on Yb3+ activated laser crystals.
As compared to Neodimium ones, Ytterbium lasers offer several advantages in terms of a better exploitation of the diode–pump output, as well as a much larger emission bandwidth that makes it possible to generate ultra-short pulses. We have achieved a record in slope efficiency with the Yb:YLF as the active medium, by operating at room temperature instead of cryogenic cooling. Noteworthy results in term of efficiency (66%) and output power (> 7W) have been obtained with a ceramic Yb:YAG.
One important aspect is the realization of instruments for effecting atmospheric measurements and for outer space spectroscopy. One proposed experiment utilises the sun Fraunhofer lines to monitor the chlorophyll fluorescence of vegetation crops and forests.
The results of this research can find applications in several fields: laser sources for biomedical applications, devices for environmental monitoring, industrial processes and diagnostics, security, devices for aerospace applications in projects by ASI and ESA.


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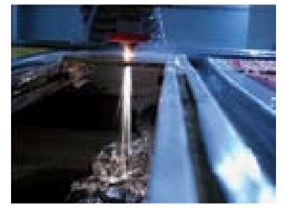
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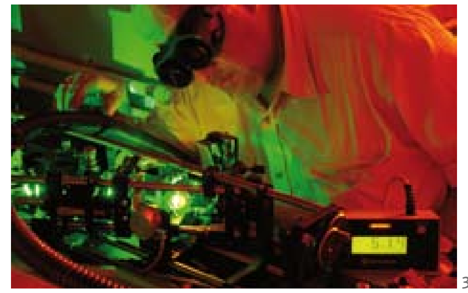
1. Development of diode pumped Yb:YLF laser.

2. Cutting natural stone sheets by CO_2 laser at 2,5 kW.

3. Laser alignment on optical bench for generation of non-linear effects.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MICROOPTICS

The focus of our research into active materials and devices for telecommunications and sensors is on the development and characterisation of optical waveguides devices. In a series of European networking projects such as NEMO, ENOC and EFONGA, IFAC has attained a well-established set of results at both a scientific and technological level. In particular, these regard:
• Optical microresonators: these have very high Q, and confine light within very limited modal volumes. The topics being studied at present are:
- label-free sensors, which are extremely sensitive, for the detection of specific substances, or biological molecules for the early diagnosis of pathologies;
- optical delay lines, for microwave transmitters.
• Fabrication and development of optical waveguide components by means of both photolithographic techniques and thin film deposition (in class 100 and 1000 clean room), and by means of direct writing with UV light or ion-beam irradiation. An in-depth study involving special glass for the realisation of innovative devices is currently under way.
• Microstructured optical fibres:
- the realisation of supercontinuous sources and their application in biological microscopy (in cooperation with ISC-CNR);
- the realisation of long-period grating for application to sensors.
A special project has recently been initiated that involves the development of waveguides in the THz band, for application to sensors and security.


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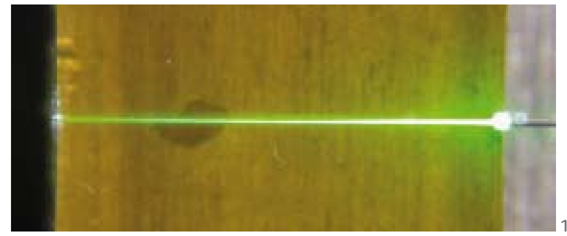
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8. Mapping by *upconversion* in the green of the optical pump guided by a gallery mode in a microsphere resonator.

9. Photolithographic and thin film deposition techniques in class 1000 clean room.

10. Upconversion in the green of Er^{3+} ions along a planar guide with 980 nm pumping.

ICT: PROCESSING AND ACCESS

In accordance with the "eInclusion" definition (European Ministerial declaration of Riga), the research team has worked for more than 20 years to identify both barriers and possibilities for improving the quality of life and including all people in a social life. Recent results include the impact of technology on people today (DfA@eInclusion project) and tomorrow (COST 219 TER project) and web sites designed according to DfA principles in the fields of tourism and dissemination (PALIO project and EdEAN network). IFAC is in charge of the DfA@eInclusion network.

Data elaboration research involves the realization of hyperspectral acquisition systems that operate in the optical range and the development of advanced algorithms and procedures in research areas such as data compression, image quality assessment, data calibration and validation, atmospheric and geometric corrections, image fusion and pansharpening, adaptive filtering and extraction of biophysical features and parameters that have an impact on applications such as landslide risk management, burnt area detection, marine and coastal environment, archaeology.


