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Physicists in Industry (7)

Physics as Driver of Innovation

Bernhard Braunecker, Leica Research Fellow (ret.)

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Innovation pipeline and knowledge transfer

The success of Switzerland's High-Tech industries is based to a large extend on their profound physical understanding of the technologies. This capability must be maintained in the future in order to further compete internationally as a leading economic nation. Only an innovation pipeline *permanently filled with proved physical concepts* leads to a continuous technology stream that can be transformed sustainably into products and services. The technology value added chain begins with basic research performed at universities and research institutes such as PSI or CERN, continues with applied research and development carried out at the ETHs and universities of applied sciences and finally flows into the pre- and product development activities of industry.

In the following we restrict ourselves to the knowledge transfer between universities and industry. It must take place in *both directions* in order to inform industry about technical progress on the one hand, and to make universities aware of developing markets on the other. This last information allows universities to redefine or fine tune their teaching programs, which also ensures their international attractiveness, being reflected in good ranking results.

National top/down programs for physics-based cross sectional technologies

If there are strong indications of so-called disruptive technologies [1] in the research pipeline, and if at the same time industry expects that their implementation in products would find positive market acceptance, then maximum attention has to be given on both sides. If it can also be seen that an arising technology could be a *cross sectional technology* affecting many industrial sectors such as mechanical engineering, chemistry, pharmacy, food, mobility, etc., then the cooperation between universities and industry should be best organized as national top/down programs.

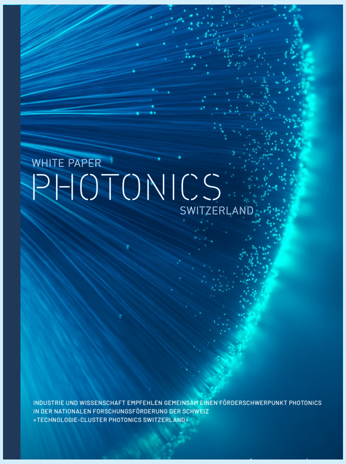
Examples of today's cross sectional technologies are digitization, algorithms, data security, advanced manufacturing, smart sensors and robots, while applied quantum physics, functional materials, modern photonics and above all the interaction of physics with life science, i.e. biology, chemistry, pharmacy and medicine are candidates for the near future. They offer best business opportunities for start-ups but also for existing smaller industries.

The aim of the top/down programs is to jointly develop technology approaches to such an extent that they can be transferred seamlessly to industry from a certain degree of maturity onwards. The participating industries do not compete but cooperate during this phase as development partners. The scientific goals are defined on an equal eye-to-eye level by the universities and the industry. The funding of the academic partners is done by the state, while the other half of the programs' costs is covered by the industry itself. However, to encourage small and medium sized enterprises (SMEs) to participation more flexible financial conditions than in the past need to be set up.

This concept was successfully implemented at the end of the 1990s in the basic programs of the ETH Board such as *Optique I/II*, *LESIT*, *TopNano21*, where physicists from universities and industry were the main drivers [2]. A similar Swissmem initiative is currently under way to establish the cross-sectional technology *Photonics* as a national priority program (see infobox).

White Paper *Photonics Switzerland*

A group of experts led by Swissmem's photonics group wrote a white paper describing photonics as both, an independent and a cross sectional technology. It shows that in Switzerland the mutual coordination and exchange of information between universities and industry must be improved to remain at the fore front of technology application. SME in particular, which contribute significantly to Switzerland's economic strength, are at risk in view of the increasing complexity of modern photonic technologies and consequently must be better included in all activities. As an effective approach the experts recommend a national top-down program, which is jointly defined and implemented by universities and industries. A first presentation of the white paper at Federal Councillor Johann Schneider-Ammann, the State Secretariat of Education, Research and Innovation SERI and and the Swiss Innovation Agency *Innosuisse* found very positive resonance.
https://www.swissmem.ch/en/organization-members/specialist-groups/photonics.html



Role of physics as a driver of progress

Today physical concepts are not only the base of engineering science and chemistry, but also of biology and even medicine. They all benefit from the quantitative understanding of the dynamic processes on a molecular level. It is e.g. impressive how Physics can support the more empirically acquired knowledge in medicine. Similarly, geotechnics,

1 The technologies show the potential to substitute traditional approaches almost overnight after having reached a certain degree of maturity. And it is foreseeable that this might happen within the next 1 to 3 years.

2 https://www.sps.ch/artikel/physik-und-gesellschaft/nationale-foerderinitiativen-zur-staerkung-des-wissenstransfers-zwischen-hochschule-und-industrie-10/

climatology research and energy technology, even modern traffic engineering, would not be so successful in their statements without physical modelling of the involved processes. This makes it possible to exceed the current limits and thus to generate new application possibilities.

Comments of industrial physicists

This discernible trend prompted us to ask some colleagues from the physics industry (see info box) for their opinion on the role of physics in their company today and in the future.

