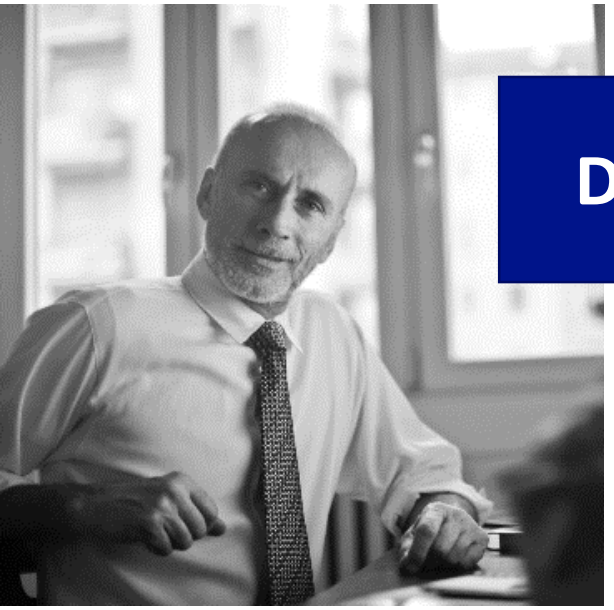

David Díaz

INFORMATION AND CYBERSECURITY

I'm an accountant and I'm very interested in science. That's why I often watch TV shows about technology. A few weeks ago, I saw Prof. Lluis Torner, director of ICFO, explaining that **a smartphone uses things that have earned more than 20 Nobel photonic prizes**, which make cameras, sensors, screens possible, as well as the technology used to manufacture microcircuits and many of their components, and to make the Internet possible. Who would have guessed that I had so much photonics in my pocket!

STORY CARD 1

Isidora Isibarne

PHOTONICS EVERYWHERE

I work for a company that designs and builds lasers: we make small ones, like the pointers you can buy in the neighborhood store, or industrial lasers that can accurately cut all kinds of material or even weld metals. I really like my job because **our products can meet the very different demands of our customers**: there are some that need extreme precision to be able to manufacture the microcircuits that are inside our smartphones and tablets, and others that require high power to weld the components of a car or make incisions in pistons of aircraft engines in a precise and reproducible way to increase their efficiency.

STORY CARD 2

Laura Lorenzo

HEALTH

I have always thought that artificial light could only bring us benefits as it allows us to live and work regardless of the hours of sunlight in a day. However, yesterday my neighbor, who is a big fan of technology and science, explained to me that **artificial light can disrupt the life cycles of living beings**.

There are many things left to understand about light pollution: that's why she invited me to participate with her in a **citizen science experiment** to help researchers study the consequences of the exposition to artificial light. Who would have thought that walking and taking pictures with my cell phone could contribute to science!

STORY CARD 3

Clara Caballero

HEALTH

We couldn’t understand modern medicine without photons as a tool to diagnose and treat patients. In the hospital where I work as a **physician**, thanks to the optical fibers of endoscopes, we can access places hidden inside the bodies of our patients without the need for invasive procedures. Various sensors and **imaging techniques** allow us to see and obtain information from within the bodies to be able to diagnose more accurately. In recent years, lasers have become an essential tool in many operating rooms for extreme precision surgery. And we haven’t even started talking about the therapies that nanophotonics enables!

STORY CARD 4

DECIDE GAME

STORY CARD

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DECIDE GAME

STORY CARD

Francesca Falcó

INFORMATION AND CYBERSECURITY

I don't know how I would do it without the internet: all the music I listen to, the stories I read, the photos I share with friends, the videos I watch, ... everything is in the cloud!

Did you know that the cloud is not as ethereal as its name suggests?

To **distribute information in an ultrafast way around the world**, we need an **optical fiber network** that physically connects all continents and cities, running even on the ocean floor. In this way, the enormous amount of data that is sent every second can reach our devices in no time, be it the data needed to run a hospital or a video of kittens, and all transported by photons!

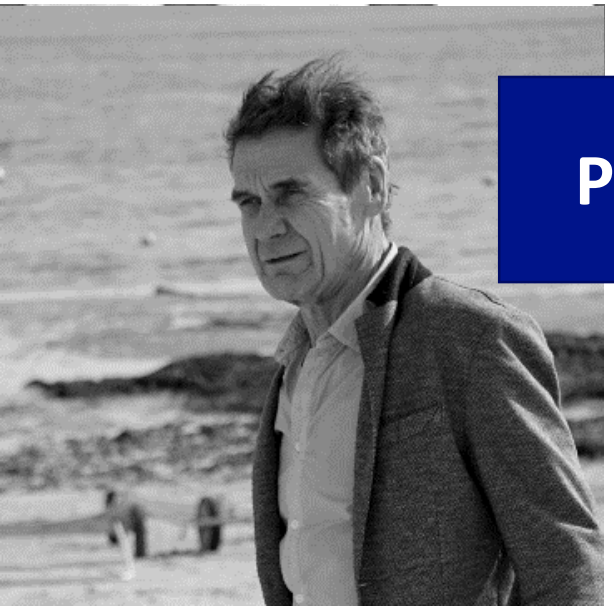
STORY CARD 5

Jun Jiang

HEALTH

I wore glasses since I was a kid and I always wanted to be like my friends who could play sports and go to the pool without having sight problems. Two years ago I was able to have eye surgery to **reduce my myopia** and I can finally see the world directly and not through my glasses! And all thanks **to the photons of an ultra-precise laser** that allowed the surgeon to make incisions in my eyes with minimal risk.

STORY CARD 6



Pere Puig

INFORMATION AND CYBERSECURITY

I like to feel safe when driving, so I'm happy with any safety innovation. For example, I'm thrilled to have **infrared light sensors** in my new car that help me park and alert me when a car gets too close, avoiding scares and even some accidents! In a few years, I hope to be able to buy a **self-driving car** that drives me around: finally I'll be more calm and relaxed when I'm stuck in traffic, because the car will do all the work. Much of the obstacle detection work will be done by infrared photon pulses, maybe even detected by graphene cameras!

STORY CARD 7

Stephan Schultz

INFORMATION AND CYBERSECURITY

HEALTH

I’m training to run the Barcelona Marathon. To improve my training, I bought a bracelet to **monitor my heart rate** at all times. The other day, flipping my bracelet, I noticed that there was a green light on the side that touches my wrist: as it couldn’t be decoration, I researched a bit on the internet and discovered that the **wearable device** gets the information about my pulse by measuring the green photons that interact with my skin.

STORY CARD 8

DECIDE GAME

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STORY CARD

Teresa Torres

PHOTONICS EVERYWHERE

I work in the **quality control department of a food company** and photonics is an ideal tool for our work, because it allows us to do our analyses in a **non-invasive** way, without damaging the products. We use photonic systems for very different processes, from controlling the shape and color of fruits and vegetables, to measuring the amount of oxygen inside the packages to make sure that the food inside does not decay too soon. Some of our suppliers also use photons to monitor the crops and optimize harvests.

STORY CARD 9

Manuel Moreno

INFORMATION AND CYBERSECURITY

In the small town where I live, the City Council has installed photonic sensors: the collected data will help them take informed decisions in the future. For example, they installed a **network of sensors to monitor air and water pollution** with open data systems, so that citizens can be informed about the environmental health. They are also working to connect the entire population to the internet network, installing **optical fiber networks** in all neighborhoods of the city. There are still many thing to do, but little by little we are transforming our town into a ***smart city***!

STORY CARD 10

Simón Salgado

ENERGY AND ENVIRONMENT

I'm a partner in a small furniture family business. A few years ago, I had **solar panels** installed on the roof of the building that we use as factory and warehouse. It was a big investment, but now I save a lot of money when it comes to paying my company's electricity bills. Plus, a choice like this is beneficial to the planet, too!

STORY CARD 11

Alina Anderson

PHOTONICS EVERYWHERE

A few weeks ago I got the job of my dreams: I’m working at a maker space, where I can tinker with all the machines they have. I love the flexible structures that can be obtained by cutting wood: without the **precision of lasers**, they wouldn’t be so easy to do! I'm also fascinated by the **new 3D printer**: thanks to its laser, we can quickly reproduce plastic parts that makers on the other side of the world have designed. It's almost like the teleporters of science fiction movies!

STORY CARD 12

DECIDE GAME

STORY CARD

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STORY CARD

Blanca Bueno

PHOTONICS EVERYWHERE

I've loved cinema since I was a child, but I decided that would be my life when I saw my first **3D movie**. The possibility of seeing the depth of the scenes on the screen seemed like magic to me. But, as is often the case in cinema, it’s just a special effect! The glasses with polarizing lenses that are given at the entrance, select different photons that come from the projectors, bringing to our eyes two slightly different images that our brain combines creating the feeling of three-dimensionality.