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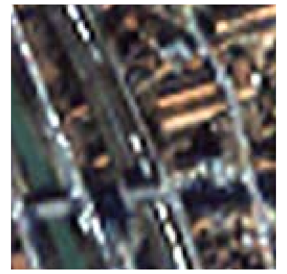
IFAC has been and is currently involved in many projects with ESA, ASI, CNRS, and the Tuscany Regional Authority. Acknowledgements of IFAC activities have been received from national and international organizations such as IEEE GRS, IEEE GRS-S Data Fusion Technical Committee, CNRS, ESA, for IFAC activities involving image fusion and hyperspectral data compression.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17 e 18. Resolution improvement by data fusion of multispectral and pancromatic images from satellite.

19. E-Dean project portal by mobile phone platform.

REMOTE SENSING: ATMOSPHERE

With the aim of characterising the physical and chemical properties of the atmosphere, we develop new observational methods, new active and passive instruments, field measurements, models and algorithms for the extraction of geophysical parameters from the acquired data.
In particular, we design and fabricate:
- Fourier transform spectroradiometers operated in the mid and far infrared spectral regions, and used in field campaigns from ground and stratospheric platforms for the measurement of atmospheric composition and radiance;
- LIDAR systems for the characterization of clouds and atmospheric aerosol, both in metropolitan areas and on remote sites such as Dome-C in Antarctica;
- Attitude systems for the control of stratospheric gondolas, used in experiments of both Earth observations and cosmology;
- Numerical codes for level 2 analyses of space observations of the atmosphere for the three-dimensional reconstruction of atmospheric composition and for the monitoring of greenhouse gasses;
- Methods for the study of the morphology of the ionosphere and for the determination of its total electron content.

IFAC has contributed to a series of projects, such as MIPAS-ENVISAT, SAFIRE, REFIR hosted by ASI and MARSCHALS, CAMELOT, KLIMA, MIPAS-ENVISAT hosted by ESA. The results can be applied to quality air monitoring and to the study of atmospheric chemistry and climatic changes.


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23. LIDAR installed on board of the oceanographic ship in Antartica.

24. Instrument REFIR-PAD, entirely built at IFAC.

25. Launch of REFIR-PAD on a stratospheric balloon, Teresina, Brasil.


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CONSERVATION

After more than 30 years of promising international research on laser cleaning of artworks that proved to be unsuccessful in solving the problems of the yellowing of stones and colour changes in pigments, the research carried out by IFAC has led to a full acceptance and integration of laser techniques as being among the most innovative conservation methodologies for stone, gilded metals, and wall paintings. IFAC has carried out studies on the interaction of lasers with materials, in order to determine the crucial parameters of pulsed emission, and to enable micrometric control of cleaning while preserving the historical layers in the best possible way.
Lasers have been developed with pulse widths of between hundreds of nanoseconds and microseconds, and these entirely avoid undesired effects. Indeed, within a few years they have become the most suitable tools for cleaning masterpieces such as statues by Donatello, gilded bronzes such as the Paradise Gate by Ghiberti, and wall paintings.
This result is now an internationally-recognised best practice. It is based on an intense interdisciplinary cooperation with conservation institutions, with restoration centres, with the EL.EN. Group, who engineered the prototype in mature products, and with many restoration SMEs, who have developed their own professional experience in the area of laser cleaning.


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29. The David by Donatello rediscovers his gilding by laser techniques developed at IFAC.

30. A phase of laser cleaning of the Arringatore, archaeologic bronze of the II sec. a.C.

31. The Paradise Gate during the laser cleaning phase at Opificio delle Pietre Dure.


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BIOPHOTONICS

The aim of biophotonics is to develop advanced diagnostics and therapies that are based on photon interaction with bio cells. In this sector, our activities involve the following topics of research:
- Preclinical and clinical experimentation of minimally invasive, photothermal laser-therapies in ophthalmic surgery, neurosurgery, dermatology, and plastic surgery;
- The development and validation of novel therapeutic and diagnostic methodologies based on laser-activated nanoparticles;
- Techniques of microfluorimetry for the localisation of biomolecules;
- Innovation transfer to industries in the field of laser technologies for surgery, diagnostics, and medical therapies.

