

Report on the evaluation of the Physics and Materials
Science Research Unit (PHYMS) at the University of
Luxembourg

Based on a peer review as commissioned by the Ministry of Higher Education
and Research of Luxembourg

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COMPANY INFORMATION

Authors

Louis Schlapbach, Dr. sc. nat., Prof. em. ETH/Empa
Olivier Dolder, MA (Interface)

INTERFACE

Policy Studies, Research, Consulting
Seidenhofstrasse 12
CH-6003 Lucerne
Tel +41 (0)41 226 04 26
interface@interface-politikstudien.ch
www.interface-politikstudien.ch

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I INTRODUCTION

The Ministry of Higher Education and Research (MESR) of Luxembourg mandated *Interface Policy Studies, Research, Consulting*, Switzerland, to organize and lead a research evaluation of the University of Luxembourg. Simultaneously, the Institutional Evaluation Programme (IEP) of the European University Association carried out an institutional evaluation of the University of Luxembourg. The results of the IEP evaluation are published in a separate report.

The research evaluation was conducted in 2016 and followed two earlier evaluations carried out in 2008 and 2012.

The University of Luxembourg has three Faculties with research units conducting research in different scientific disciplines. In addition, there are three interdisciplinary centres.¹ The evaluation focused on the research performance of the University research units and interdisciplinary centres. This report presents the evaluation of the Physics and Materials Science Research Unit (PHYMS).

The observations and recommendations presented in this report are based on a peer review by the following three experts working in the research unit's research fields:

- Leticia Cugliandolo, professor of theoretical physics and high energy physics at the University Pierre et Marie Curie – Paris VI, and director of Ecole de Physique des Houches, France
- Helmuth Möhwald, professor of physics and physical chemistry and emeritus director at the Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany
- Christian Wetzel, professor of physics, applied physics, and astronomy and professor of materials science and engineering at the Rensselaer Polytechnic Institute, Troy, NY, United States

The peer review consisted of a self-assessment report written by the PHYMS and a hearing at the research unit that took place in September 2016. The evaluation assessed the period 2012 to 2015. The hearing, which was organized and moderated by Interface, consisted of a self-presentation by the research unit, a group discussion of the self-assessment report, and several individual and group interviews. These included interviews with representatives of the management team, professors, PhD candidates,² and further members of the research staff. Based on the experts' assessments, the report was finalized by Louis Schlapbach (sub-contractor of Interface) and Olivier Dolder (Interface). The report has been approved by the experts.

¹ The Interdisciplinary Centre for Contemporary and Digital History was established in 2016. It is not part of the evaluation, as the assessed period is 2012 to 2015.

² The University of Luxembourg calls its PhD students 'PhD candidates'.

The overall results of all unit evaluations are summarized in a synthesis.³ The synthesis report includes the findings of the interviews conducted with representatives of the management team at the University of Luxembourg.

The report is divided into two parts: The first part discusses the expert team's observations gathered during the evaluation process. The focus is on the input, the output, and the outcome/impact of the research unit:

- *Input* includes the preconditions for the research conducted, such as strategies, financial and human resources, infrastructure, organization, and quality assurance systems.
- *Output* includes the performance of the research unit, exemplified through research results and their dissemination.
- *Outcome and impact* refer to the medium- and long-term effects as well as the relevance of the output for science, society, economy, and politics.

The second part presents the expert team's recommendations for further development of existing strengths and overcoming observed weaknesses.

The evaluation team would like to thank everyone involved for preparing and implementing the hearing at the PHYMS, for making the documentation available, and for participating in interviews.

³ Rieder, Stefan et al. (2017): Evaluation of the University of Luxembourg, Interface Policy Studies, Research, Consulting, Lucerne.

2.1 OVERALL ASSESSMENT

The development of the PHYMS over the evaluation period 2012–2015 is impressive. The unit, as a part of a young university, has increased its research quality and quantity considerably. The research unit has published papers of high quality and in an appropriate quantity. The experts evaluate very positively the fact that the PHYMS has been able to acquire two European Research Council (ERC) grants and two ATTRACT positions⁴. Compared to a typical physics department, the research unit is still small and needs a distinct research strategy for its future development. In the experts' view, the research focus on condensed matter physics and materials science chosen by the research unit is appropriate.