STORY CARD 13

Dr Ernesto Espinosa

PHOTONICS EVERYWHERE

When I was studying at the Academy of Fine Arts, I would have never thought of pointing a laser at a picture by Leonardo da Vinci like I am doing right now! Don’t worry, I don’t want to damage it: the laser allows me to clean it and to bring it back to its original splendor.

Lasers and photonic analysis techniques are very useful tools for **restorers of works of art** like me: they allow us to analyze different aspects of works of art (such as pigments, or the process followed by the artist) without jeopardizing the integrity of the pieces. My work mixes **art and science**: I’m sure Leonardo himself would love it!

STORY CARD 14

Gerard Grau

INFORMATION AND CYBERSECURITY

This year I started the master's degree in Photonics in Barcelona. In one of the subjects, I discovered that photonics has a lot to do with my other passion: **drones**. If we fill these small planes **with photonic sensors**, we can get valuable information about places that would be difficult to reach. This makes drones not just fun toys, but **important tools** for studying the environment, searching for oil, gas, or mineral deposits, monitoring areas of natural disasters or crops.

STORY CARD 15

Olivia Ortiz

HEALTH

I am a **high school physics teacher** and to motivate my students I always try to connect the concepts I explain with things from everyday life.

The Sars-CoV-2 pandemic has made it easy for me to explain **infrared radiation**, as we find devices in many places that **measure temperature quickly and remotely**. These thermometers are photon sensors that capture the infrared radiation emitted by our bodies. Also **UVC ultraviolet light** can be useful to disinfect, because it can destroy eventual pathogens.

STORY CARD 16

DECIDE GAME

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STORY CARD

Núria Navas

INFORMATION AND CYBERSECURITY

A few days ago, I saw my two-years-old daughter trying (unsuccessfully) to slide the page of a newspaper with her finger. For a person like her, who was born in a world where there are **screens everywhere**, even on the fridge, it is natural to think of being able to interact with any surface or written word. This would not be possible if in recent years the screens had not improved so much, gaining in definition and functionality. Who could have imagined being able to interact so intuitively with a machine a few decades ago?

STORY CARD 17

Zahra Zadeh

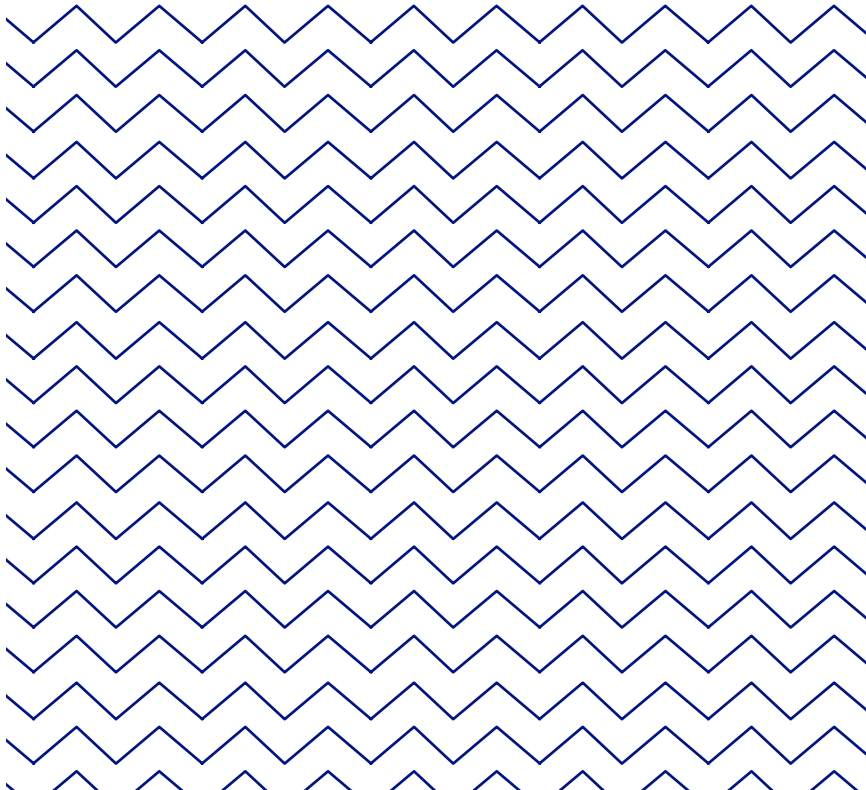
INFORMATION AND CYBERSECURITY

Living in a mountain village with few shops, I usually buy everything I need online. However, there are many people in the village, including my grandmother, who would rather spend more than one hour in the car to the nearest city than leave their data on the internet, because they are afraid of cyberattacks.

Although this is a serious danger, I'm not worried, because I read that there are also many people who are studying new ways to improve the **security of our communications**, and it seems that the most promising techniques have to do with the exotic properties of quantum physics!

STORY CARD 18

STORY CARD



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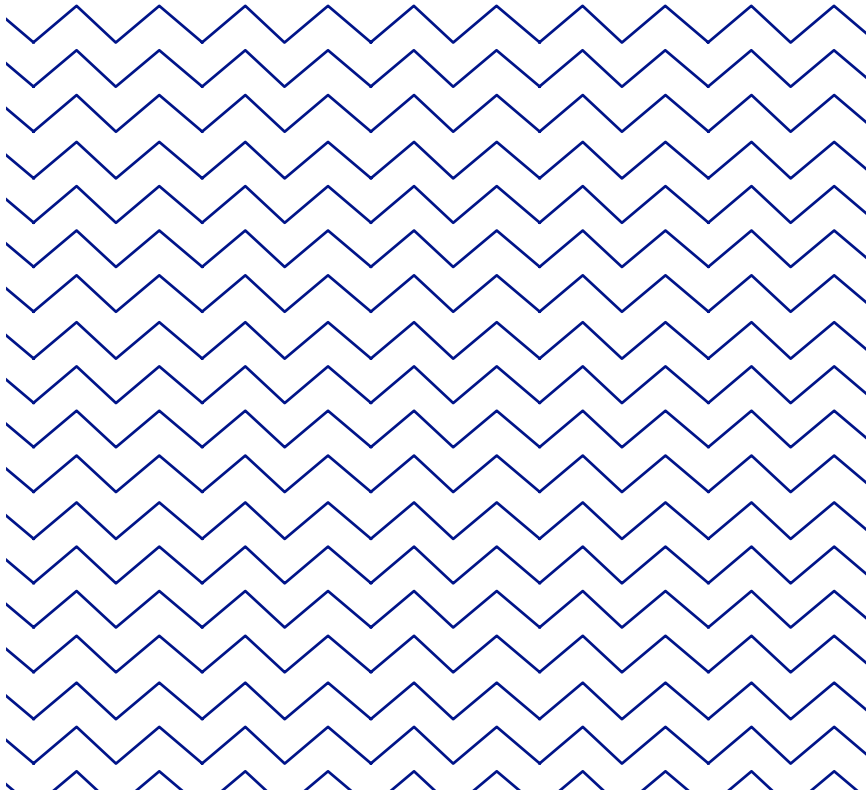

DECIDE GAME

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ICFO and research

PHOTONICS EVERYWHERE

ICFO is a research center founded in 2002 to **advance the boundaries of knowledge in photonics, science and light technology**. There, more than 400 people from around the world work to better understand the world around us or to create new technologies that could solve global problems in the fields of health, information and cybersecurity, energy and of environmental protection.

The cutting-edge science that is developed there attracts talent and funding, fosters collaborations with companies and research centers around the world, and yields visible results that translate into numerous patents and spin-offs.

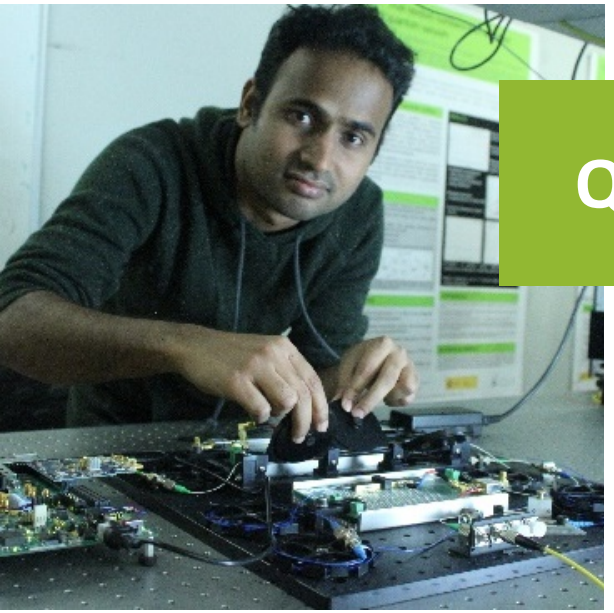
INFO
CARD 1

ICFO, a different and diverse place

PHOTONICS EVERYWHERE

Diversity is a key element to find creative and original solutions to problems: this is why diversity is an important asset for a scientific research center. At ICFO, there are **people of more than 60 nationalities with diverse backgrounds** (there are people who studied physics, chemistry, engineering, biology, neuroscience, mathematics, computer science, ...): with this mixture of cultures, languages and experiences it is easier to create an open and tolerant environment where new ideas can thrive and grow.

