December 2018

# TWINFUSYON NEWSLETTER VI

Dear reader,

After three fruitful years, the TWINFUSYON project is coming to an end and it is a pleasure for us to present our last newsletter to you. Many lessons have been learned and many achievements have been made. A lot of work has been done, but much more work has been stimulated by three wonderful years of discussions and interactions and, therefore, much more work is ahead of us! We are proud that a community has been developed reaching out the world!

Throughout the implementation of TWINFUSYON, we have seen that many different options exist to develop biosensing opportunities.

We thank you for following our progress and we hope that the results listed below will continue to be a valuable contribution for your professional work.

Sincerely,

***TWINFUSYON team***

# CONTENT



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# PAST TWINFUSYON EVENTS

## EPIOPTICS workshop

*13th -19th July 2018, Erice, Italy*

The workshop brought together researchers from universities and research institutes who work in the fields of (semiconductor) surface science, epitaxial growth, materials deposition and optical diagnostics relevant to (semiconductor) materials and structures of interest for present and anticipated (spin) electronic devices. The school focused on assessing the capabilities of state-of-the-art optical techniques in elucidating the fundamental electronic and structural properties of semiconductor and metal surfaces, interfaces, thin layers, and layer structures, and assessing the usefulness of these techniques for optimization of high quality multilayer samples through feedback control during materials growth and processing.

## EMFL Summer School: Science in High Magnetic Fields

*26th-30th September 2018, Arles, France*

Following the long tradition of the high-magnetic-field community in Europe, the EMFL summer school was held from 26 to 30 October 2018. The school has taken place in the pleasant environment of Camargue region in South France, nearby the city Arles known for its Roman history.  This time, the school was co-organized with the TWIUNFUSYON project.

This school was dedicated to recent advances in science in high magnetic fields. The lectures given by 16 renowned speakers - experimentalists and theorists - covered important areas of current research in high magnetic fields: semiconductor physics, low dimensional materials and nano-objects, soft-matter, strongly correlated electron systems, magnetism, superconductivity, molecular systems, high-magnetic field technology and experimental techniques, but also other important aspects of scientific work such as public outreach.

The 60 participants of the school were selected primarily among young researchers: Master/PhD students and postdocs working. Those working in laboratories joined in EMFL, but also in other universities and research institution not only from Europe. The participants had an opportunity, during a specially dedicated poster session, to present their own research results.

## The Twinfusyon Young Research Team Achievement

By the beginning of the TWINFUSYON project, a group of 12 young scientists was originally composed to cover specializations in theoretical and experimental physics, anorganic and organic chemistry, biochemistry and biology. After one year this group was joined by another four young researchers strengthening the physical background of the group.

The group benefited from the interdisciplinary environment at the project schools and workshops, from the stays at the partner institutions, and from interactions within CEITEC, both with their senior colleagues and within the group.

Among the most significant achievements of the Team belongs number of publications and conference contribution through various branches of research. The researchers acted mostly in larger group of authors (frequently international), contributing at least in part the knowledge acquired in the TWINFUSYON project.

## Assessment of Twinfusyon Secondments

Thanks to the TWINFUSYON project, researchers from The Central European Institute of Technology od Masaryk University (CEITEC MU) were granted the opportunity to participate in a secondment programme and spend some time at partner institutions: The Institute of Nanotechnology of The National Research Council (CNR-NANOTEC), Italy, The Johannes Kepler University in Linz (JKU), Austria, and at the Laboratoire National des Champs Magnétiques Intenses (LNCMI), France.

During the three year time of the project duration, 14 secondments took place in the total length of nearly 800 person-days, which corresponds to approximately 26 months. Seven secondments were effectuated at JKU, four at CNR-NANOTEC and three in LNCMI. One additional secondment took place at Max Planck Institute for Solid State Research in Stuttgart, Germany. The mobility of researchers helped to enhance the transfer of knowledge, of lab best practice.

