

THE INSTITUTE OF PHOTONIC SCIENCES (ICFO): A PASSION FOR LIGHT

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This note serves as a presentation for the Institute of Photonic Sciences, a research institution created in 2002 under the auspices of the Department of Universities, Research and the Information Society (DURSI) of the Catalan Government and the Technical University of Catalonia (UPC). The Institute is engaged in research and the training of doctoral students and technologists in the field of photonics, a science that many international agencies coincide in regarding as one of the essential horizontal technologies of the 21st century, and also one of the key ingredients for producing scientific and technological advances in a great variety of areas.

Contents

1. The aim of ICFO
 2. Why photonics?
 3. The road to excellence
 4. Cutting-edge research
 5. ICFO researchers: experience and future
 6. The first spin-off
 7. Coming soon: new premises
 8. Difficult but possible
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1. The aim of ICFO

The Institute of Photonic Sciences (ICFO) appeared on the Catalan scientific scene on 6 March 2002. Its creation was made possible thanks to the impulse of two key institutions in research in Catalonia: the Catalan Government, through the Department of Universities, Research and the Information Society (DURSI), and the universities, in this case the Technical University of Catalonia (UPC).

The aim was to provide the country with a national research centre with the capacity to exert a global effect, based on scientific excellence and engaged in the study of the optical sciences. Photonics is a science that many international agencies coincide in regarding as one of the essential horizontal technologies of the 21st century, and also one of the key ingredients for producing scientific and technological advances in a great variety of areas. This is why research and training in optical sciences and technologies, based especially on laser light, are now a priority in all advanced countries.

The activities planned by ICFO for the period 2002-2006, from the moment the Institute was set up, are aimed at forming a solid, well-structured centre that can face the future with a guarantee of success. The centre is built on three main foundations: research, training, and the transfer of technology and knowledge to society.

For the time being, ICFO is still a young institution in a phase of growth and development. Nevertheless, the centre already has a large group of very productive researchers, including some

20 doctoral interns who learn and train through advanced research. It is also about to start up the first company to have arisen out of an idea made possible by that research, in other words, its first spin-off.

2. Why photonics?

Photonics, together with other transversal technologies such as electronics, will imbue every corner of our society. Today the applications of photonic advances encompass a wide variety of sectors, including the information and communication technologies, optoelectronics and optical nanotechnologies, biotechnologies and life sciences, remote sensing, optical quantum information sciences and technologies, and lasers and laser systems.

In the field of telecommunications and information technologies, photonics allows high-speed data transmission and storage. Transmission by optical fibre has enabled the worldwide development of the Internet, and has been a key tool for the birth of the information society.

Photonic applications in the sphere of medicine, health and biotechnology are increasingly numerous. Photonics lies at the root of such important non-invasive techniques as colorimetric diagnosis, constitutes the basis of photodynamic treatments of some types of cancer and has made possible the use of laser as an ultraprecise microsurgical instrument, now within the reach of most hospitals and health centres worldwide. However, the applications of photonics in this field has only just begun.

Photonics has also contributed to the advancement of genomics, by providing DNA reading and decoding systems; moreover, very possibly it may be applicable in chemical reactions at an atomic scale through femtobiology and femtochemistry. One of the most promising photonic technologies may enable real-time non-invasive viewing of cellular biochemical processes.

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This ability of photonics to reveal information non-destructively is precisely behind another field of application, remote sensing, as it allows the construction of a wide range of optical radars based on sensors that respond to temperature, pressure and humidity, and also to many chemical parameters. This opens up new possibilities for environmental management and agriculture.

Photonics has numerous applications for consumer goods, including compact disc readers, supermarket bar code readers and night surveillance equipment, among others. It also has many uses in industry, from inspection and quality control to cutting and incision operations on various materials, writing, and so on.

As regards more advanced scientific applications, photonics is essential for most precision scientific equipment used in nanotechnologies, optical microsystems, biochips and quantum information systems.

ICFO has plans to conduct research projects in most of these sectors. These projects will be based on creativity and seek to push back the frontier of knowledge in the various areas of optical and photonic sciences.

3. The road to excellence

The ICFO model is one of creative research, based on curiosity, passion for the unknown and hard work. The centre is engaged in research and the training of doctoral students and technologists with a multidisciplinary academic approach that includes basic research and the applications this can subsequently have, together with the transfer of technology and knowledge to society.

ICFO is organised into small autonomous groups made up of doctoral students and young post-doctoral researchers, led by a tenured researcher. ICFO encourages its staff to collaborate with other researchers at universities and research centres in the same sphere, and also with businesses and private organisations. The aim is to pool efforts and resources with all other allied institutions in order to increase the country's scientific and technological capabilities in the field of photonics.