INFO
CARD 2



One of the ICFO laboratories where technologies for quantum cryptography are being developed

Quantum cryptography

INFORMATION AND CYBERSECURITY

We share on a daily basis a lot of private information (personal, financial or health data) that could be intercepted: the cryptographic protocols that currently protect them would not work with more powerful computers in the future.

A solution could come from quantum physics: it allows you to **design cryptographic protocols that would withstand the attacks of any computer** (present or future). There are still many technological challenges to the integration of quantum cryptographic systems into the telecommunications network: solving them is the goal of CiViQ, a European Quantum Flagship project that ICFO coordinates and in which others research centers, universities and large and small companies participate, including Quside, an ICFO spin-off founded in 2017.

INFO CARD 3

Prototype of graphene-based wearable device to detect vital signs

Graphen-based light sensors

INFORMATION AND CYBERSECURITY

HEALTH

There are things our eyes cannot see. For example, infrared and ultraviolet radiation (which our eyes and conventional cameras cannot capture) carry information that can help us control the quality of food, monitor the health of our body, or see in adverse conditions (darkness, fog).

With **the graphene-based sensors being developed at ICFO** in collaboration with Qurv (an ICFO spin-off born in 2020), it would be possible to do all of these things and even more with small, low-cost detectors easily integrated into current electronic systems and wearable technologies.

INFO CARD 4

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Prototype by Droplite

A laboratory in a chip

HEALTH

For a blood test, we have usually to go somewhere where they fill several tubes with our blood and we then have to wait a few days for the results. Thanks to the effective interaction between photons and gold nanoparticles, **a blood analysis laboratory can fit inside a chip of a few centimeters** that allows us to obtain the results in just 10 minutes from a single drop of blood.
This technology developed by **Droplite** (an ICFO spin-off company born in 2018) is currently validated to detect hormones linked to the reproductive cycle, allergies, antibodies for some veterinary or human diseases (such as malaria and COVID-19), but it has many other potential applications.

INFO
CARD 5

Non-invasive sensor for the early detection of neurological pathologies in premature babies

Non-invasive diagnosis and monitoring

HEALTH

Did you know that photons can penetrate a few centimeters inside our body? In ICFO and Hemophotonics (an ICFO spin-off born in 2013) we use this property to get real-time information about what's going on under our skin (oxygen concentration and blood flow) in a non-invasive way.

This can **help medical professionals detect and monitor neurological diseases**, as well as improve the diagnosis of certain diseases, such as thyroid cancer. This technology also has applications in the fields of neuroscience, oncology, anesthesiology, diabetes and sports medicine.

INFO CARD 6

Detection of microorganisms in water

ENERGY AND ENVIRONMENT

We are used to going to the beach without worrying about illnesses, because there are entities such as the Catalan Water Agency (ACA - it's acronym in Catalan) that monitor the water along the beaches, ensuring the safety of bathers. Thanks to photonics, **on-site analysis** within a few hours will soon be possible, significantly reducing waiting times for **detecting the presence of harmful microorganisms**.
For this reason, the ACA has agreed with ICFO to develop this technology to monitor the state of the Catalan beaches. This same technology could also be applied in the field of food safety and other industrial sectors.

INFO
CARD 7

(*) data updated on October 2020

Knowledge and Technology Transfer

PHOTONICS EVERYWHERE

ICFO puts the maximum effort in transforming the knowledge generated there into a positive impact on society in the form of products and technologies in collaboration with the industry or through the creation of spin-offs.

ICFO has obtained more than 100* patent families in the fields of health, information and energy. These include innovations in microscopy and optical manipulation, nanotechnology devices, solar cells, graphene sensors, laser systems, advanced displays, 3D printing, wearable devices, quantum technologies and compact sensors for use in hostile environments.

ICFO has surrounded itself by an ecosystem of companies with which it collaborates in different industrial projects, many involving its 9* spin-offs and as well as others still in the incubation stage.

INFO CARD 8

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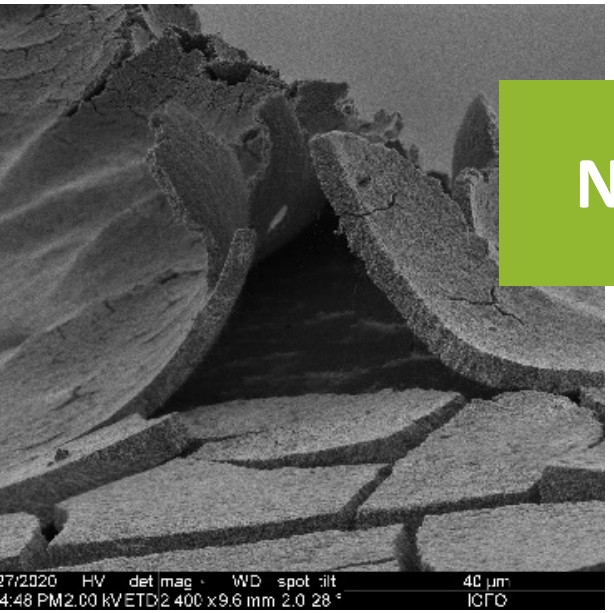


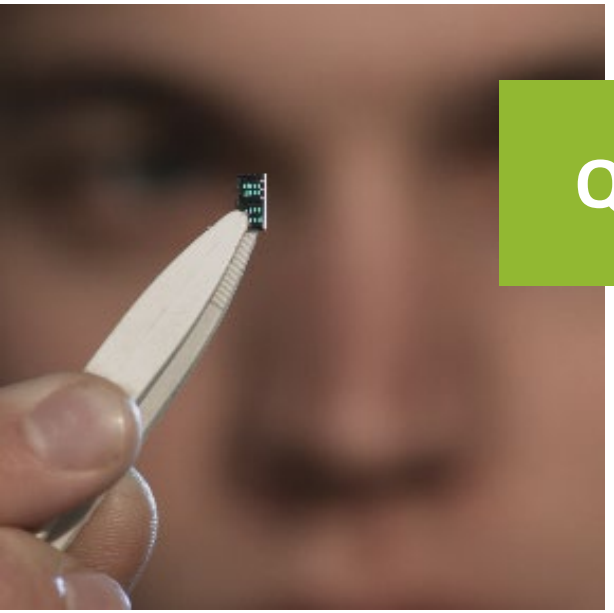
Carbon structure seen with an electron microscope. Some nanotubes can be seen inside the "cave".

Nanotechnology

If we split the diameter of a hair into a thousand parts, we would get to the scale of the nanoparticles that are made in ICFO. **Despite being so small, these particles are useful for different innovative technologies.**

At ICFO, many people are exploring the nanoworld, trying to improve our knowledge of the new phenomena that emerge at this tiny scale. They also aim to develop new technologies, such as new materials for mobile phones and wearable devices, diagnostics and treatment of diseases, sensors of photons and solar cells.

INFO
CARD 9



Quantum technologies

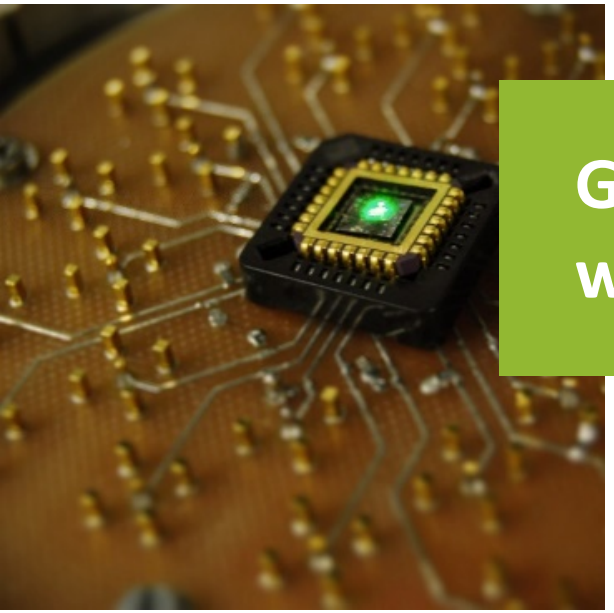
INFORMATION AND CYBERSECURITY

Quantum physics describes the world at the atomic and molecular scale: in recent years, the scientific community has learned to **take advantage of phenomena that appear at the microscopic scale to create new technologies**.

Quantum technologies are expected to improve the way some physical systems are studied, the security of our communications, the computational speed of computers, and the sensitivity of sensors.

With more than half of its groups working in these fields, ICFO joins its efforts with other research centers and companies that are actively involved in local (**QuantumCAT**) and international (**European Quantum Flagship**) networks that aim to accelerate the arrival of these technologies within the reach of society.