# OUR INTERDISCIPLINARY MESSAGE: THE VOICE TO THE YOUTH!!

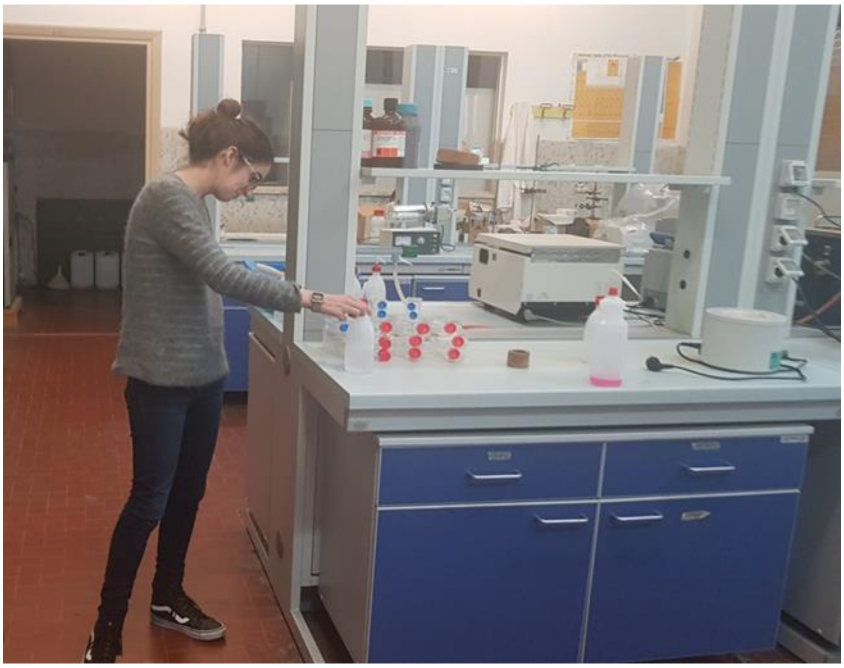
**While the challenges can be frustrating, interdisciplinary research offers rich learning opportunities. Although Twinfusyon is finished, we will not go back to our traditional silo. We will not close the lines of communication now we have opened them.**

**Depending on your field, you might find that you often have the opportunity to get involved in inter-disciplinary projects — try to share what you have learnt and spread the word.**

## Yael Vela Gutierrez

*PhD student in physics at Universidad de Cantabria-Spain and trained in Chemistry and Material Science at Chemistry Department at CNR-NANOTEC, Italy*

I am a physicist by training. Specifically, I am supposed to be a theoretical physicist. I spent the first three of my PhD years working only with a notebook, a pencil and a computer. I only worked, talked and coexisted with other theoretical physicists. For my last year of PhD, my advisor decided that I have had enough theory, and he thought that sending me to work with chemists was a good idea. To make things even better, I went to work with experimental chemists. I didn't even study chemistry in high school, which made those three months quite an experience.



The first thing you notice when you start to work with people from other areas (chemists in my case) is that, when facing a problem, the way of thinking and the language is completely different. Communication becomes a real issue. In my case, I didn't expect it to be that different since between physicists we always make the joke: "chemistry is just applied physics" (sorry chemists, full respect to your discipline). Many times, after ten minutes of discussing I realized that we were talking about the same thing, however, because in many cases we call things differently, we weren't understating each other. Other times (let's be honest, the majority of times), I just didn't have a clue about what they were talking about. For me, what has proven to be the most efficient tool to reach a complete understanding is: stop them and ask to be explained the problem and all the weird words you don't understand like if your brain is formed by two neurons. You may think: "Oh, I cannot do that, they will think I am stupid". So what? By following my method, you will end up knowing the meaning of all the words at first you didn't understand, and you will learn a lot new science (which is the main point in a scientist life). In this way, since they will explain the problem starting by the foundation, you can, by asking the right questions (I cannot help you with that), build in your brain the concept making the connection with the language you feel more comfortable.

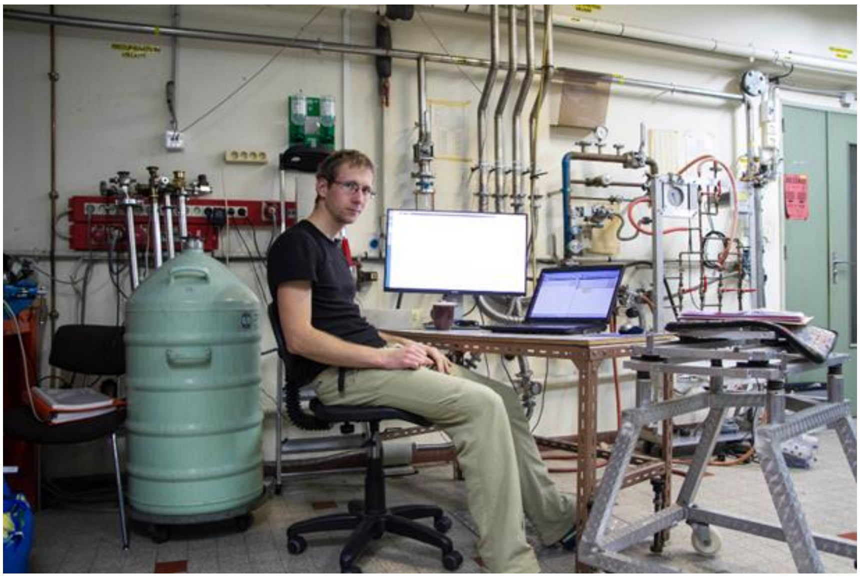
The funny part is when you are asked to explain a concept in the most simplistic way you can. Then you will realize that you don't understand the subject, not completely. This will push you to rethink about the topic and have a deeper understanding. So, at the end, everyone wins: you got a deeper understanding, and the other one gets familiar with the new topic in a way he/she can completely understands while overcoming the language barrier (mission accomplished!).