Most work in photonics is done in Europe, the United States, Japan and Australia. Business activity and the presence of centres of higher education and research in this field show a direct correlation. ICFO aspires to be a point of refer-

ence in Europe and worldwide in the field of photonic sciences, form alliances with other centres from all over the world dedicated to related disciplines, and collaborate with the international community in the field of photonics by participating in specific dissemination activities and promoting similar ones. It is a very ambitious and difficult challenge, but one that it is attainable, and which the researchers of ICFO are prepared to face. In doing so they will have the support and backing of the founding institutions and also the other institutions and agencies involved in the funding of scientific activities that are decisive for the development of ICFO. Foremost among these institutions are ICREA (Catalan Institution for Research and Advanced Studies) and AGAUR (University and Research Grant Management Agency), belonging to the Catalan government, and the Ministry of Education and Science of the Spanish government.

As for the creation of professional links with other research centres, ICFO has contacts with the best centres in the world in its field. For example, collaboration agreements have been signed with two of Europe's leading centres in quantum optics: the *Max-Planck-Institut für Quantenoptik* in Germany and the Quantum Optics Center (QUANTOP) of the *Niels Bohr Institutet* in Denmark. In the framework of these agreements, ICFO has as distinguished invited professors and scientific advisers Professor Ignacio Cirac, director of the *Max-Planck-Institut für Quantenoptik* in Garching (Bavaria) and Professor Eugene Polzik, director of the Quantum Optics Center of the *Niels Bohr Institutet* at the University of Copenhagen.

Along the same lines, this year several ICFO groups have joined the European research networks that make up the most advanced groups

in quantum optics and nanophotonics. Thus, the nanophotonics groups have joined an excellence network promoted by the European Commission called PHOREMOST (NanoPhotonics to Realise Molecular-Scale Technologies). This is a consortium comprising some 35 universities and research centres that have established links and common research objectives with the intention of putting this emerging science in a key place on the European and worldwide science scene.

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At ICFO there are two research groups in nanophotonics, led respectively by Dr Gonçal Badenes and UPC lecturer Dr Jordi Martorell and formed by a total of 12 researchers, with several projects in this area. They will shortly be joined by a third group leader, ICREA researcher Dr Niek van Hulst, specialising in nanophotonics applied to processes of biochemical interest, who will provide a new dimension to the area with innovative research programmes. Another indicator of the importance ICFO attaches to nanophotonics is the recent acquisition, in conjunction with UPC, of 3D e-beam lithography equipment, which will enable ICFO and UPC researchers to investigate this area in much greater depth than had hitherto been possible.

The other European network that has been joined by several ICFO groups is the QUDEDIS

consortium for research in ultracold atoms in the area of quantum optics. This network, promoted by the European Science Foundation (ESF), currently comprises leading research institutions and groups from 13 countries. At present ICFO has four groups dedicated to quantum optics, working on a total of eight projects. ICFO is the first research centre in Spain to have built a magneto-optical trap for ultracold atoms, which will make it possible to undertake high-level research projects in this line. This advancement puts Catalonia and Spain on the map of centres that explore the quantum frontier, thus opening up a host of possibilities.

ICFO's scientific, administrative and engineering staff and its technical service account for 70 jobs in total, funded to a large extent through competitive projects and various national and international external research support agencies.

4. Cutting-edge research

ICFO has 10 research groups at present, some of them only just set up. There will be 13 by the end of 2005, and 16 by the end of 2006. Each will have its group leader, as well as post-doctoral researchers and doctoral students who will be registered at a Catalan university, most of them at the Technical University of Catalonia (UPC).

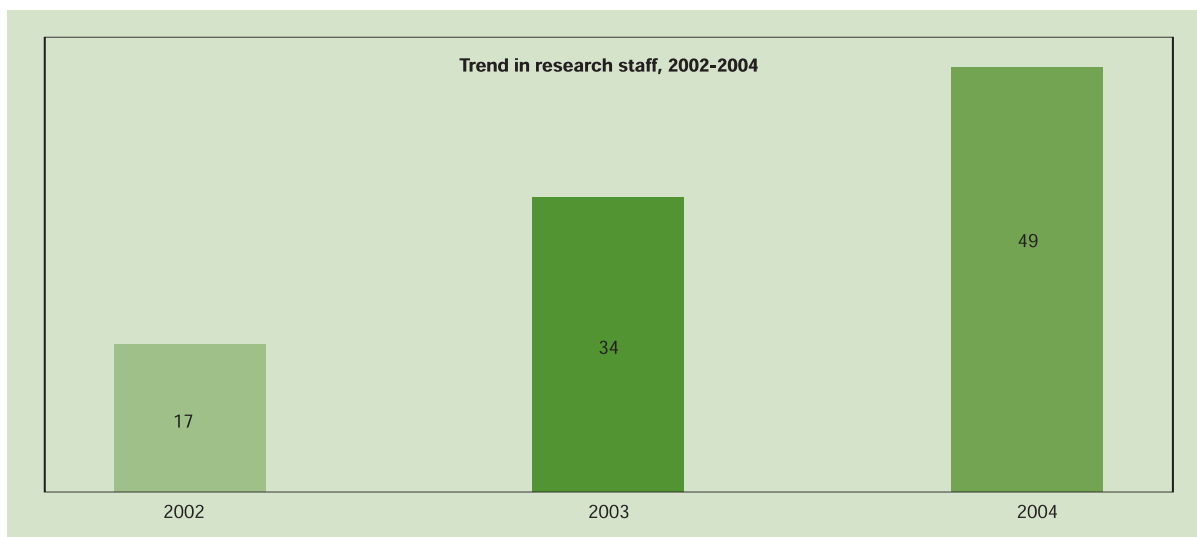
ICFO is currently engaged in developing nearly 30 research projects in the various areas cover-