2.2 INPUT

Research strategy

In the experts' view, the development of the PHYMS is not yet completed. They observed that the unit's growth thus far has been driven by the selection of excellence in the recruitment of professors and associate professors rather than by a discipline-oriented development plan. This was an appropriate strategy for the early phase of development. Now it is time to develop a distinct strategy enabling stronger internal synergies. The PHYMS laid a foundation for an anticipated specialization towards industry relevant topics with important basic research.

Human and financial resources, infrastructure, and equipment

The unit's growth over the past years – with one or even two professor appointments per year – seems adequate to the expert team. The unit's recruitment process has resulted in the engagement of very good international researchers. The current balance between theorists and experimentalists (i.e. there are approximately the same number of each) and the planned development of the PHYMS towards a higher share of experimentalists including stronger development of computational science are appropriate in the experts' opinion. On the other hand, the experts find the number of master's degree and PhD candidates enrolled in the PHYMS' programmes too low, and this requires measures in the future development of the research unit. The PRIDE doctoral school⁵ seems to be a suitable tool to contribute to this goal.

⁴ The ATTRACT programme of the Luxembourg National Research Fund (FNR) is designed for researchers not yet established in Luxembourg who demonstrate the potential to become leaders in their field of research. The funding scheme offers promising junior researchers the opportunity to set up their own research team within one of the country's research institutions (see <www.fnr.lu>).

⁵ PRIDE is the programme of the FNR for funding doctoral research in Luxembourg. Under this programme, a block of PhD grants is awarded to a consortium of excellent researchers grouped around a coherent research and training programme (see <www.fnr.lu>).

The in-house equipment available for the researchers (i.e. microscopic, spectroscopic, and diffraction tools) in some of the experimental groups is rather modest. The expert team is of the opinion that the installation budgets (hiring or start-up packages) for professors coming from external institutions are appropriate. However, there is hardly any budget available for the funding of additional new installations or for the renewal of equipment, neither within the University of Luxembourg nor through the Luxembourg National Research Fund (FNR). There is a need for investment in equipment, as a part of the equipment is older than 10 years. In the experts' view, a reinvestment of 10 percent of the original investment should be foreseen per year. This would entail around one million euros per year with the current unit size and would increase with further expansion. Material synthesis and characterization capabilities exist mostly in the Photovoltaics group; they need to be developed for other experimental groups.

The access to electronic libraries and journals seems to be limited within the research unit. The PHYMS has access to the most important physics journals but not to all important journals in the broader context of material sciences. For example, the researchers have no access to highly respected journals such as those from the Royal Society of Chemistry (RSC) and American Chemical Society (ACS). The experts are of the opinion that access to important journals is crucial for a university institution and its research.

According to the experts, the available laboratory and office space (about 20m² per researcher) is adequate but should be increased with future personnel growth of the PHYMS. The space should be shared according to the needs of the research groups. The needs of the theoretical and experimental teams are very different, and assignment of laboratory space has to be handled flexibly according to the changing needs of individual research groups.

The maintenance of the infrastructure of a part of the building is unsatisfactory and causes safety risks (e.g. chemical hazard due to imperfect ventilation within some fume hoods). Apparently, there are administrative obstacles to achieving fast and adequate solutions.

Organization

The research unit has about 70 full time equivalent (FTE) grouped into 10 rather independent groups of the 10 Principal Investigators (PIs). The experts doubt that all of these groups are large enough to reach critical mass. The PHYMS seems to be aware of this and describes in the self-assessment report its attained expertise in the fields of: (a) theoretical soft matter and statistical physics, (b) experimental soft matter physics, (c) electronic structure theory and computation, (d) magnetic and multiferroic materials, and (e) photovoltaics. The experts encourage an appropriate clustering of the 10 independent groups and recommend presenting the clustered groups rather than the 10 PI-based organizational structure when communicating with external partners. In the experts' view, the PHYMS could also use the following clustering: Soft matter, Magnetism, and Energy and Polymers in experimental, computational, and theoretical research.

A steering committee of all PIs, together with the *adjoints de recherche*, having independent PhD supervision rights, guides the research unit. The managing head of the unit chairs this committee more or less as *primus inter pares*. The experts learned that the research unit prioritizes academic freedom in small groups over strong internal clustering. This may justify the relatively weak position of the unit head. However, the experts see internal clustering as useful for internal collaboration, for the achievement of a critical mass and higher research productivity, and, moreover, for better representation of the unit to the outside on any occasion. Therefore, the experts see a need to readjust the balance between independence and cooperation of the research groups for the further development of the PHYMS. They recommend increasing the position power of the unit head with the aim to maximize the synergies between the groups.

