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Evaluation of the Research Part of the University of Luxembourg: Evaluation Report

Department of Physics and Materials Science (DPhyMS)

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Wim van Saarloos (chair), Luisa Bausá, Philippe Boyer, Aurélien Decelle, Ayodhya Tiwari

Executive Summary

This report is part of the assessment of the research performance of Luxembourg University and covers the Department of Physics and Materials Science, part of the faculty of Science, Technology and Medicine. The Department of Physics and Material Science pursues fundamental and applied research and thorough education in physics and materials science covering a broad multidisciplinary spectrum of expertise which was expanded to biophysics and quantum technologies over the past five years. The Department is organised in 20 research groups across five key areas: Quantum Science & Technology, Statistical Physics & Machine Learning, Soft & Living Matter, Photovoltaics & Sustainable Energy, and Spectroscopy & Functional Materials.

The Department of Physics and Materials Science is a very strong department, with many research lines at international top level, and in some cases even world leading. Moreover, the Department has a good societal impact and is well positioned to continue to acquire funding from the FNR and the EU.

In the panel's view, the Department is pivoting from the initial buildup and growth phase to a phase of maturing and consolidation. The Department is advised to explore the implications of this for its future strategy. We could imagine that it pays to take advantage more of the five thematic clusters into which it is organised in positioning and organising the Department and in hiring and making its MSc programme internationally more distinctive and attractive. Professionalisation is also needed in supporting knowledge valorisation (startups, collaboration with industry) and outreach.

Communication within the three different university levels – department, faculty and rectorate – seems suboptimal. Improving this requires attention at all three levels, clarification of roles in communication, and improvement of communication channels.

Specific recommendations for the Department are:

- Maintain its high ambitions for scientific excellence and the collaborative spirit.
- Decide on future options (balance between growth and consolidation).
- Align the five clusters with the university strategy's three pillars.
- Strengthen the promotional, and maybe also the organising, role of the clusters.
- Increase participation in consortium programmes of Horizon Europe.
- Organise (internal) support for knowledge transfer.
- Analyse costs/benefits/alternatives of undergraduate programmes.
- Explore strategic cooperation with other universities for teaching and research, especially to make the master's programme more attractive internationally.
- Improve the gender balance, developing an approach to recruit more women.

Specific recommendations for the university are:

- Locate the whole Department in Belval *as soon as possible!*
- Strengthen technology transfer support to realise the commercialisation potential of the innovative research conducted by the Department.
- Develop a dual-career programme to facilitate Departments in attracting excellent female professors.

- Create more possibilities for internal promotions, within strict criteria of excellence.
- Create a chemistry department.
- Improve the lines of communication between the different levels of the university organisation and make sure that decisions are taken at the appropriate level.

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1 Introduction and background

1.1 Introduction to the evaluation

The Ministry of Research and Higher Education (MESR) of Luxembourg mandated Technopolis Group with the evaluation of the research part of the University of Luxembourg. This evaluation was conducted from May 2024 to June 2025. According to Art. 50/2 of the modified law on the organisation of the University of Luxembourg of June 27th, 2018, based on the original law of 2003, the University is subject to external evaluation every four years. The present evaluation assesses both the research and institutional aspects of the University. The main time period to be covered by this exercise is 2018-2023. Next to a retrospective assessment of achievements, the evaluations' prospective elements include the evaluation of the strategies and plans of the University as well as the evaluators and the panel assessment of challenges and opportunities ahead.

The University's mission, as defined by law, is threefold: to offer higher education courses leading to degrees, diplomas and certificates; to conduct research; and to contribute to the social, cultural and economic development of Luxembourg.

This report is part of the assessment of the research performance of the Universities' 13 research departments and three interdisciplinary centres and covers the Department of Physics and Materials Science part of the faculty of Science, Technology and Medicine. The evaluation is based on international external peer review and covers the performance of the research department, taking into account various aspects such as inputs (e.g., finances, human resources, infrastructure, strategy) and outputs/impacts (e.g., research outcomes, innovation activities, services). A separate report covers the assessment of organisation, management, and governance matters.

The observations and recommendations presented in this report are based on a peer review by the following experts working in the research entities' research fields: Prof. Em. Dr. Wim van Saarloos (Chair, Leiden University), Prof. Luisa Bausá (Universidad Autónoma Madrid), Prof. Philippe Bouyer (University of Amsterdam), Prof. Aurélien Decelle (Universidad Complutense de Madrid) and Prof. Em. Dr. Ayodhya Nath Tiwari (EMPA, Zürich).