The applied research activities are strategically dedicated to satisfying the demands of industrial innovation. The projects are carried out within the framework of regional, national and European programs, with networks and associative consortia, by means of private contracts, in cooperation with public and private centres such as the IFAC-EL.EN. Spa Joint Laboratory for Laser Application. IFAC is a partner in Photonics4Life, a European network of excellence for biophotonics. IFAC also coordinates the regional innovation network OPTONET with a large number of private enterprises in Tuscany that work in the field of optics, optoelectronics and bio-medics, with universities, and with national research centres.


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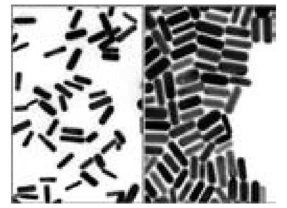
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4 e 5. Laser-assisted eye surgery for corneal suturing in cornea transplant.

6. TEM image of gold nanoparticles tested experimentally for activation of photothermal processes.

7. Fluorescence sensor for monitoring the phenolic maturity of winegrapes.

SENSORS

Possessing the capacity to carry out a specific and systematic monitoring, thus enabling timely and targeted interventions, is a common problem in priority areas such as health, the environment, the cultural heritage, and the agri-food industry. In these areas, optoelectronic technologies offer great potential, both in the development of specific sensors and in the investigation of new fields of application. Our research activities, which are related to this context, are addressed to the study of methods and measurement techniques based on optoelectronic devices, the application of these to the above-mentioned priority areas, and their technological transfer to public institutions and industries.
The commitment involved in several national and European research projects has enabled us to design and develop sensors for *in situ* or remote measurements of chemical-physical and biomedical parameters. These have been successfully applied in different fields, ranging from the development of fiber-optic and micro-optical sensors for quality and safety monitoring in the agri-food sector (MIUR FIRB BIOSENS, EC NoE NEMO Projects) to the development of optical sensors and biochips for the detection of clinical parameters (EC Projects CLINICIP and CAREMAN) and to the development of LIDAR sensors for the monitoring of the environment and the cultural heritage (ESA projects, FIRB SAIA, technology transfer actions).


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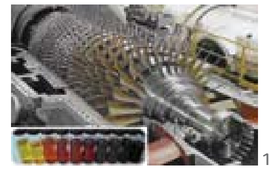
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11 e 12. Diagnostic device based on a biochip for simultaneous detection of proteins for point of care applications.

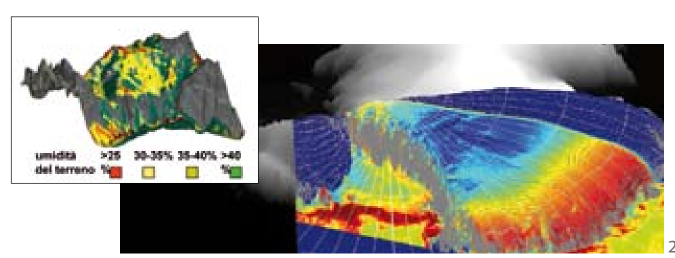
13 e 14. Fliorescence LIDAR in a measurement campaign on state of conservation of Coliseum.

15 e 16. Various types of alimentary and lubricant oils classified by optical microsensors.

REMOTE SENSING: SURFACE

Remote sensing of the Earth's surface deals with the estimate of the geophysical parameters of the observed areas, such as reflectance, emissivity, surface temperature, soil moisture content, snow water content, vegetation biomass. This enables us to carry out regional- and global-scale monitoring, based on quantitative analyses, through advanced aerospace systems in both optical and microwave bands. This involves the:
1) Development of imaging spectrometers and interferometers, such as ALISEO (Aerospace Leap-frog Imaging Static interferometer for Earth Observation) as payload for the Italian Space Agency's MIOSAT satellite;
2) Calibration and validation of high-resolution data collected by aerospace optical sensors (such as the airborne MIVIS and CHRIS placed on board the European Space Agency's PROBA-1 satellite);
3) Customization and characterization of advanced detector arrays operating in the visible and infrared optical range;
4) Analysis of images and data of satellite sensors both active (SAR) and passive (radiometers) in the microwave band such as SSM/I, AMSR-E, ERS-1/2, ENVISAT/ASAR, JERS-1, ALOS/PALSAR, TerraSARX;
5) Development of inversion algorithms for the estimate of geophysical parameters with satellite data.