Richard Feynman (what kind of physicist would I be if I don't quote this guy?) technique of learning had 4 steps: #1 Pick and study a topic. #2 Explain the topic to someone, like a child, who is unfamiliar with the topic. #3 Identify any gaps in your understanding. #4 Review and Simplify.

So, if you don't believe me, I hope you can trust Richard Feynman.

## Leonid Bovkun

*PhD student in physics and engineering in Nizhny Novgorod & CNRS-Grenoble*



In November 2018, I have defended my PhD thesis after three years of studies under joint supervision of University Grenoble Alpes in Grenoble, France and Russian Academy of Sciences (RAS) in Nizhny Novgorod. My doctoral project was dedicated to optical and electric properties of particular electronic devices, which are based on based on semiconductors with a relatively narrow electronic band gap. These devices became recently intensively studied due to their specific, so-called topological properties, and gave rise to one of most dynamically evolving area of current condensed matter physics. At the same time, the very same or similar devices are for long time used, and further developed, as efficient emitters and detectors of infrared radiation, with rather direct application impact. The topic of my thesis thus lied at the border between fundamental and applied research, and concomitantly, it also involved two different areas of research: condensed-matter physics and electronic engineering. In my thesis, I managed, in my view successfully, to combine approaches typical for both fields and took advantage of stimulating environment in both supervising laboratories. In the Institute of microstructures, RAS, I could profit from its long tradition of applied-driven research in electronic engineering. My hosting laboratory in France, the Laboratoire National des Champs Magnétiques Intenses, CNRS in Grenoble, provided me in training oriented towards fundamental research in condensed matter physics under extreme conditions. My PhD studies, and in the end also my freshly defended PhD thesis, show that multidisciplinary research may be efficiently conducted. Nevertheless, it is important to note that in my case, both involved disciplines - fundamental condensed matter physics and electrical engineering - share a significant part of theoretical methods and experimental tools, and to certain extent also the terminology. This greatly simplifies crossing the barrier, which always exists between different fields of science. In this respect, I can imagine that the situation may be much more complicated when dealing with disciplines from more distant fields of natural sciences, or even from social sciences.  Another interesting aspect of my PhD multi- (or better to say) double-disciplinary research is relatively broad choice of options for my after-PhD career. At present, I have decided to stay in fundament physics and continue as a post-doctoral researcher at University in Wurzburg, Germany.

## Jean-Pierre Perin

*PhD student in physics at JKU and involved in the interdisciplinary training at TWINFUSYON partners*

Coming from a perhaps more engineering-oriented education, I have furthered my studies with a Master's degree in Nanoscience and -Technology at the Physics department of the Johannes Kepler University Linz, Austria. The related thesis was completed at the Center for Surface and Nanoanalytics, time during which I had the opportunity to get involved in the TWINFUSYON project.

The main research topic of the thesis was aimed at the calculation of electromagnetic fields at structured surfaces by means of numerical methods. If the core of the work had a theoretical flair, many of the structures studied were application-related; the computation of the fields by finite element method was for example performed towards the optimization and dimensioning of a biosensor plate. Working on such systems called for knowledge not only in our field of predilection, but demanded further a broader overview, extending through many overlapping fields.

Although some of the work done was unquestionably interdisciplinary, I must say that – from my perspective – I have mostly benefitted from the TWINFUSYON project through its organized events as workshops, and Winter and Summer Schools. Such conferences brought together people with various backgrounds over a common topic of interest. Not only did such meetings allow a glimpse at the broader perspective, but had the added value of providing another look, a fresh view, and encouraging novel ideas.