The assessment is based on a self-evaluation report submitted by the department, background information on the Luxembourg research system information provided by Technopolis Group, and an on-site visit of the Department in January 2025. The hearing, which was organised and moderated by Technopolis, consisted of a self-presentation by the research unit and its research groups, as well as group interviews with junior researchers from the Department, external partners and clients.

The committee applied the following evaluation criteria and organised the present report accordingly: quality of the research, impact of the research (third mission), and future potential of the research in the department/IC.

The evaluation team would like to thank all those who helped us prepare the evaluation, those who provided information and those who were interviewed during the consultation.

1.2 The Department

The Department of Physics and Material Science pursues fundamental and applied research and thorough education in physics and materials science covering a broad multidisciplinary spectrum of expertise which was expanded to biophysics and quantum technologies over the

past five years. The Department is organised in 20 research groups across five key areas Quantum Science & Technology, Statistical Physics & Machine Learning, Soft & Living Matter, Photovoltaics & Sustainable Energy, and Spectroscopy & Functional Materials.

The Department includes 17 professors, 13 research scientists, 54 postdocs, 140 PhD students (of which 57 at LIST) and 14 support staff. Total funding in 2023 was almost €18m. 55% of the budget of the Department comes from external funding (mainly FNR and ERC).

2 Research strategy and organisation

The strategy of the Department is focused on excellence of research and staff and has resulted in a research portfolio that is internationally at the forefront of physics and materials science. Many of the research projects also show a nice synergy between theoretical and experimental work.

The Department has in recent years clustered the research programmes of its Principal Investigators into five thematic areas, termed "clusters". These clusters are not organisational units and indeed most researchers are active within several of them. The clusters serve as rough thematic labels and as stimuli for cooperation and for sharing resources, rather than as strategic areas of focus. The cohesion of the research programme reflects this: the research programme is essentially the sum of the programmes of the individual researchers, who aim for excellence, while taking advantage of the collegial atmosphere that fosters collaboration. Thematic strategic choices essentially play no role in the hiring.

Many of the new professors have been hired with financial support from one of the FNR ATTRACT schemes. This means that planning of financial resources for staff is to a large extent determined by the opportunities (or permission) the Department has to apply for these schemes.

A strong point of the Department is that decisions on larger research infrastructures are taken collegially, which naturally promotes sharing of equipment within the Department and the acquisition of equipment from which several PI's benefit.

The panel is impressed by the attention the Department is giving to important modern topics like open access publishing, open science, research integrity etc. as well as to training, guidance and evaluation of graduate students. Each year, PhD students discuss their research, progress and plans to a committee of three staff members. The dropout rate of PhD students is small and most finish their PhD in four years. These are signs of a healthy and stimulating research atmosphere for graduate students.

While the Department has experienced significant growth during the evaluation phase, during the last few years there have been fewer hires and the growth of the Department has slowed. The flat organisational structure and open research and hiring strategy have served the Department very well during the growth phase, but the panel does feel that the Department should critically assess its position and strategic options for the future now there is a need to consolidate.

It appears indeed likely to the panel that the Department is pivoting right now from the growth phase to a phase of maturing and consolidation. If so, the risks of the present strategy are

- A loss of visibility due to lack of coherence.
- The present 'consensual' procedures may not work with many more professors, should the department continue to grow.

- Loss of attractiveness for new excellent staff, PHD and MSc students and participation international programmes (increasingly depending on (critical) mass, visible programmes, synergetic research groups, available research support, etc.).
- Fewer opportunities for support for large coherent programmes and to be involved in European research consortia aimed at thematic programmes.

An additional strategic issue for the Department, as well as the faculty and the university as a whole, cis whether to start a chemistry department. From the perspective of the Physics and Materials Science research developed in the Department, the existence of such a Department makes perfect sense and would be highly beneficial. Collaboration with a Chemistry Department would greatly enhance the facilities and access to innovative systems and studies, further accelerating the Department's research and impact. The panel strongly supports this proposal, since chemistry provides an important link with the life sciences (biochemistry), materials science and engineering. The faculty could build on the seeds provided by the Department and its hiring strategy to build up an excellent chemistry Department which is well connected to other Departments and interdisciplinary centres of the UL.

Finally, the fact that the Department is split over two campuses which are quite far apart has a strong negative effect on the research itself and on the staff and students. Moving the Department and faculty to a single location in Belval of is of utmost importance and should not be postponed any longer.