INFO
CARD 10



Graphene-based broadband camera designed by an ICFO team

Graphene, a material with a great future

PHOTONICS EVERYWHERE

Graphene is the first 2D material to be manufactured in the world. Despite being only one atom thick, graphene is stable and surprisingly strong. Its physical properties make of it an excellent conductor of heat and electricity, as well as being flexible, extensible and transparent. All these characteristics make **graphene a very interesting material for the development of new technologies**.

Institutions are aware of the potential of this material and have created the **Graphene Flagship** (at the European level) and **GraphCAT** (at the local level) to accelerate research on this material and bring its benefits to society. ICFO employs some of the world's leading experts in the field of graphene, participating in many of the projects of these two networks.

INFO CARD 11

The square of different color on the O of the ICFO logo is a transparent solar cell

Transparent and flexible solar cells

ENERGY AND ENVIRONMENT

Sunlight is a free and inexhaustible source of energy that we must learn to use efficiently, especially in the current context of climate emergency.
At ICFO, several people are **studying new materials to create transparent and/or flexible solar cells** that would allow us to obtain energy from places that currently aren't used for the generation of energy. For example, they could be integrated into electric cars to increase their autonomy or into the windows of buildings to maximize the surface area of sunlight capture and therefore energy production. They could also be integrated into clothing or wearable devices, reducing the size of batteries and therefore of the object.

INFO CARD 12

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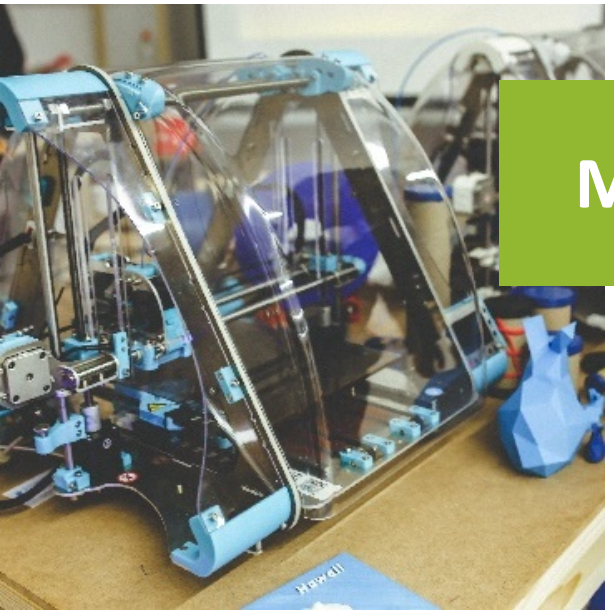


Multicolor 3D printing

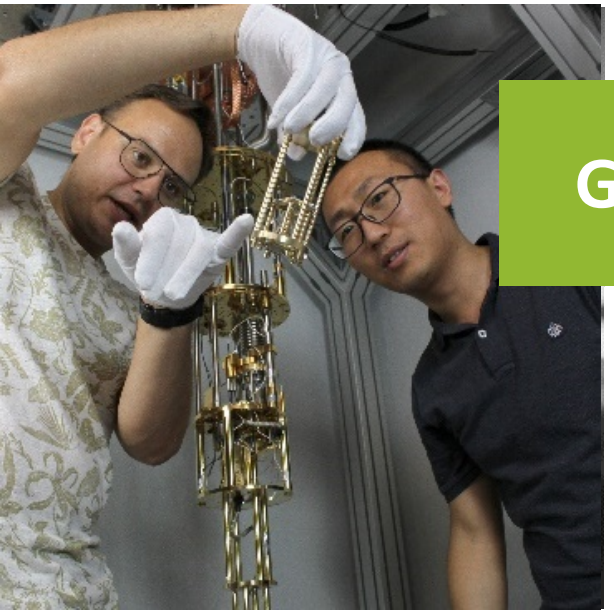
PHOTONICS EVERYWHERE

Digital manufacturing is one of the key innovations of the fourth industrial revolution we are experiencing. The ability to print 3D objects has opened up countless new possibilities on both the small scale of makers and startups, and the industrial scale.

One of the most interesting techniques to quickly obtain complex objects is sintering, but it has the important limitation that it can only create black or gray objects.

A recent technology developed at ICFO **allows different colors to be added to this 3D printing technique,** opening the door to new potential applications and the possibility of integrating artistic and aesthetic design into digital manufacturing.

INFO
CARD 13



Part of the ICFO team working on this project with the device that allows to observe the properties of graphene

Graphene with a twist

PHOTONICS EVERYWHERE

Graphene is a material of a single layer of atoms with incredible properties: transparent, resistant, flexible and an optimal conductor of electricity and heat.

In 2018 it was discovered that **two superimposed layers of graphene with a small rotation between them** could transform this already interesting material in itself into a **superconductor**.

This was very important news for the scientific community and it even was published in the New York Times! It allows us to better understand the phenomena that take place in superconductors and potentially to design materials that conduct electricity without losses at room temperature, reducing the waste that takes place with current materials.

ICFO is one of the few laboratories in the world where it is possible to transform graphene into a superconductor.

INFO CARD 14

ICFO scientists testing the equipment before sending it to hospitals

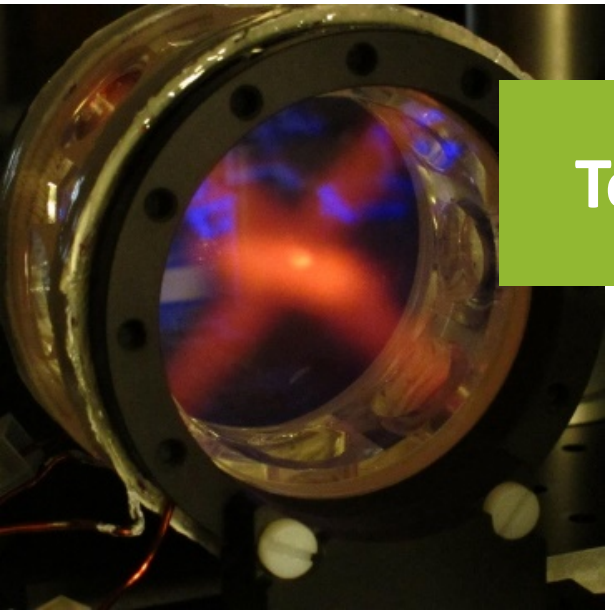
Shedding light on COVID-19

HEALTH

During the first big wave of the COVID-19 pandemic, an ICFO team worked intensively with a medical team at Parc Tauli Hospital near Barcelona to test a new idea: to **evaluate with photonic devices microvascular dysfunctions in COVID-19 patients.**

This could be a low-cost, non-invasive option for patients and easy to use for healthcare professionals to help establish the best treatment during the different phases of COVID-19 and help customize treatments. The project spread to different countries around the world and was even selected to be one of the 23 scientific projects funded by the European Union in the late summer of 2020 to deal with the pandemic.

INFO CARD 15



Clouds of cold atoms inside one of the ICFO laboratories

Towards a quantum internet

INFORMATION AND CYBERSECURITY

New emergent quantum technologies are promising to revolutionize the world of information and communications: to make the most of this potential, the European Union is planning to **build an infrastructure for quantum communications**, which would connect quantum devices, becoming a quantum internet. This infrastructure will take advantage of the current optical fiber network for short and medium distance connections and will combine with satellites to cover the longest distances. Thus, thanks to quantum physics, the most sensitive data such as personal, financial, governmental as well as the electricity grid, air control, or healthcare system will be protected.

INFO CARD 16

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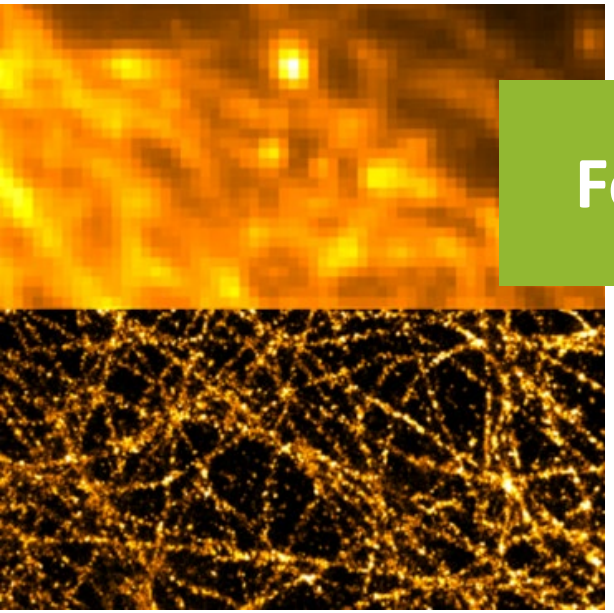
Focusing on the smallest details

HEALTH

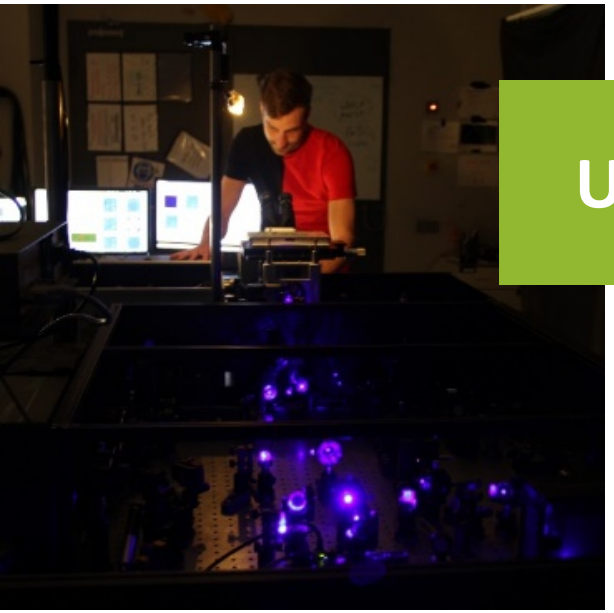


Microtubules visualized with a conventional microscopy technique - top - and a super-resolution technique - bottom.