Evidently, with various backgrounds and geographical locations, many of us do not share the same language, be it for example the mother tongue. This has however never been a major issue as we would resolve most of the time, unsurprisingly and like most scientists, to the use of International English – the language of science – for sharing ideas and getting to know fellow students and researchers. Even so, every "community" has developed its own vocabulary and it does take some time and effort to adjust to the various jargons; this gap can only be closed by encouraging the various communities to meet and get acquainted to one another; as such, the TWINFUSYON project has played its role.

## Karel Kubíček

*International doctorate in structural biology at CEITEC-Brno*

I am chemists by high-school education and at the university I continued studying physical chemistry and prepared samples for my diploma thesis at the department of biochemistry. Here for the first time I was using nuclear magnetic resonance (NMR). I gained my PhD in structural biology and continued in the field during a postdoctoral stay. As structural biology represents a cocktail of chemistry, biology, physics, and mathematics which perfectly fits to my interest, even at the current position of assistant professor for biophysics I am still using NMR for studying structure and dynamics of biomolecules and their complexes.

There would be the possibility, and some labs are doing so, to split the work in kind of manufacture – wet -lab techniques by one student/researcher, physico-chemical techniques by another scientists and presentations or teaching or writing up manuscript by another person. This seems to be effective as everyone focuses on a particular task and fine tunes every step within his/her own part of the process. In such an arrangement people are strongly dependent on one another and are risking not to understand others tasks very well as they do not need to deal with "those" things – it's somebody's else task and for me it could remain a black-box.

This is, however, not the best approach particularly in the field of structural biology where already preparing the sample represents an achievement. And it is necessary that the person performing measurements (NMR, small-angle X-ray scattering – SAXS, isothermal titration calorimetry – ICT, cryo-electron microscopy – cryoEM) knows how does the sample behave when handling it – i.e. freezing, changing temperature etc. Biological samples are often unstable and handling or mishandling them prior or during measurement can be critical not only for that particular measurement but also for the project as such.

Therefore, understanding the biological details of the samples (from composition to preparation and purification) is as important as understanding the instrument – all its setup, limits and signal/data processing.

Typically, and it was same in Linz, (condensed matter) physicists see their samples as $SiO_2$, GaN etc. which last for long time and one can measure and remeasure them several times. Biological samples are sometimes difficult even to transport from one room to another not speaking about two cities.

Other typical problem is the sensitivity of measurements – while in condensed matter physics, samples are often solid (poly) crystals, biological samples are small amounts (tenths to hundreds of microliters) and therefore signal is weak or the measurement takes much longer than in the case of measurement of crystals.

Structural biology represents for me the best example of what people should understand under the term of biophysics. And structural biology needs physicists, mathematicians, biologists, informaticians to interact with one another. It was working well in the past - e.g., discoveries concerning the molecular structure of nucleic acids and its significance for information transfer in living material - https://www.nobelprize.org/prizes/medicine/1962/summary/; studies of the structure and function of the ribosome - https://www.nobelprize.org/prizes/chemistry/2009/summary/; developing cryo-electron microscopy for the high-resolution structure determination of biomolecules in solution - https://www.nobelprize.org/prizes/chemistry/2017/summary/ . And it will be needed in the future. While solving more complex system – so called molecular machines.

In Linz, I had the great possibility to see microtomy and electron microscopy, see and understand the physics behind and fill the gap in my background and learn technique that will enable my scientific growth. To see how to calibrate coils, understand how does the phase plate improves contrast etc. was very useful.

Physicists are organized people and what they do is possible to describe with equations, graphs, formulae and diagrams. There are very little approximations compared to structural biology. Therefore the main problem is to explain how a system comprising thousands of atoms can be studied and calculated while in physics it is not possible to describe system comprising tenths of atoms with accuracy “good enough”.

So, my typical problems are to convince others that it is possible (and worth) studying my systems of interest and that with all the approximations and neglections the results is accurate and corresponding to “reality” “well enough”. When meeting with scientist from the field of condensed matter physics, I was lucky enough to meet patient people with whom we talk and listen one to another, read books of different topics and look for a solution of any problem.

## Recommendations

The biosensor sector represents a significant market to optical-electronic-microsystems developers while at the same time there is a strong pull for new technology solutions.