3 Quality of Research

The Department of Physics and Material Science of the University of Luxembourg is relatively young, compared with physics departments at other Universities, with a successful trajectory and strategy that has led it to gain a prominent position in highly relevant areas of physics and materials science, both nationally and internationally. It maintains a high relative citation index and strong scientific output. The presence of highly cited researchers (including the most-cited researcher in Luxembourg, listed by Clarivate among the most highly cited researchers in the world), along with other signs of international recognition such as APS and Optica Fellowships, editorships of relevant journals, and more, highlights the Department's global impact. Its ability to attract international faculty (a very high number of applications for positions from renowned institutions) both shows as well as reinforces its strong international reputation. The articles selected in the self-assessment report are the result of high-quality research and have been published in the most prestigious journals, demonstrating notable impact, as reflected in the number of citations they have received. The average Field Weighted Citation Index of their articles is around twice the world average. They have made significant contributions to key research areas, with publications that reflect a well-balanced representation across the different topics and groups within the Department.

Excellence is further emphasised by the strong internationalisation of research activities. The publications in the self-assessment report reflect collaborations with renowned institutions, underscoring the global interest and impact of the research. Moreover, the lead author in each of these publications is affiliated with the Department, highlighting the expertise and reputation of the Principal Investigators. Last, the synergy among different research groups is clear, with members from various clusters/groups contributing to the selected publications, thereby enhancing the overall quality and impact of the research.

The panel considers that collaboration is a defining strength of the Department. It engages in interdisciplinary research initiatives with potential impact in health, digital transition, and

sustainable development. This is evidenced by the involvement in ERC-funded projects across multiple panels, as well as strategic partnerships with institutions such as LIST. Researchers are also actively collaborating with industry partners, such as Google, Janssen Pharma and First Solar, reinforcing the societal relevance of its research. This underscores its commitment to fostering cross-disciplinary knowledge exchange. The outstanding ability of the PI's to secure external funding in prestigious programmes (see below) also demonstrates external recognition for the quality of their research.

While the Department excels in many areas, there are opportunities for further growth. In addition to potential synergies with a (possible) future chemistry department, the panel considers that expanding international collaborations, particularly through Horizon Europe programmes, could also further enhance global engagement and drive strategic development in collaborative projects.

Overall, the Department of Physics and Materials Science has a highly successful research strategy, maintaining an internationally competitive edge. It excels in securing funding, publishing high-impact research, and fostering interdisciplinary collaborations. The Department is an international player, with (larger) pockets of research that are of global excellence in terms of originality, significance and rigour.

4 Resources

4.1 Financial resources and infrastructure

The Department has demonstrated an outstanding ability to secure external funding, amassing approximately €45m during the evaluation period, surpassing the total state funding. It has secured nine ERC grants, an EIC Pathfinder Open grant, and some Horizon Europe grants. In national funding, with FNR, the Department has been successful in ATTRACT and PEARL grants (to attract excellent researchers) and has secured many DTU projects, for large PhD programmes, with the consequent impact on the training of PhDs. For the future success of the Department, access to these FNR programmes clearly remains crucial.

While the staff already has a very good track record in acquiring individual European grants from the ERC, the panel is convinced that there are also good future opportunities to attract more funding from Europe by participating in larger framework programmes (Horizon Europe); so far participation in these appears limited to the PV/Energy cluster. In addition, collaborative programmes with industry, supported by the FNR, could be tapped more.

The panel is impressed by the quality of the available research infrastructure. The Department has consistently invested in state-of-the-art scientific instrumentation. This long-term strategic commitment not only strengthens the Department's research capabilities but also enhances its positioning within the European scientific landscape and fosters collaborations at both national and international levels. The fact that there is a base budget at the Department which can be used for investments in infrastructure – even though the budget has effectively shrunk due to inflation – and that there are bonusses when staff members have acquired external funding, is a key element of the possibility to maintain top-notch research infrastructure (experimental equipment). Also, the fact that equipment is shared and that decisions about large investments are taken collegially, while one group is required to take responsibility for the equipment, is the other key element of this success.

However, concerns have been raised regarding the long-term maintenance of these instruments due to the temporary contracts for technical staff and/or PhDs that run the

equipment. A more structured HR and financial strategy for equipment maintenance would ensure sustainable research operations. Plans for centralising support facilities and budgets run the risk that decisions about allocating support and budgets are taken without involving the researchers themselves. This should be avoided.