ed by the centre: biophotonics, nanophotonics, quantum optics and non-linear optics. The researchers work to achieve scientific objectives that offer a wide range of applications in the fields in which they may be used, which include telecommunications and quantum computing, medicine, biology, the environment and nanotechnologies. For example, the group leader in the field of biology, ICREA researcher Dr Dmitri Petrov, heads several projects relating to optical tweezers for manipulating biological material. Optical tweezers are thin, precise laser beams that make it possible to trap and manipulate living microscopic and submicroscopic biological material. Dr Petrov uses them to manipulate and study cancer cells. The improvement of optical tweezer technology has become a front-line objective in Europe. For this reason, one of the 10 EU-funded NEST (New and Emerging Science and Technology) programmes, called *Advanced Techniques for Optical Manipulation*, is based on creative research into this technology, and the ICFO group led by Dr Badenes plays an important part in this programme. Optical tweezer technology has a huge array of applications in the fields of medicine and health, and allows micro-manipulation of greater precision than any mechanical means currently available.

5. ICFO researchers: experience and future

ICFO bases its potential on the dedication, knowledge, experience and capability of its researchers and seeks to help create local wealth with international talent. It is in the process of building a balanced structure of researchers from all over the world, with a diversity of specialities and experience in the field of the photonic sciences that are gradually shaping the research

Table 1
ICFO research staff, 2002-2004



structure of ICFO. Some of these researchers are Catalans who were working abroad and decided to come home when ICFO was born, with a will to continue to work on the research frontier just as they had been doing in the organisations that had recruited them elsewhere in the world.

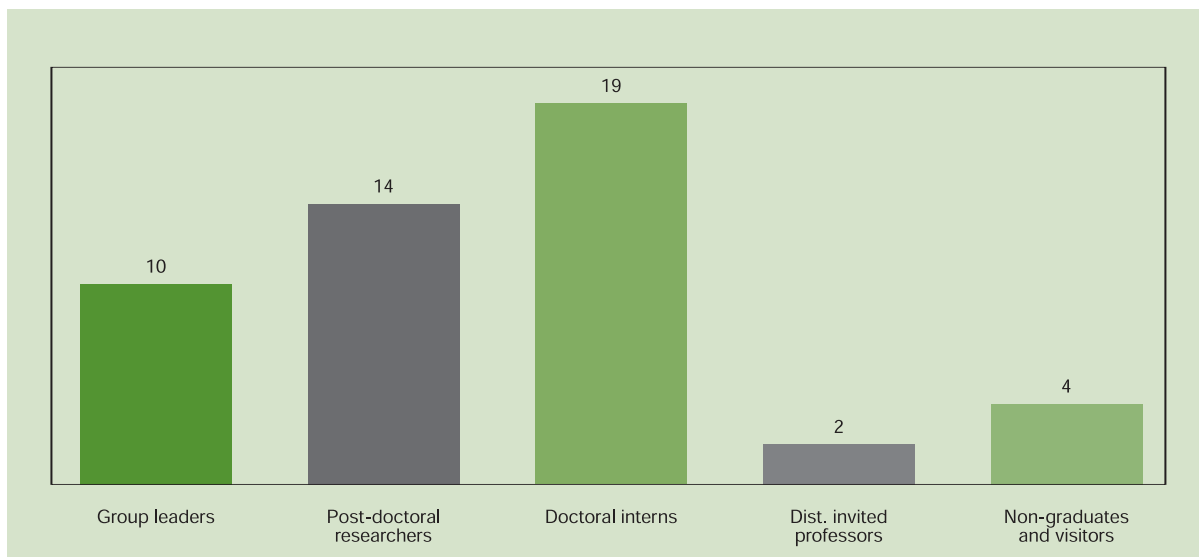
In its first year, ICFO took on 17 researchers including doctoral students. In 2003 the figure rose to 34, and at present ICFO has a scientific staff of more than 50, counting all professional categories. ICFO's scientific, administrative and engineering staff and its technical service account for 70 jobs in total, funded to a large extent through competitive projects and various national and international external research support agencies.