External research collaborations and service provision

The research unit lists numerous national and international collaborations. The experts appreciate the scientific collaboration on the international level with high-reputation partners. These collaborations result in involvement in common projects at the European level, in internationally co-funded projects, and finally in joint publications. Contacts with national and European industry partners are listed as well; they create a rather modest income of only 100,000 euros per year (see section 2.4).

Quality assurance system

The research unit assures its quality by publishing in peer-reviewed journals, by successfully applying for external funding, and by having a clear recruitment strategy for new academic positions. This is adequate in the opinion of the experts. In terms of public trust in the research unit's academic integrity, the experts expect that the Ethics Review Panel of the University of Luxembourg assumes the task of implementing the European Code of Conduct for Research Integrity at the University level.

2.3 OUTPUT

In the expert team's view, the PHYMS published papers of high quality, in well-chosen journals – some of them high impact journals – and in an appropriate quantity during the period 2012–2015. The research unit was very successful in securing third party funding. The experts evaluate very positively the fact that the PHYMS acquired two ERC grants as well as two ATTRACT positions. The PHYMS also successfully acquired university-internal competitive research funding, which the experts also assess positively. Finally, for the experts, the fact that researchers were asked to give invited and plenary talks at international conferences demonstrates the good research quality and the enhanced visibility of the PHYMS. In addition, the experts rate highly the important participation of most of the PIs as peer reviewers for scientific journals and public funding agencies (e.g. French National Research Agency, German Research Foundation, or Swiss National Science Foundation).

The already impressive research output could be increased if the teaching load of the PHYMS members could be reduced, e.g. by also engaging qualified scientists from the external Luxembourg Institute of Science and Technology (LIST) or possibly from the

University's interdisciplinary Luxembourg Centre for Systems Biomedicine (LCSB) to teach individual lectures or entire courses.

The research unit filed seven patents in four years, three of them at the United States Patent and Trademark Office. In the same period, seven patents were granted to the PHYMS, one of them from the European Patent Office. In the view of the experts, this is a good start, but it is still insufficient. Moreover, the PHYMS was not successful in commercialization of research outputs (e.g. the PHYMS did not provide any evidence of the establishment of a single start-up company). Innovation or entrepreneurial spirit is still missing and should be developed as early as at the PhD candidate level.

For the purpose of a more detailed description of the research output, the experts chose a classification of efforts in the following research domains: Soft matter, Magnetism, Energy, Polymers, and theoretical research (as suggested in section 2.2):

- *Soft matter*: The soft matter field (theory and experiment) is interesting and develops broadly in very different areas, e.g. dynamics in ordering liquid crystals or complex or micro fluidics. The appointment of a new professor in 2013 is very positive, as it has brought much imagination and new spirit into the research unit. The expert team sees potential for a development towards sensors in collaboration with other institutions such as the LCSB or LIST. It is especially gratifying to observe the successful collaboration between simulation and experiment. However, this field is distinguished by the complementarity of many spectroscopic, microscopic, and scattering characterization methods, which will need considerably more equipment investments. The research is at the front internationally, as shown by high impact publications, an ERC grant, and appointment offers for the PI from other institutions.
- *Magnetism*: The research output in this subunit is good. It includes an extended review paper on newer magnetic phenomena at the nanometer scale, including dynamics. The materials studies are of the well-known Rare-Earth-Iron-Boron permanent magnet family and of magnetostrictive materials. The classical magnetic neutron diffraction in small angle technique is applied in a clever approach to the newer dynamic phenomena making use of time resolution. Modelling is done in parallel. The expert team identifies room for improvement in the use of synergies with the Condensed Matter Physics group and their work on dynamics in small systems and in strengthening collaboration with the Materials Research and Technology department at the LIST, working on multiferroic materials. Transfer of results for innovative sensor technologies might be a future outcome.
- *Energy*: The research activities are very solid and very relevant for photovoltaics (PV) applications. Thin film CIGS type experimental work as well as band structure studies are conducted. The results on kesterites in particular are a pioneering contribution internationally. In the experts' view, a reorientation of the research to include newly emerging materials should be considered. The experts support the necessity for such research in Luxembourg and point out that there is very strong competition in the PV field. According to the experts, the research group is visible and well integrated in the international scientific PV community. The work on liq-

uid phase deposition of films has strong affinities to soft matter sciences, and cooperation could serve understanding and control of the process.