The activity, whose results can be applied to the monitoring of the surface at both local and global scales, is supported by industrial research contracts (e.g. Selex Galileo SpA, the Tuscany) Regional Authority, the European Space Agency, and the Italian Space Agency. (NOWCASTING, LEIMON, DOMEX, COREH2O projects).



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20. Installation of ALISEO on board of an airplane.

21. ALISEO, the Aerospace Leap-frog Imaging Stationary Interferometer for Earth Observation on MIOsat.

22. Local scale soil moisture (Cordevole basin) and global scale brightness temperature (Antarctica) maps by using microwave satellite sensors.

MICROWAVES

The various research lines study systems that employ microwaves for remote sensing and dielectrometry for monitoring the environment and the cultural heritage. For microwave remote sensing, our activities regard:
- The development and calibration of microwave radiometers;
- The execution of measurement experimental campaigns with airborne or ground-based microwave radiometers and scatterometers on various surface types (agricultural and forest vegetation, snow, ocean).

As for the cultural heritage, innovative techniques have been developed in order to evaluate the state of conservation of wall paintings and their monitoring. One example, which is the subject of a US patent, is a diagnostic system based on dielectric spectroscopy coupled by evanescent field.
The device measures the presence of humidity and salts in the plaster layer of wall paintings. The activities in this sector are carried out in close cooperation with very prestigious conservation institutions. The objective of technology transfer to industry has been completed with ELAB Scientific, a spin-off company of IFAC.

A third group studies physical methods for the control of electromagnetic environmental pollution and of the exposure of the population to e.m. fields: 1) evaluation of the impact of e.m. fields emitted by electric ducts on both the environment and health; 2) dosimetric evaluation of the exposure of health personnel to NMR emission; 3) occupation-related exposure to e.m. fields.


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26. Microwave Sensor SUSI for measurements of dielectric spectroscopy applied to wall paintings diagnostics.

27. Microwave radiometer for experimental observation of natural surfaces (crops, vegetation, forests, snow).

28. Modelling and visualization of current density induced in the head of a goldsmith using a RF oven.


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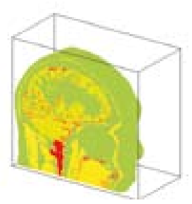
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DIAGNOSTICS

The Institute develops innovative diagnostics for studying the cultural heritage for conservation and archaeometry purposes. One example involves reflectance sensors based on optical fibres, which are actually capable of determining which pigment has been employed in each point of a painting. Other optical fibres may be treated in order to write periodic gratings (Bragg), thus becoming sensors of strain or of compression in the structural elements. The problem of controlling condense formation in artworks and architecture has been solved by means of an optical fibre sensor that was validated in the SENSORGAN project. In addition to point analysis, IFAC has developed an instrument for imaging spectroscopy in the visible and infrared range, both in diffuse reflectance and in fluorescence. The instrument obtains information on pigment composition and on pictorial layers crossed by IR radiation: the latter has recently been extended down to the THz range.
Our investigations also include artefacts of contemporary art, as in the POP ART project. In archaeometry, at present IFAC acts as chairman for AIA, the Italian Association of Archaeometry. In this sector, IFAC has proposed studies employing also laser, XRF and neutron techniques. In the AUTHENTICO project, IFAC employed LIPS diagnostics in order to excite plasma emission from metal artefacts. The spectroscopic components of these are then analysed in order to determine objective methods of authentication.


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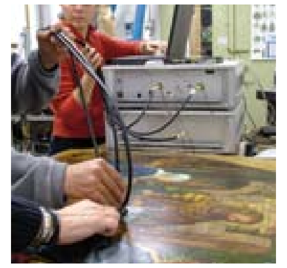
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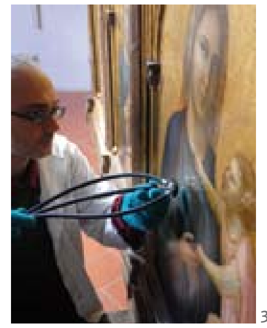
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32. High definition hyperspectral scanner for the image spectroscopy of paintings.

33 e 34. Portable fibre optics sensors applied on apintings for pigments analysis.

35. LIPS instrument for objective authentication of bronze artefacts and other metals.