Applications of biosensors in environment, food and health monitoring enable the improvement of the quality and safety of life, enhance the sustainability of the processes because of better process control, and enable product innovations that benefit consumers and society. The TWINFUSYON project has identified many opportunities for further applications of opto-electronic biosensors. However, the project also identified problems in the articulation of demands by the various sectors that can be solved by optronics biosensors, and expression of opportunities by technology companies that could benefit the environment, food and health.

The challenges to be addressed are more in innovation than research: e. g., a pure technology push approach, and technology providers need to know the targeted sector very well in order to provide a solution that can be an integrated part of the process management system of the companies. To address these constraints, innovation projects driven by users are needed and not only projects that primarily target research and development.

With “price/cost” as the most important decision factor for the deployment of new technologies, the current situation can be considered a chicken and egg situation (price depends on quantity, quantity depends on price).

To fully benefit from all the opportunities further coordination of the cross-sector exchange of knowledge, ideas and research is required. The project therefore recommends follow-up to identify targeted information exchanges and R&D derived from existing and future roadmaps on the different application fields that are supported by both biosensors and nanoelectronics companies. Coordination activities across the different funding areas/programmes involved (sensing, environment, health and ICT) at European Commission level will also be beneficial. In addition to delineating the more promising applications it should take care of other collateral aspects such as increasing the awareness of the end-user industry, taking the appropriate role of this industry (mostly SMEs with limited R&D capacity) into consideration. Additionally fostering a better interconnection of technologist players into research innovations can help ascertain business models that will be more appropriate for successful exploitation.

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| Recommendation | Issues | Benefit/Impact |
|---|---|---|
| Promote the combination of a better fabrication technique and new physical effects | Convince especially SMEs in investing in new fabrication methods | New market opportunities for micro- and nano-engineered optical sensors |
| Favour, low-cost high-throughput nanofabrication techniques such as self-assembly or nanoimprint | Prepared skilled person-nel | Materials with lower dimension usually show higher mechanical strength and flexibility |
| Promote eco-design to save costs and become more environment friendly | Convince the key stake-holders that they will save money | Stakeholders will acknowledge that the use of optronic biosensors can be cost effective |
| Favour real-time moni-toring | Increase time resolution | Improved confidence of the consumer |
| Favour materials and systems that promote both green practices & end-user markets | For example the develop-ment of low cost routs to 2D materials | Good impact since a large market can be shared by consumers and producers |
| Promote interdiscipli-narity not only at R&D but also in SMEs/ industry | there are few cross-over disciplines that capture the necessary skills needed to detect and identify chemicals/ biagents in a meaningful way | Developmnt of ultrasensitive and multiplex transduction mechanisms bringing the bio/chemical information needed and mediation technology |
| Favour financial support to push-up the develop-ment of R&D based so-lution | Updating of standards and regulation. Compa-nies are seeking for tech-nology candidates in which they can safely in-vest. | Economic benefit thanks to a huge mar-ket |
| Support optronic sys-tems that bring new markets for manufactur-ers & consumers | Handheld spectro & opto analyzers | Save energy. Improve safety |

## What does the future look like: The next generation of sensors

Integrated optical-electrical devices, circuits and subsystems are expected to improve their technical characteristics and drive drastic reductions in the sensor costs. In addition, in the coming years, new quantum based concepts and metamaterials with exotic optical properties, among others, will be explored and potentially developed for sensing purposes. All mentioned R&D directions in this roadmap will contribute to significantly increasing the real use of optronics technologies in real applications and hence to expand their market.

Along with sensor miniaturization, new optronic devices are creating opportunities for next-generation medical and environmental sensors. After years of development, ultrasound transducers based on capacitive detection or piezoelectric detection are finally emerging, with the first handheld imaging diagnostic systems Much effort is being invested in non-invasive devices for better environment as well as patient comfort. For instance, Apple has invested lots of money and manpower to develop an optical non-invasive sensor in its smartwatch, which constantly checks the wearer's blood glucose level.

Exceeding "wearable", the next generation of sensor integrating medical devices should be "forgettable": that is, sensors must adapt to all wearables, textiles, and other accessories. Flexibility and stretchability are pending parameters for the next sensor generation, likely in the form of body "stickers" that detect the presence of certain molecules in sweat. Meanwhile, electrochemical sensors are leveraging printed electronics development and new biocompatible substrate research, and should offer supplementary functionalities.

## UPCOMING EVENTS

TWINFUSYON partners will continue its dissemination activities and will present several common papers during the Year 2019.


Our web page will be still available for you, visit us!