The ICREA researcher contracting programmes and the AGAUR grant programmes (both funded by the Catalan government), the Ramon y Cajal, Juan de la Cierva and Torres Quevedo pro-

grammes (funded by the Spanish Ministry of Education and Science), and others set up by the European Union, such as the Marie Curie fellowships, have made it possible to incorporate into ICFO the most highly qualified research staff, both scientifically and professionally speaking. Expertise and excellence are two of the main characteristics shown by candidates to lead a group at ICFO.

ICFO's post-doctoral researchers and doctoral students are its greatest asset. They are young graduates from universities all over the world in countries as far afield as Austria, Germany, France, India, Korea, China, Iran, Poland, Russia, Rumania, Bulgaria, Italy and Mexico. They form teams together with researchers and students from Catalonia and the rest of Spain to improve their training through research. These students, who once they have graduated as doctors in their speciality will leave ICFO and continue their pro-

Table 2
Categories of research staff at ICFO (2004)¹



professional career in some other organisation, are taking their doctorate mostly at UPC, although some are doing so at other Catalan universities, following programmes that include various different aspects of photonics.

Support for doctoral students in the form of scholarships, courses and seminars, with access to competitive experimental research infrastructures and participation in top-level programmes, is fundamental if they are to become mature scientists with leadership skills, whether in public or private laboratories or as founders of firms based on cutting-edge technology. Some of these doctors will also join companies, contributing their experience, their know-how and the resources

they have acquired at ICFO in the use of concepts, tools and new technology.

6. The first spin off

It is also one of the missions of ICFO to transfer technology and knowledge to society and promote spin-off ventures by researchers and students. It is in this context that the first spin-off company is about to emerge from ICFO, or more specifically from the group led by Dr Majid Ebrahim-Zadeh. Dr Ebrahim-Zadeh, from the University of St Andrews (Scotland), joined ICFO in 2003 through the ICREA programme and works in the field of optical parametric oscillators (OPOs), in

¹ Of the 10 group leaders, two are ICREA researchers and three (the three junior group leaders) are contracted through the Ramon y Cajal programme; of the 14 post-doctoral researchers, one has a Juan de la Cierva scholarship, three are contracted through the Ramon y Cajal programme and one through the Torres Quevedo programme; and of the 19 doctorate interns, 4 have an AGAUR scholarship.

other words, tunable multicoloured lasers. Dr Ebrahim-Zadeh is studying whether the same laser device can be used to tune to different wavelengths, i.e., different colours of light, thus enabling different particles to be detected. This is of use for the environment, medicine, industry and all those fields that require remote sensing, because a single laser system can detect more substances and particles, thus cutting costs and saving time. The project for the business idea, called RADIANT, was presented by Dr Ebrahim-Zadeh with the help of Dr Sara Otero, of ICFO's Projects Unit, for the annual competition organised by the UPC/EAE INNOVA programme and was awarded first prize. The necessary steps are now being taken to set up the company.

7. Coming soon: new premises

Provisionally, ICFO researchers are doing their work at the Nexus II and Omega Buildings on UPC's North Campus, but during the first half of 2005 all ICFO activities will be moved to new premises at the Mediterranean Technology Park (PMT) in Castelldefels. The first part of the new building that will house the centre is about to be completed at the time of writing. This first part will have 3,700 m² of floor space and will include some 20 individual research laboratories, a small manufacturing and characterisation laboratory and also the Nanophotonics Laboratory, to be shared with UPC.

8. Difficult but possible

To sum up, ICFO is a very youthful centre going through a period of vigorous growth. It aspires to occupy a place among the best and to yield results worthy of international acclaim. All the action taken by ICFO in this creation phase is aimed in this direction: the recruitment of leading scientists committed to quality creative science and working on research projects on the frontier of their field, collaboration with other institutions both locally and internationally, the educating of young scientists and technologists who are motivated and trained through projects that provide them with mobility, access to laboratories equipped with state-of-the-art technology and direct contact with the most important scientist worldwide, and the encouragement of the entrepreneurial spirit.

ICFO seeks to be admitted into the club of the best centres in the field of photonics in order to contribute effectively and in collaboration with the other actors in the system to the collective task of pushing back the frontier of knowledge and at the same time produce wealth and welfare for society.

For further information and updates on developments at ICFO, we recommend a visit to the web site <http://www.icfo.es>.