- *Polymers:* In the experts' view, the R&D work on polymers is traditional work and serves applications and collaboration with industry. It started prior to the foundation of the University and was continued with good results. However, the experts see more potential for the work on polymers and the valorization of those results within a more applied environment.
- *Theoretical research:* This research is carried out in the research unit by four PIs and their groups. Their work covers extensive numerical simulations (e.g. the influence of van der Waals interactions in various systems, ab initio electronic structure calculations) and analytical studies (fluctuations in small systems, stochastic thermodynamics and chemical networks on one side, and modern condensed matter problems on the other). All of these topics are very timely. The work carried out on stochastic thermodynamics by one faculty member is excellent, and he recently received an ERC grant to continue this line of research. The topics studied by the theoretical investigators are wide but not orthogonal. Future internal collaborations are foreseen, and there are plans to interact with members of the LSCB on the dynamics of chemical networks.

Collaborative efforts between the theoretical and experimental research groups exist: In soft matter, theorists and experimentalists have successfully established a collaborative project and are on an excellent trajectory in the experts' view. However, collaborative efforts are not numerous or not yet well visible. Generally, there is room for improvement, as described above.

To summarize, some of the research topics enjoy high international visibility, and there is no doubt that they will strengthen the branding of both Luxembourg and the University of Luxembourg in the international scientific community.

2.4 OUTCOME AND IMPACT

The experts identified a growing impact of the PHYMS on science and enhanced visibility in the international scientific community, although there is room for improvement, especially regarding national visibility.

Since material sciences are the basis for industrial development, the potential long-term impact is apparent. There are various ways to have an impact: The University can train staff for industry, it can facilitate the creation of start-ups, and it can attract industrial enterprises or serve as a consulting agency for day-to-day industry needs. At present, the expert team sees room for improvement in this regard. No start-up company has yet been founded that can be traced back to the PHYMS. On the positive side, the experts learned that all of the research unit's former PhD candidates have found employment in industry or have chosen to continue their scientific careers at other universities.

The PHYMS has many contacts with industry, but the research unit does not generate much income based on these contacts. The experts are of the opinion that PHYMS researchers' experience and knowledge should be used to create more income and to intensify the knowledge transfer for innovation.

National visibility needs more development aiming at stronger recognition and partnerships for innovation as well as aiming at recruitment of students from Luxembourg. The expert team sees room for improvement regarding presence in the media (via press releases) and in communications. The unit needs to intensify advertisement of their achievements and communicate their demands to the upper management of the University and respective government institutions. It is generally a particular advantage of a small university in a capital to have direct and regular access to policy makers.

2.5 STRATEGY FOR THE FUTURE

As mentioned above, the experts are of the opinion that the development of the PHYMS is not yet completed and that it is of vital importance for the PHYMS to develop a distinct strategy enabling stronger internal synergies. The experts were therefore surprised that the research unit presented its future vision in a very modest way.

The strategy for the future of the PHYMS should address the following points especially:

- *Management and organization:* The unit should develop trust in more top-down leadership in order to benefit from synergies, and it should strengthen the position of the head of the research unit. Furthermore, the PHYMS should structure itself around several topics (e.g. as proposed around the topics soft matter, magnetism, energy, polymers, and theoretical research) by merging or clustering research groups. This new structure should be presented in all activities of the unit (e.g. internal and external communications, publications, or recruitment processes). The new structure entails that competences in physical chemistry for the synthesis and characterization of new materials should be developed as part of the experimental groups instead of as an additional unit.
- *Growth and recruitment:* The PHYMS should aim to double its size over the next 10 years in order to secure a critical mass in more sub-disciplines of material sciences, maximize the potential of synergies, and improve scientific output. The experts stress that future recruitment should be based on a new recruitment concept that aims to strengthen the internal collaboration and coherence of the different research groups. Scientific excellence of candidates needs to be a criterion, but it should not be the only one. In this context, the experts assess the planned development of the PHYMS towards a higher share of experimentalists, including stronger development of computational science, positively.
- *Research targets and mission:* In the experts' view, the PHYMS needs clear and explicit research targets. The basis for an agenda of that kind is that each cluster or research group should define its mission. In the opinion of the expert team, a possible mission for the soft matter cluster, for example, could be responsive and

self-repairing materials, with clear potential in drug delivery and bio sensing. This mission unleashes potential for collaboration (e.g. with the LCSB), while still preserving much academic freedom for the PIs.