Question 1: How important are concepts from physics in your field of work?

UC: Concepts of applied physics and a good understanding of electrodynamics, thermodynamics and mechanics are prerequisites for innovation in electric motors.

RC: Nothing new can be developed in our space sector without physics.

BGH: Overall, it should be noted that the continuing trend towards smaller physical structures requires the application of new processes in the respective manufacturing context (e.g. plasmas and particle-surface interactions in different speed ranges for structuring and changing surfaces).

RH: Very important, especially concepts for energy conversion, photonic, thermodynamics are necessary.

RL: The Comet Group manufactures high-tech products in which physics plays a decisive and fundamental role: Vacuum capacitors, electron beam tubes, X-ray sources/tubes and complete X-ray systems.

MR: AMS develops various types of sensors for consumer and industrial applications. The basis for most products are located in the area of semiconductor, material and micro/nanotechnologies, or in their sciences.

RV: Optics & Photonics are an essential part of industrial physics. Photonics has grown very strongly in the last 25 years and has changed our daily lives massively. Innovative concepts of photonics, such as new lasers, optical data transmission, nanophotonics, meta-lenses, 3D printing etc. can only be developed with the means of physics.

Question 2: Do you observe that the complexity of physical technology approaches is generally increasing?

UC: Yes, the power density of the drives is constantly increasing, and the analysis of the phenomena that occur is becoming more complex. Simple engineering approaches reach their limits.

RC: Yes, an increase can be observed, which is being accelerated by the development of new materials and electronics in particular.

BGH: The individual technology approaches are not necessarily more complex in themselves, but overall complexity is increasing due to increasing diversity.

RL: The complexity of the technology approaches remains more or less the same, however the requirements tend to increase, but not fundamentally. We are constantly trying to improve quality, yield and reliability, which increases the complexity of production and other processes. The integration in higher-level systems and the digitization of measurement data and parameters are becoming increasingly important. Of course, we are also looking at completely different physical approaches to achieve the same results as with traditional technologies.

RH: Yes, fast. Our company is active in the field of CO_2-neutral energy supply based on methanol. The number of published scientific articles explodes in practically all areas such as the extraction of CO_2 from the air, photovoltaics, optimization of Si-based PV cells, electro-catalytic, electro-enzymatic and photocatalytic methanol production.

MR: Products are continuously becoming more integrated and complex. Physics as a basic knowledge enables the combination of different technologies.

RV: No! The technology relevant for industry today and in the next 5 years is usually based on physical concepts which are well understood. The physical approaches to technology, which will only become relevant for industry in 15 to 20 years' time, are just as complex as physics has always been.

Question 3: How much do you differentiate yourself from the competitors through physical/technical innovation?

UC: Technical innovation is at the heart of business success in a high-wage country.

RC: We try to realize innovations faster than the competition in our products and physical innovations play the decisive role.

BGH: The question is less whether physical/technical innovations permit quantitative differentiation or whether differentiation offers a competitive advantage. For Swiss companies, technological leadership is usually indispensable, not least because of the reputation generally attached to them. Thus, there is already an expectation that the solutions are

Contact persons

UC: Ulrich Claessen, R&D Manager of *Maxon Motors* AG in Sachseln / OW, which produces electric motors in numerous variants. (https://www.maxonmotor.ch)

RC: Reinhard Czichy, President of *Synopta GmbH* in Eggersriet / SG, which produces optical terminals for satellite communication. (https://www.synopta.ch)

BGH: Bernd-Günther Harmann, Patent Attorney of *Kaminski, Harmann Patentanwälte AG* in St. Gallen. (https://www.khp-law.ch)

RH: Reto Holzner, Chief Scientific Officer of *Silent Power AG* in Cham / ZG, dealing with innovative energy storage concepts. (https://silent-power.com)

RL: René Lenggenhager, CEO of *Comet Group AG* in Flamatt / FR, specializing in industrial X-ray, high-frequency and electron beam equipment. (https://www.comet-group.com)

MR: Markus Rossi, Vice President of *Heptagon-AMS AG* in Rüschlikon / ZH, who supply Mems-based photonic subsystems for international mobile phone manufacturers. (https://www.hptg.com)

RV: Reinhard Völkel, CEO of *SUSS MicroOptics SA* in Neuchâtel / NE, which manufacture micro-optics for a wide range of sensor applications. (https://www.suss-microoptics.com) in any case at the forefront of technical development, and it is less the extent of differentiation or its additional effect that comes to the fore. Rather, the decisive criterion seems to be the continued membership in the group of technically leading suppliers, rather than the increase in a technical "distance".

RH: Very strong. Thanks to the innovative use of physical properties, we want to develop and sell low-noise, low-maintenance, lightweight, environmentally friendly and reasonably priced products.