While the quality of the cameras improves every day, there is always a detail in some photo that we can't discern because there isn't enough resolution. This problem is especially important for biologists who want to study cell structures, as there is a **physical limit to the resolution of the images** that can be obtained.

At ICFO there is a laboratory specializing in taking high-resolution photos and other advanced microscopy techniques that allow us to better understand the microscopic world and reveal the secrets of life.

INFO CARD 17



Experimental setup to study some of the relevant molecules for photosynthesis

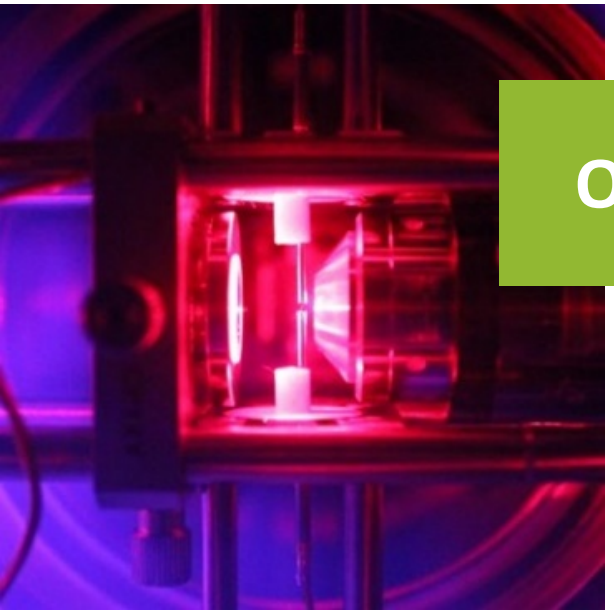
Understanding photosynthesis

ENERGY AND ENVIRONMENT

Some organisms can transform sunlight into the energy they need to live with photosynthesis. This process, resulting of millions of years of evolution, is incredibly efficient: they can transform 95% of the light that reaches them into energy. In contrast, the best solar commercial panels today translate only 20% of energy into electricity.

At ICFO, we use ultrafast laser pulses to **"photograph" the molecules responsible for capturing light energy** found in photosynthetic organisms in order to better understand this process and improve the efficiency of solar panels.

INFO CARD 18



Optical tweezers in one of the ICFO laboratories

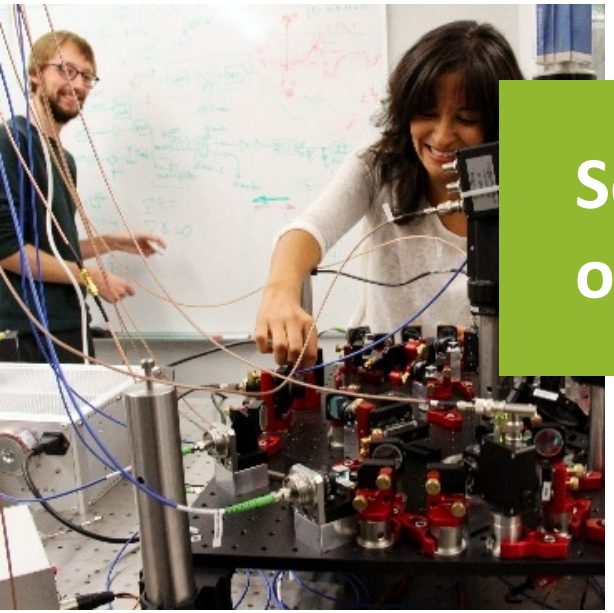
Optical tweezers

PHOTONICS EVERYWHERE

A well-focused photon beam can **trap objects and move them in a delicate and precise way**: this is not science fiction, but an extremely useful and versatile photonic technique that earned its inventor the Nobel Prize.

You can find optical tweezers in various ICFO laboratories in different areas of application: for example, they are used to trap atoms in order to better understand their properties, to measure the mobility and elasticity of some cells or to study small objects on the border between quantum and classical physics.

INFO
CARD 19



One of the ICFO laboratories where they cool atoms close to absolute zero.

Some of the coldest corners of the world

PHOTONICS EVERYWHERE

ICFO has some of the coldest corners in the world, but no one can get in. There the temperature is lower than in deep space: only small fractions of a degree (**hundreds of nanokelvins**) above absolute zero. Only a few laboratories in the world can reproduce these conditions in small vacuum chambers, where they can trap small quantities of atoms (from a few million to a single one, depending on the experiment): in order to be able to **study the interesting quantum properties that appear at such low temperatures**, it is fundamental that the atoms are as cold (and therefore as still) as possible.

INFO CARD 20

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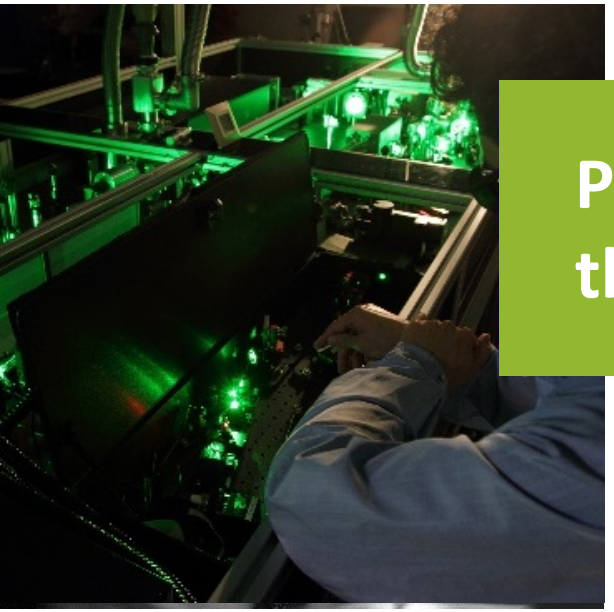

One of the ICFO lasers that can generate ultrafast pulses

Photographing the moviments of the electrons

PHOTONICS EVERYWHERE

To capture images of some very fast things (such as a bullet passing through an apple) it is essential to illuminate them with a pulse of light as fast as the scene that we want to capture. Thus, in order to **observe the behavior of the electrons in some chemical reactions**, it is necessary to **send extremely fast light pulses**.

So fast that one second would have to be divided by the number of seconds that have passed since the beginning of the universe to get its duration (a few **attoseconds**).

In one of ICFO laboratories, they are working on the generation of these pulses to study phenomena that can help improve the synthesis of chemicals or the performance of fuels or computers.

INFO CARD 21

Person observing a sample inside ICFO's clean room.

Clean room

PHOTONICS EVERYWHERE

In order to push the limits of knowledge in the field of nanotechnology as it's done at ICFO, you need exceptional instruments, which allow scientists, for example, to evaporate metals or make extremely tiny incisions with electron beams.

With these instruments, ICFO scientists **manufacture samples and devices** that – thanks to their **nanometric structure** - allow them to observe new phenomena or to obtain innovative products. In order to do this, they need an extremely clean space, as a single grain of dust could spoil their research. That's why there is a clean room at ICFO, where different scientific groups can work together to better understand the nanoworld.

INFO CARD 22

Citizens participating in NightUp Castelldefels.

Citizen science

PHOTONICS EVERYWHERE

ICFO encourages society to be part of the scientific community through rigorous **scientific experiments that require citizen participation**, making society aware of the importance of science in an attractive way, and enabling everyone to significantly contribute to scientific research.
In recent years, ICFO has coordinated various citizen science experiments, such as the **BIG Bell Test**, involving more than 100,000 citizens in a series of cutting-edge quantum physics experiments conducted in 12 leading laboratories around the world. It also organized **NightUp Castelldefels**, a pilot experiment to test whether we can use the sensors in mobile phones to gather useful data for studies on light pollution.

