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Massimo Altarelli directs the XFEL project, a laser to study matter in depth

"Nanotechnology will speed up progress. There is nothing to fear if we act responsibly"

Last May Barcelona hosted the First International GENNESYS Congress on Nanotechnology and Research Infrastructures, the first international event in this field, organised by the UAB Research Park, the Materials Science Institute of Barcelona and the german synchrotron DESY. Among the numerous scientists and experts who participated in this congress was Massimo Aldarelli, Managing Director of the European XFEL project, an X-ray Free Electron Laser that will enable us to acquire a much deeper understanding of matter. Professor Altarelli told UABDivulga about the latest advances in nanotechnology and reflected on the course of this new science in the forthcoming years.

Professor Massimo Altarelli earned a PhD at the University of Rome in 1971. Through a Chair at the Max-Planck Institute for solid state research, he became the Research Director of the ESRF Institute in Grenoble, and later head of the Theoretical Physics Group. He has served as Director

and Executive Director of the Elettra Synchrotron Light Laboratory in Trieste, Italy. His scientific interests include the theory of condensed matter, the electronic structures of solids, the dispersion and absorption of X-rays in heavily correlated and magnetic systems and third- and fourth-generation X-ray source applications. In 2005, the international steering committee appointed him the European XFEL project team leader, and in 2009 he took over the overall management of the European XFEL.

-Broadly speaking, what does nanotechnology consist of? Is there any difference between nanotechnology and nanoscience?

-The difference between science and technology (“nano” or otherwise) is that science is the activity that strives to further knowledge, to discover things we didn’t know or understand before, while technology is the use of this knowledge to resolve a given problem or supply means for industry. Technology is the application of the knowledge yielded by science, and nanotechnology specifically enables you to work at the atomic and molecular level to create new materials or modify existing materials.

-Nanotechnology seems to be related to several different disciplines. Do you think that this poses an obstacle when you have to coordinate scientists from different fields?

-Yes, there is a sort of organisational barrier in science enterprise since the traditional disciplines overlap somewhat. For example, if you study chemistry you have to learn quantum physics and know the physical underpinnings of electrical phenomena. A reorganisation of the competences of each discipline takes place to such an extent that we can no longer distinguish research in biology from research in chemistry or physics. However, today the younger generations are extremely well prepared after earning their doctorates, as they were trained in a more global kind of science. The fact is that the institutional regeneration in science is truly swift. In a matter of ten or twenty years, the system is totally “rinsed out” with “fresh water”: old directors leave, new researchers join... For this reason, we have immediately benefited with younger and better trained generations.

-What does the XFEL project that you’re supervising consist of?

-The idea is to be able to generate a source of X-rays with new properties, produced by a huge linear superconductor accelerator 1.7 km long in which the electrons are accelerated in superconducting radiofrequency cavities to generate extremely intense X-ray pulses. These pulses are extremely short, quicker than the vibration characteristic of atoms, so we will be able to “photograph” atomic processes as they happen. Plus, there is a characteristic property of lasers, coherence, which entails a constant phase relationship along the entire wave, and since the length of X-ray waves is 0.1 nanometres, around the size of an atom, this places us at the atom’s own scale, allowing us to clearly elucidate the atomic structure of matter.

-So the key is the speed of the pulse, for it to be quicker than an atom’s vibration...

-Exactly. There is an example that is often used to explain it. Imagine that we have to photograph a horse galloping and we put the camera exposure at one second, for instance. We will not be able to see the horse’s legs because they’ll be blurry. However, if we use a millisecond exposure,

we will get a clear picture, and if we take one picture right after another, we can see the movement that has taken place between them. This is precisely what we want to apply to chemical and biological reactions, molecular processes, catalysed reactions...

-What kind of facilities does nanotechnology research require?

-The concept of nanotechnology is very broad. It encompasses all the strategies to be able to interact with matter on an atomic and molecular scale, so it needs all the tools that pave the way to the atomic scale. For example, we can use a variety of methods to see atoms, depending on the situation. We have Scanning Tunnelling Microscopes (STMs) and Atomic Force Microscopes (AFMs), which are small instruments that could easily fit on this table, or we could use an electron microscope, which could fit into this room, or a synchrotron or a neutron source or, we hope within a few years, the XFEL laser, all of which measure several kilometres long.

Depending on what we want to know, we use a different instrument. For example, the STM can only see surfaces; the electron microscope can offer a bit more information; the electron source penetrates the material more deeply; and the neutron source even further. So the kind of analysis requires a specific kind of instrumentation. The idea is not to buy the cheapest device and make do with it. It doesn't work that way.

-One of the fears that nanotechnology triggers is the loss of control over nanoparticles, since they can be dispersed around the environment. Is this an unfounded fear?

-I occasionally run into these reflections in newspapers and the press. Let us look at the case of agriculture. We rarely think it can be damaging to the environment, but it is. The impact of agricultural activity has wiped out forests and destroyed natural resources. The goal is to regulate human activity within a legal framework, controlling it and being respectful of the environment. For millennia, mankind has believed that the Earth had an infinite capacity to regenerate itself, that the changes we made on it were insignificant... But that's not true. We are increasingly aware about this problem, which will help us to take countermeasures, such as in nanotechnology, so that the new advances are used rationally.

-How far can nanotechnology take us? Are we aware of its reach?

-Basically I think that it will allow us to make much quicker progress in important areas of technology. Imagine, for example, the case of genetics. Since ancient times, mankind has modified living beings by breeding plants and animals with specific characteristics so that tomatoes can be bigger, for example, after several generations. Now with genetic engineering, everything is much quicker. If we want to develop a plant that is immune to a specific kind of insect, we can actually get at its genes and modify them so that this plant develops some sort of mechanism to prevent it from being devoured by this insect.

-Don't you think that science's quickening pace might trigger fear of spinning out of control?

-Well, let's think about transport. I'm from Rome, so you can imagine the ancient Romans, when Julius Caesar had to transport his armies from Rome to Hispania: he had certain resources at his

disposal to do so, like horses, boats... If we think about Napoleon 18 centuries later, he moved his troops using the same means. Now let's look at the past 100 years. We can see that things have radically changed. As science progresses, discoveries are speeding up. We may have many fears, but this is a natural phenomenon that is taking place.

It is true that this acceleration is yielding some negative effects, but it also has some wonderful effects, such as the billions of people around the world who can eat every day thanks to the "Green Revolution" that has benefitted countries like China, India and Brazil... which are turning into world economic powers. Progress is positive by its very definition and if it takes place at a quicker pace, so much the better.

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