4.2 Human resources, careers, and related policies

The Department has grown significantly during the evaluation period, and in doing so has been very successful in attracting excellent scientists to join the Department. It has done so via a deliberate strategy of throwing the net wide, i.e. by hiring the best scientist that would fit irrespective of his or her particular research topic. Moreover, potential candidates are invited several times to the Department, first for a talk and then later for further discussions and for exploring mutual interests. This has allowed the staff to assess whether the candidate will fit and strengthen the open and collaborative atmosphere. This open hiring strategy, which goes hand in hand with a collegial atmosphere that naturally stimulates mutual collaboration, has served the Department extremely well during the growth phase.

Concerning human resource development of the staff, the opportunities for internal promotions seem to be limited by the restriction of the university on the number of such promotions. Since the number of promotions is quite small, this limits human resource development in some cases. In addition, even though financial means are often available, the restriction on the number of permanent positions for support staff is sometimes negatively impacting continuity of projects, such as the successful Scienteens outreach programme.

5 Contribution to teaching

The Department of Physics and Materials Science is actively involved in teaching at the Bachelor's, Master's as well as at PhD levels with a significant number of students in its doctoral programme. The PhD programme has a strong international character, promoting a diverse and inclusive learning environment.

Education at BSc and MSc is primarily done to provide opportunities to Luxembourgish young people to study physics, and to be able to pick the best of them for PhD positions later on. Students receive solid training that equips them for the international job market, opening a broad range of career opportunities.

The number of students, both at the bachelor's and in master's level, is however low and that reduces the opportunities to hire good local students, which Is further aggravated by the competition from other jobs for these students; for instance teaching positions at secondary schools were pointed out to be very advantageous for the students in terms of salaries. In addition, the drop-out rate at the bachelor level is quite high. The master's programme does not appear to be very distinctive and appealing at the international level.

Despite the low number of master's students, the number of PhD students is quite high, funded by the FNR supported DTU programmes. These students contribute strongly to the research in the Department.

Teaching loads for staff were considered to be well adapted to research tasks. The staff provides an excellent research environment which has a positive impact on student training, particularly for PhD students. High-level research activities, together with seminars and academic discussions, contribute significantly to their development.

Reviews from the PhD students showed a good integration within the Department. They explained how they are supported during their research and seem to be happy with the format. PhD supervision is taken seriously by the members of the Department. The PhD dropout rate is low. The PhD candidates can also benefit from guidance from their supervisor to find a job in the private sector or in academia at the end of their PhD.

An important issue, hampering the research by the PhDs, is the twin locations of the faculty (Limpertsberg and Belval), which is unpractical and hampers internal cooperation. Further, the Belval site has all the typical university facilities that improve student life (sports equipment, an active student life, etc.) so students who work mostly at Limpertsberg miss out on most of this.

Finally, the PhD thesis has to be handed in within 4 years, conditional on the publication of a first author article and another as secondary author. The panel applauds the efforts of the university to ensure that PhDs finish their PhDs within the set time period. The university has a strict policy, where it is only possible to extend the contract and study period beyond the 4-year limit due to major (e.g., health-related) issues. But there should be good support and progress monitoring and sufficient room for extensions of situations beyond the PhD control.

6 Contribution to the third mission

The Department is actively engaged in knowledge and technology transfer activities with very good outreach efforts targeting the society and industries. Especially commendable is the Scienteens programme where the Department engages with high school students, teachers and general public, educating them about different topics of physics, sustainability and interesting aspects of research and roles of researchers. The members of the Department have organised a Physics Olympiad for high school students of Luxembourg, and number of TEDx events/talks. Educated and trained students from the Department are contributing to Luxembourg as e.g., industry employees or teachers.

The Department also collaborates with other research institutions, government, and private agencies of Luxembourg to address the challenging topics of societal and industrial relevance. It has worked with ministries on projects such as "Luxembourg in transition" and "RISIK 2050". Through innovative research and training programmes the Department has been contributing to the digital and sustainable transformational developments of Luxembourg. However, there is scope for further involvement of Department's expertise in government policy fora.

Members of the Department have several international collaborations and they frequently organise conferences, workshops, summer schools. Overall, the panel is impressed with the outreach activities of the Department but have also realised the challenges of continuity of the outreach activities, especially Scienteens, due to lack of long term or permanent supporting staff for maintaining outside university links.

The panel encourages the Department to continue with their outreach programmes of societal and industrial relevance and recommends employment of a specifically devoted permanent staff for liaising the outreach activities in sustainable manner.