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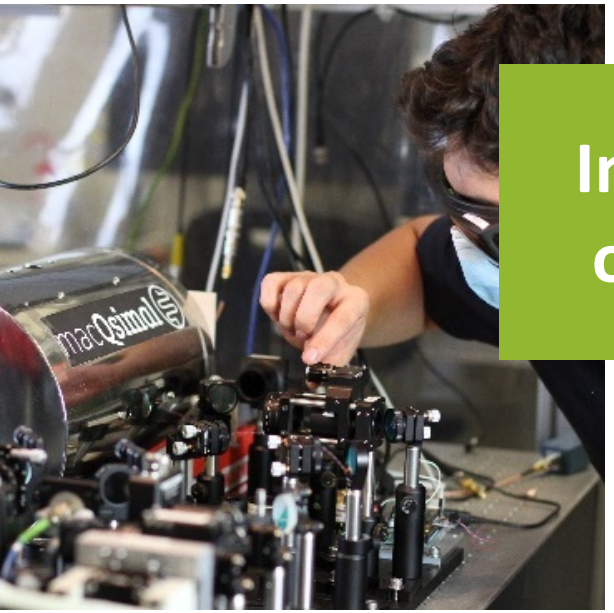
CARD 23



Prototype of an ultrasensitive quantum magnetic field sensor.

Improving our perception of the world

INFORMATION AND CYBERSECURITY

The small changes that light undergoes when crossing spaces and materials can help us **measure with high accuracy** many characteristics of the world around us, such as distance and temperature.

At ICFO we work to obtain very resistant sensors to measure temperature and electric fields in extreme conditions, such as a fire. We also investigate how to build ultra-sensitive sensors thanks to the properties of quantum physics, such as a scale that can detect the presence of just one atom with carbon nanotubes or cold atoms that could measure the small magnetic fields generated by our brain.

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Artificial intelligence to advance science

INFORMATION AND CYBERSECURITY

We are used to movie or music platforms suggesting us what to watch or listen to next. This is possible because algorithms can learn, if we give them a series of initial examples: it is a branch of artificial intelligence called machine learning.

Apart from improving technological services, machine learning is also very useful for people looking for solutions to complex scientific problems. At ICFO we use artificial intelligence to find new strategies to solve complex quantum physics problems, predict the motion of individual particles (very important for biology), or increase computational speed (optimization) for some complex algorithms that apply to significant day-to-day problems.

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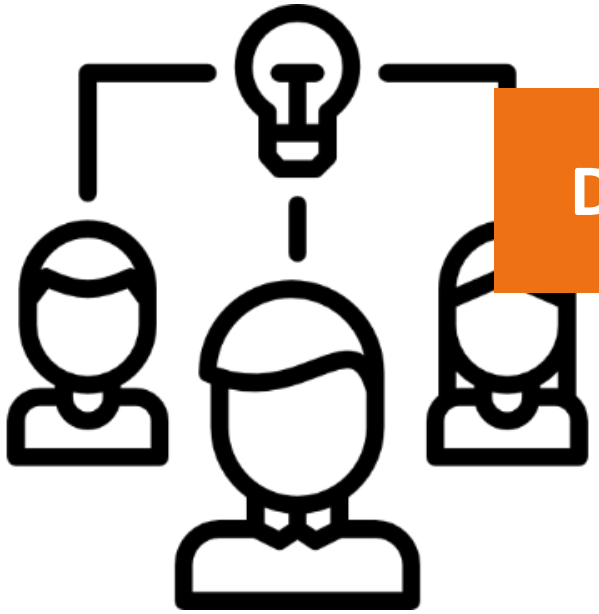

Diversity

If we asked you to draw a scientist, how would you represent it? This experiment has been done many times and very often people imagine a middle-aged white man. This is due to the **stereotypes** that have been spread among society for centuries, but it is also true that there is a **problem of representation** of minorities in science (as there also is in many other sectors of society).

This is not only a matter of social justice: science would benefit greatly from more diversity because it is a creative and collaborative process. How can we successfully foster diversity in science?

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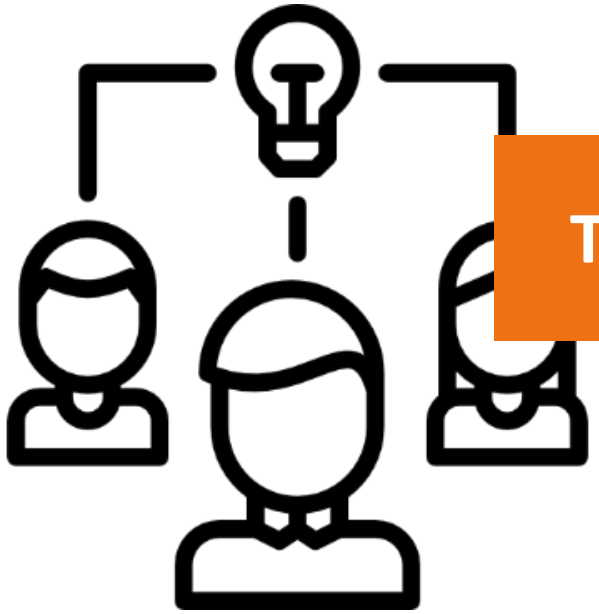
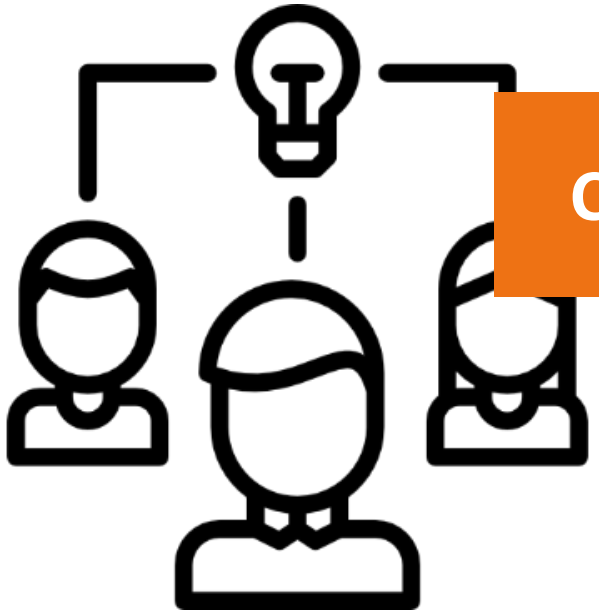


The value of science for society

Having a basic knowledge of different scientific fields and understand how scientific knowledge is generated is important for all citizens. The COVID-19 pandemic is an example of this: it is easier to accept and correctly apply public health recommendations (and help curb the spread of the virus) if we understand the scientific reasons behind them and how policy makers got to these conclusions.
Even if everyone learns science during compulsory education, it is clearly **not enough for society to value science and its results: how can we change that?**

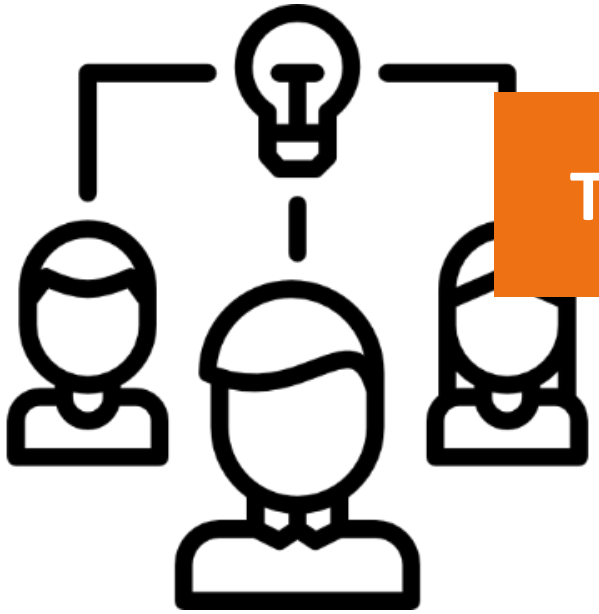
THINKING CARD 2



Can we trust science?

Technology and science have been a part of our lives and such influence grows overtime. **Is this positive?** There is a part of the population that does not trust scientific results and rejects technological advances: what do you think of their position?

THINKING CARD 3



There are more urgent issues

Science and technology have improved and are improving the quality of our lives. However, **there are still many urgent and important problems** that require immediate solutions that scientific research cannot offer us directly and quickly. Perhaps we should focus our efforts on reducing social inequality, unemployment, hunger and poverty. **Or can science and technology help in these aspects as well?**

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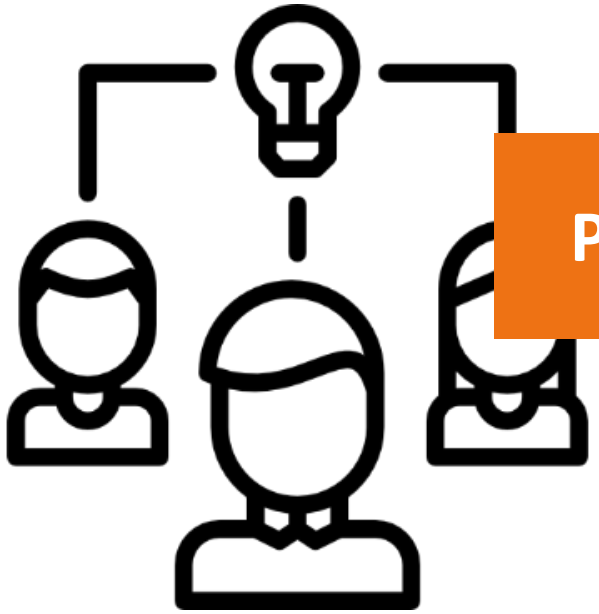
Fundamental or applied research?