RL: We differentiate ourselves strongly from our competitors because we master the technical and physical processes to such a high degree that there is little competition. Innovation is a fundamental driver of our business. Our physicists and engineers understand excellently what we do, be it the excellent basic understanding of physics and the physical and technical processes or more and more the simulation of them. This allows us to understand physics and its applications in our products even better. Simulation not only provides a better understanding, but also a higher speed and lower costs in development, since fewer functional samples/prototypes are required and/or these are used later.

MR: Our competition is mainly in Asia, and we have to achieve the same manufacturing costs. This is only possible if we see technical innovation as the main differentiator.

RV: Not much! We have a total of four PhD students in the field of photonics, but they come from engineering and mechanical engineering. A pure physicist not only has to deal with technical questions, but we need him to address new kinds of questions.

Question 4: How important is a profound physical understanding of the technologies used in order to develop them further and implement them reliably in industry?

UC: Very important. The understanding must be tested in practice ("working knowledge").

RC: This understanding is essential.

BGH: Essential.

RH: Very important. The vast majority of our employees have a profound education in physics or electrical engineering.

RL: Since all our components "work" at the limits of physics, it is essential to have a broad and very deep understanding of the technologies used. As mentioned above, simulation is very important, but also the analytical understanding of physical processes and technologies. When working at the limits of physics (surfaces, purity, high voltage).

MR: For sensors of all kinds (optics, electronics, environment, acoustics) a comprehensive understanding of the physical basics is absolutely necessary: from the first concept to implementation in products and their manufacture in mass production.

RV: The important key technologies of photonics are essentially based on the basic principles of mathematics, physics, chemistry, mechanical engineering and computer science. Even though a large number of courses, some of which are very specific, are offered today, these can be traced back to the six important pillars. A profound understanding of physics is just as necessary as good knowledge in mathematics, chemistry, mechanical engineering and computer science.

> **How to solve apparent cultural differences?**
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> It is important in top/down programs to minimize the impact of inherent cultural differences: while at the universities 'Time to Maturity' is considered as success criterion, which usually corresponds to the duration of a doctoral thesis of four years, its equivalent in industry is 'Time to Market' with typical durations of a maximum of two years. A time conflict? Since, however the doctoral or master theses are also supervised by industrial physicists in the basic state programs, the transfer of knowledge is 'adiabatic' avoiding wrong decisions and a resilient trust between individuals and institutions is formed.

Question 5: At what intervals do you expect technology changes in your field in the future, and how important is the discipline of physics?

UC: The time intervals for technology changes in motors are long (> 10 years), in controller technology and sensors shorter (new processors, new control methods, new sensor principles e.g. Giant Magnetic Resonance). Additive manufacturing of motors would be a disruptive manufacturing technology.

RC: In our space division, technology changes are often implemented rather late in products because these first have to prove themselves. In other ground-based activities (astronomy, metrology), technology progress can be used more quickly. However, we do not expect anything revolutionary new in our areas in the next 5 years. But physics is essential for us to be able to assess and understand these changes.

RH: Technology improvements are already underway at an annual rate, and even faster in some areas. A good physics education helps enormously, just to separate the wheat from the chaff within a useful period of time, not to mention to familiarize oneself with the innovations.

BGH: This question cannot be answered in general. On the one hand, the definition of a technology is difficult in itself, and on the other hand, the determination of whether and when a change has taken place is problematic. Moreover, not every technical discontinuity necessarily leads to significant changes in the market or disruptive business models. Nevertheless the future will be marked by technology changes, where most of which may need the solution of physical problems, see e.g. Quantum Computing.

RL: I expect fundamental technology changes in a period of 3 to 5 years, where physics and semiconductor technology (which is also physics) will play a decisive role here. However, fast and intelligent data processing combined with sensor technology are also becoming increasingly important. They allow to increase the physical performance of components like a better noise suppression by physical modelling.

MR: Individual product categories change every 1-2 years; the technologies on which they are based can change significantly every 3-5 years. Many innovations are not evolutionary, i.e. require fundamental developments, not engineering.

RV: In 10 years robots will invent, develop, assemble, program, and control/monitor other robots. Half of all current subjects and many technical professions will disappear. But physics will always remain and Out-of-the-box thinking, creativity and abstraction must come from physics.

Conclusions

The answers of our colleagues from industry show that the results of applied physics are indispensable for the future development of technologies, products and services in Swiss industries. But applied physics depends on the results of fundamental research. The complete knowledge transfer chain must therefore be kept at the highest level. In Asian countries, state agencies set the standards for universities and industry, monitor and control their implementation. In Switzerland, however, with its liberal tradition, the freedom of research and industrial self-responsibility must remain the cornerstones of success. We can only counter the state dirigism of big Asian countries with better cooperations, for which the top/down basic programs would be well suited managing instruments with proven efficiency. More than until now SMEs must be better involved, but they themselves must also learn that in addition to engineering skills a profound knowledge of physics will be required in order to stay ahead in the future.