- *Collaboration:* The future strategy should include consideration of how the PHYMS wishes to intensify its collaboration both within the research unit and with other University internal and external institutions. The LIST and the LCSB are very interesting potential collaboration partners and should be taken into serious consideration for future collaboration projects.
- *Valorization of results and technology transfer:* The experts see a need for a concept regarding the valorization of research results. In this context, an entrepreneurial spirit should be established, and creation of start-up companies as well as patent filings should be supported and promoted by the PHYMS.

3.1 SUMMARY

The PHYMS shows remarkable development over the evaluation period 2012–2015: The focus on condensed matter and materials science is well chosen. The research unit increased its research quality and quantity as well as its international visibility. The PHYMS published papers of high quality, in well-chosen journals, and with an appropriate quantity during the period under evaluation. Further, the expert team evaluates very positively the fact that the research unit was able to acquire two ERC grants as well as two ATTRACT positions. Despite the impressive output, compared to a typical physics department, the PHYMS is still small and therefore needs a distinct research strategy for its future development and growth. In the opinion of the experts, the current organizational structure with 10 rather independent research groups and with a head having little formal power is a weakness of the unit. As a result, internal and external collaboration is not sufficiently intensive, some research groups have not yet achieved a critical mass, and the visibility of the PHYMS is still too low. In addition, the research unit lacks entrepreneurial spirit and shows only moderate numbers of patents and little industry income.

3.2 RECOMMENDATIONS

Based on the observations stated above, the expert team formulates the following recommendations for the research unit, the University, and the MESR.

Recommendation 1: Reconsider the presentation of the research topics in the organizational structure

The current organizational structure with 10 rather independent groups is a consequence of the high importance of academic freedom within the research unit. However, the experts doubt that all of these groups are large enough to reach a critical mass. The expert team therefore recommends that the PHYMS either merge some of these groups or at least cluster them. Clustering is beneficial not only for the achievement of a critical mass (to successfully compete in the international science and research landscape, to achieve impact, or at least to receive bigger chunks of funding) but also for internal collaboration, higher research productivity, and better national and international communication and visibility.

Recommendation 2: Develop a better balance between academic freedom and top-down leadership

At present, the head of the research unit has a relatively weak position due to the high priority of academic freedom for the different PIs. The experts see the importance of academic freedom for researchers but also see the need for stronger leadership for further development of the research unit and to increase the use of synergies between the groups. Therefore, the experts recommend that the PHYMS increase the research unit head's position power.

Recommendation 3: Increase visibility and knowledge transfer for innovation

According to the experts, the low internal and external national visibility of the research unit is a weakness of the PHYMS. They recommend that the PHYMS increase its visibility in the University, science, society, and politics through: (1) intensified media work, (2) intensified knowledge transfer for innovation, and (3) higher scientific excellence and increased internal and external research collaboration. The experts also recommend that the PHYMS create an entrepreneurial spirit within the research unit. To establish entrepreneurial spirit, the PHYMS should demand that the Faculty create a technology transfer office and establish formal procedures regarding patent filings.

Recommendation 4: Invest more in maintenance of infrastructure and assure reinvestment in equipment

Maintenance of the building infrastructure needs more attention to prevent safety issues. The experts urgently recommend that the University invest more in the maintenance of infrastructure and renewal of equipment. The expert team also recommends constant reinvestment in the PHYMS' equipment by an amount of 10 percent of the original investment per year and by creating a fund for new, and the renewal of, equipment.

Recommendation 5: Improve access to electronic journals

The experts are of the opinion that it is important for researchers to have access to all important journals in their respective research fields. Access to electronic journals in the broader context of material sciences seems to be limited at the PHYMS. The experts recommend that the University improve the access to electronic journals.

Recommendation 6: Double the size of the unit within the next 10 years

The PHYMS has developed well and has increased its size considerably since its creation in 2003. Nevertheless, the unit is still small compared to a typical physics department. The expert team therefore recommends that the PHYMS and the University double the size of the research unit within the next 10 years. Having a doubled size, the unit would have a critical mass in many sub-disciplines of material sciences and could fully profit from internal synergies and improve research quality and quantity. Finally, a larger size is an opportunity for the PHYMS to become more visible.

Recommendation 7: Cease research on polymers within the unit

The PHYMS focuses mainly on basic research (partly use-inspired), whereas the PHYMS' former research on polymers is very technology-oriented (R&D for industry). The experts recommend transferring in the medium term the application-relevant work on polymers to a different research institution, as they see more potential for this activity and its valorization within a more applied environment.