It is not easy to predict when a particular technology will be available to society: for example, nuclear fusion has been close to solving the problem of energy production for years, but there have been always unforeseen technical issues that delayed its implementation. On the other hand, some technologies that are now ubiquitous, such as lasers, owe their origin to the curiosity about some fundamental questions, such as the interaction between photons and matter, without a specific application in mind.

How can we choose the research fields that will bring us the most benefits?

THINKING CARD 5

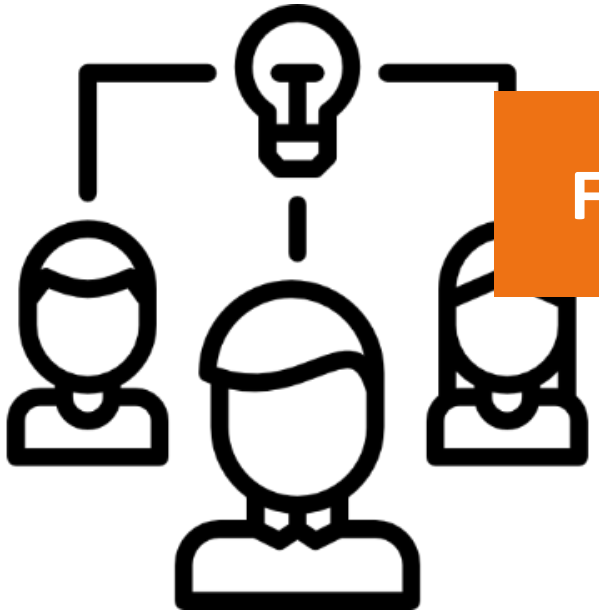


Peer review

Unlike radio or TV talk shows, in science not all opinions have the same value. Only if you can **support your thesis with experimental evidence and logical reasoning** your discovery will be accepted by the scientific community. Therefore, journals publishing scientific results use the principle of **peer review**: a new result can only be published if it is accepted by a group of experts in that field who carefully examine the methods and conclusions of that research.

When spreading scientific results quickly is vital, as in the case of new discoveries about the SARS-CoV-2 virus during the pandemic, does it make sense to adopt this system to certify the validity of the results or it is better to accelerate the spreading of the new information?

THINKING CARD 6

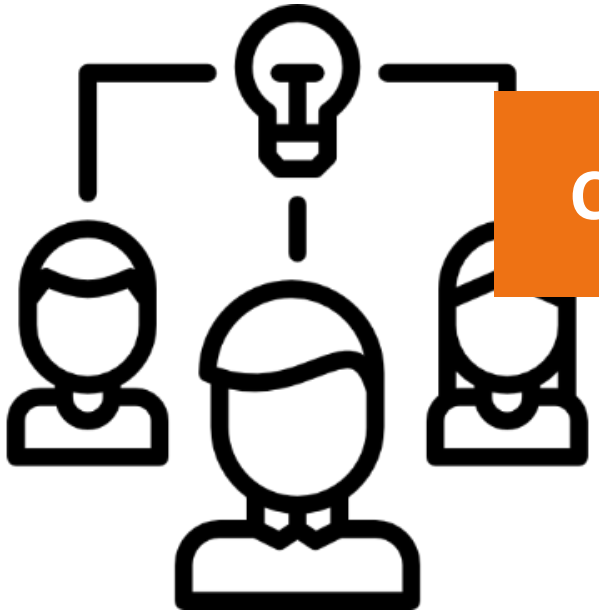


Fake news

In order to express **critical opinions about the news** that we receive through the media outlets, advertising, social media... and avoid falling into scams or misunderstandings, it is important to keep up-to-date about the latest news in science and technology. Sometimes, however, the information comes from pseudoscientific sources of dubious reliability.

How do we handle this often questionable flow of information?

THINKING CARD 7



Can we predict the future?

In the 1960s, most futuristic representations for the years around 2000 included flying cars. Now, more than twenty years later, our expectations for the future have changed quite a bit. Does it make sense to listen to someone who promises that their field of study will bring us the technology of the future? **Can we really make predictions about the future of science and technology?**

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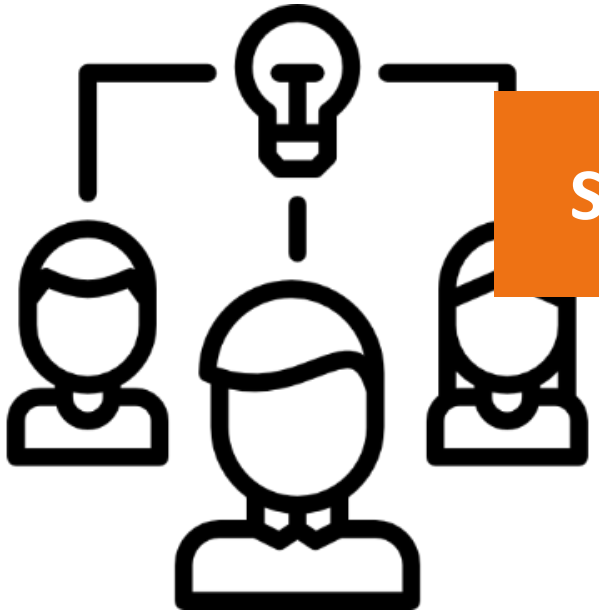
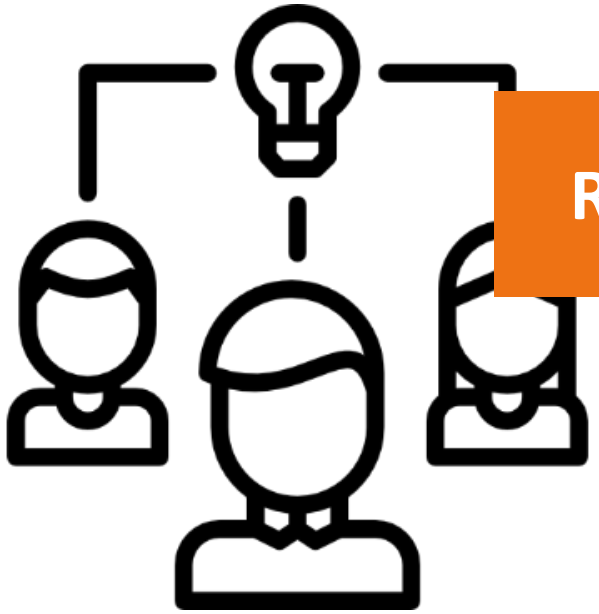


Side effects

A priori, knowledge is not negative: it is the use that people make of it that sometimes creates negative consequences. We know that scientific advances in recent years have brought immense benefits, but also new ways of attacking the security and freedom of people.

Is it necessary to investigate everything, knowing that in some cases misused knowledge can lead to dangers?

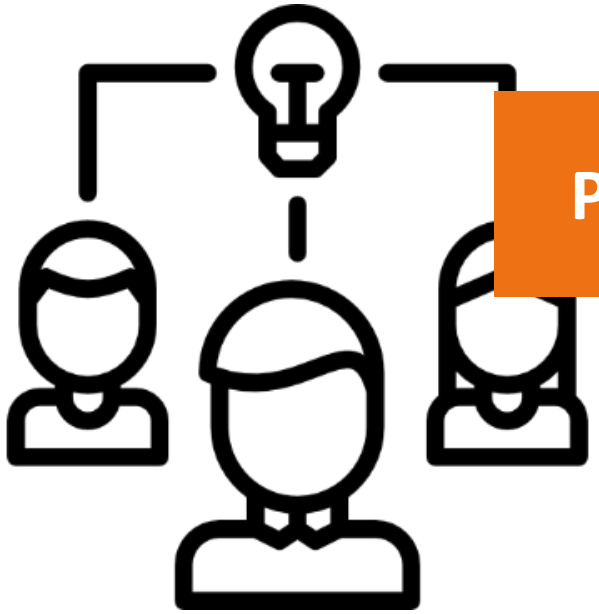
THINKING CARD 9



Recover the investment

Fundamental research, such as in certain fields of photonics, needs financial resources, and often has no direct application in the short-term at the commercial or industrial level. On the other hand, if one does not invest in fundamental research, it is difficult to reach the level of development required to to **generate economic wealth with technological products**, since this implies a deep knowledge of its basic concepts. How can we solve this "circle"?

THINKING CARD 10



Public or private research?

Many people argue that knowledge should be property of all mankind as a whole. On the other hand, applications development often takes place in industry, which is the one that makes the big investments in exchange for an economic return, often privatizing knowledge.