The panel is impressed with enthusiastic efforts of the Department members to explore the commercial potential of their innovative research as indicated by number of patent applications and various national and European projects. Good examples of cooperation with industry and setting up startups, where quite fundamental physics research has industry impact. A faculty participated in co-foundation of Heidelberg based startup company Quastify GmbH, utilising quantum physics-based artificial intelligence (AI) concepts for faster and cost-effective

discovery of novel materials for some specific applications. The company was founded outside Luxembourg because of lack of support by UL.

The recently founded startup company in Luxembourg, TRACE CRYSTAL is a good example, resulting from a long-term interdisciplinary research collaboration of the Department and the Interdisciplinary Centre for Security, Reliability and Trust (SnT). It has developed a technology for secure authentication of physical objects based on unique and unclonable artificial fingerprints. Authentication of pharmaceuticals and precious art objects are some of the examples of market potential. The TRACE CRYSTAL Company is trying pilot projects to develop customer relationships but facing some challenges in dealings with University's Partnership, Knowledge and Technology Transfer Office (PakTTO). It was mentioned to the panel that the staff members of PakTTO do not have adequate time or experience to provide the needed guidance on several important aspects of commercialisation of innovative research results: Mismatch of strategies on use of IP for startup creation or quick monetisation by licensing to established companies, the long time taken for decision making and lack of seed funding and other resources are some of the obstacles encountered by the Department. Since there is no organisational coordinator at Departmental or Faculty level on technology transfer and spinoffs, opportunities for more economic impact by the department are missed. This should be addressed urgently.

There are some other good examples of projects with potential for commercialisation, e.g., an innovative technology for production of biogenic, tuneable multi-purpose microparticles which can potentially substitute microplastics in a range of products such as, soaps, cosmetics, paints, and tyres. Another example is a collaborative project for achieving visually pleasing coloured patterns on solar cells with the use of polymerised cholesteric liquid crystals for structural colour generation.

The economic and societal impact of the department is considered good. Research of the department is relevant for the economy/society and has potential for economic or social impact. The department's interactions with the private sector and the public is at a level that can be expected for academic institutions.

7 Overall assessment and recommendations

The Department of Physics and Materials Science is a very strong department, with many research lines which are at international top level, and in some cases even world leading. Moreover, the Department has a good societal impact, and is well positioned to continue to acquire funding from the FNR and the EU.

In the panel's view, the Department is pivoting from the initial buildup and growth phase to a phase of maturing and consolidation. The Department is advised to explore the implications of this for its future strategy. We could imagine that it pays to take advantage more of the clusters in positioning and organising the Department and in hiring and making its MSc programme internationally more distinctive and attractive. Moreover, professionalisation is needed in supporting knowledge valorisation (startups, collaboration with industry) and outreach.

Specific recommendations for the Department are:

1. Maintain the high ambitions on scientific excellence and the collaborative spirit.
2. Decide on future options (balance between growth and consolidation).

3. Align the five clusters with the strategy with three pillars (consider whether the cluster of Statistical Physics & Machine learning is optimal, as it is more defined in terms of the tools used than in terms of physics topics and focus of the department.
4. Strengthen the promotional and maybe also the organising role of the clusters.
5. Increase participation in consortium programmes of Horizon Europe.
6. Organise (internal) support for knowledge transfer.
7. Analyse costs/benefits/alternatives of undergraduate programmes.
8. Explore strategic cooperation with other universities for teaching and research, also to make the master's programme more attractive internationally.
9. Improve the gender balance, develop an approach to recruit more women.

Specific recommendations for the university are:

10. The split of Department over two campuses is detrimental for further development of the Department, and for its staff and its students; it is a disincentive for collaborations within the Department and university, and with the Interdisciplinary Centres, and it is demotivating to students. The university should locate the whole Department in Belval *as soon as possible!*
11. Strengthen the technology transfer support close to the faculties to realise the commercialisation potential of the innovative research conducted by the Department.
12. Develop a dual career programme to help Departments attract excellent female professors.
13. Create more possibilities for internal promotions, within strict criteria of excellence.
14. Create a chemistry department: it will strengthen the link with the overall university strategy and the link with life sciences. By all means use the Department of Physics and Material Science as an example of how to build up a vibrant and excellent new Department, but do not integrate Chemistry in it.

Finally, there is a widespread feeling at the Department of not being heard or consulted by the higher levels at the University. This may reflect the fact that communication lines were short and informal during the start-up phase of the university, while the growth and professionalisation of the university implies that the lines of communication and command are changing. Improving this requires attention at all three levels, and clarification of roles in communication and improvement of communication channels.

15. Improve the lines of communication between the different levels of the university organisation and make sure that decisions are taken at the appropriate level.

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