How can we combine public and private interests in scientific research?

THINKING CARD 11

The applications of fundamental sciences

On several occasions, applications and techniques that today are ubiquitous and have a broad impact were developed as a secondary stage to reach the main goal of the research project. For example, the Internet was born in an international research center on particle physics such as CERN; the navigation satellite systems (GPS, Galileo) owe their accuracy to the theory of general relativity.

Sometimes, research fields that in principle have no obvious applications, generate useful technologies as side effects. **Should we then invest in fundamental research for the potential benefits coming from its eventual byproducts?** Or is the advancement of knowledge sufficient reason to put resources into it?

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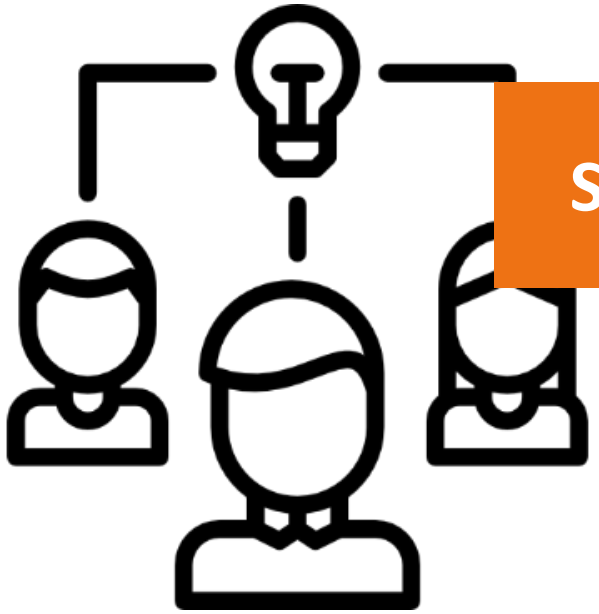
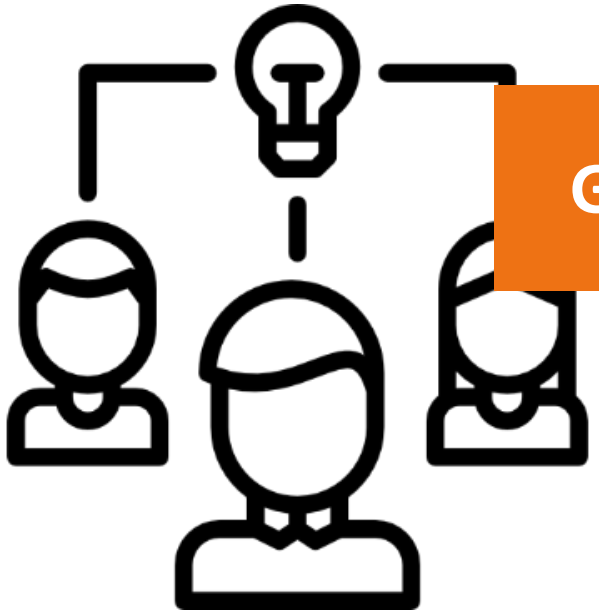


Sciences or humanities?

The boundaries between natural sciences and humanities have never been well defined. For example, think of Leonardo da Vinci: was he an artist or an engineer?
Today, **many artists talk about science or technology in their works.** On the other hand, scientists offer **new tools and possibilities** to creative people (the Arduino board was invented to help designers integrate electronics into their projects).
Does the distinction between sciences and humanities still make sense?

THINKING CARD 13



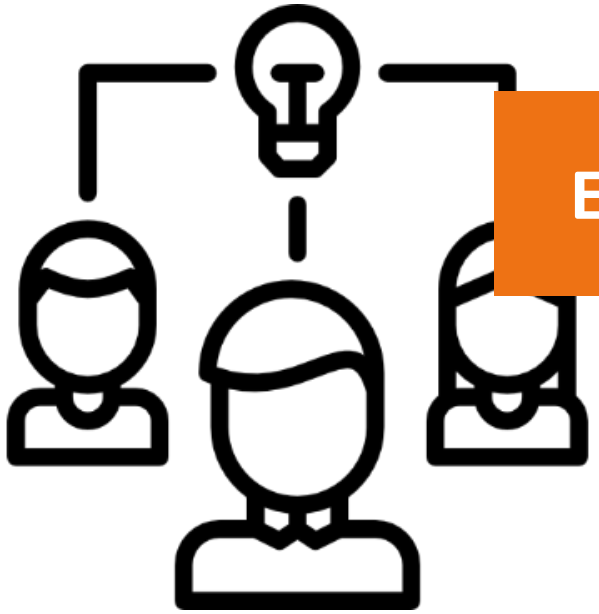
Global science

Science is an international activity: the vast majority of scientific discoveries are made by multinational teams and result from collaborations between institutes and companies in different countries.

People in the world of science often move to expand their experience, so it is very common to find people from different countries in a research center. The **cultural mix** creates an **open and tolerant environment** that helps the creation of new and original ideas that allow research advancement.

So does it make sense to associate an important scientific discovery with a country, as we can often read in the news?

THINKING CARD 14



English as a *lingua franca*

During the Cold War years, most of the discoveries made in the Soviet countries were published in Russian and therefore were not easily accessible at the global level. It is evident that **clear and effective communication is at the heart of scientific progress**.

Today, English is widely used as a common language. Scientists who do not speak well English, may be in disadvantage, because it is harder for them to express themselves correctly and to disseminate their ideas and results than for their English native-speaker colleagues. How can we ensure equal opportunities independently of the native language of scientists, while maintaining a common language that allows for quick and effective communication within the science community?

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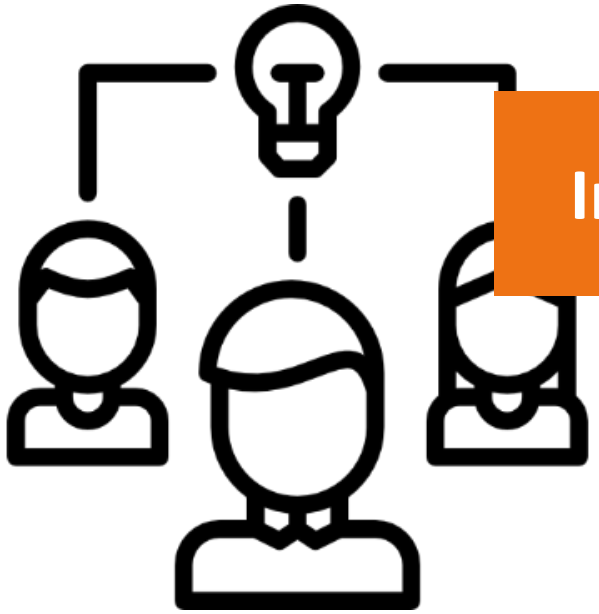

In person or virtual?

Conferences are the perfect opportunity for scientists to share their work with colleagues around the world, exchange ideas, and establish new collaborations.
In recent years, the climate emergency has begun to open the debate on whether travel should be reduced in favor of **virtual events**, which **do not allow socialization** and bonding to occur naturally as in a in person conference.
The 2020 pandemic has accelerated this debate: should scientific meetings be in person or virtual?

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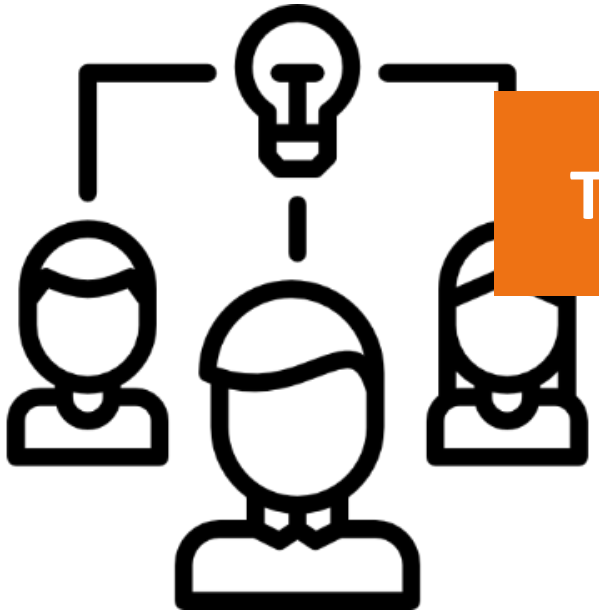

Teamwork

ICFO scientists work closely with each other and often with colleagues from other institutes around the world and from other disciplines. Many scientific advances are the result of teamwork.
Still, one often reads stories of quasi-heroic characters who apparently alone changed the scientific field in which they worked. Also the most prestigious science awards, the Nobel Prizes, are awarded to a maximum of 3 people, who often have not even worked together, even if behind many revolutionary ideas there is a team of researchers. **Should we value more the role of teamwork in science and recognize more explicitly that results often come from a collective effort?**

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