Expert report, panel 9

KTH's Research Assessment Exercise (RAE) 2021

Panel chair:
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Introduction

This expert panel report is part of the Research Assessment Exercise (RAE) 2021 at KTH Royal Institute of Technology. The report is based on the self-evaluation on panel 9 and aims to provide recommendations and feedback to the involved departments and KTH.

Expert panelists:

- Prof. Wolfgang Eberhardt, chair, DESY-CFEL and TU-Berlin
- Prof. Olga Botner, Uppsala University,
- Prof. Eleni Diamanti, CNRS, Sorbonne University,
- Prof. Yassin Hassan, Texas A&M University, USA.
- Prof. Martti Kauranen, Tampere University
- Prof. Stephanie Reimann, LTH, Lund University
- Dr. David Sonnek, Industrifonden, The Swedish Industrial Development Fund
- Prof. Horst Vogel, Swiss Federal Institute of Technology Lausanne (EPFL),

Panel 9

Coordinator: Prof. Bengt Lund Jensen, KTH Royal Institute of Technology
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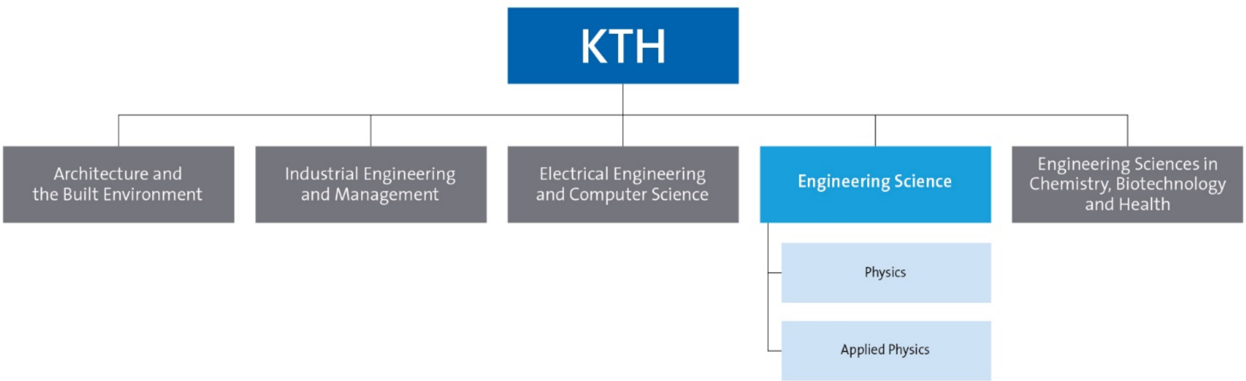

Part A: Summary of the whole panel

1. Strengths, weaknesses, and recommendations

Common to the departments within the research area covered by the panel

Strengths:

- Excellent scientific record and high international reputation. Many groups consistently publish in high impact journals.
- Participation in high class international projects – top infrastructures; partnership in experiments at the international flagship facilities in their respective field of research.
- Excellent laboratory infrastructures.
- Attractive for PhD students and potential new faculty, both nationally and internationally.
- Excellent track record of spin-off companies; several groups have founded spin-off companies, which have been bought out by major companies in their field or are successful and profitable in the market.
- SciLifeLab makes good use of synergies between different universities (Stockholm University – Karolinska Institute).

Weaknesses:

- Both departments exhibit an organically grown structure where synergies are realized by personal relationships rather than organizational structure.
- The scientific cooperation between different groups could be enhanced.
- The number of PhD students should be higher. Very often we find groups where a professor has only one or two PhD students. Well educated PhD students are the major ‘product’ of a university.
- Cost structure – overhead and rents – are a problem and essential laboratory infrastructure has to be operated and maintained by external grants without support from KTH.
- The central university administration appears to have grown too large and inflexible, as for example the ‘Research Support Office’.
- The committee had the impression that there was a large number of researchers with unclear career opportunities. A strategy for their promotion prospects in the researcher track should be developed.
- We were told that the KTH central administration has no clear policy developed with respect to spin-off activities.

2. Feedback on the formulated visions and strategies

That can lead to increased quality of research at KTH and increased impact

Due to the need to attract a very high level of external funding, the long-term strategy is largely externally determined by funding opportunities. Nevertheless, the individual groups have well-developed strategies for their own research goals and objectives. Many groups are at the forefront of their field of research internationally.

3. Ideas and recommendations for essential steps

Develop a strategy process for replacing retiring faculty and actively searching for 'young talents' to be hired at the level of assistant professor. A 'standing committee' should be established to search for and identify promising young researchers suitable for entry level faculty positions. Because of the nationwide '5-year rule', these appointments should be made early and based upon the potential of the candidates rather than waiting for and relying on well documented achievements.

Essential infrastructure (including spearhead laboratories of individual groups) should be supported by the central KTH administration to ensure continuity and renewal of the instrumentation. There should be clear guidelines and a transparent evaluation which KTH infrastructures qualify for this support. These should be reviewed periodically to determine if they are still fulfilling their role at the forefront of technology.

4. Potential links and synergies

SciLifeLab is an excellent example where synergies between different institutions are realized (KTH, SU, KI). These activities should be strengthened further. Synergies concerning teaching and education, especially at the graduate level, should be explored also with groups from SU who are located at AlbaNova.

5. Recommendations for strengthening the departments and their future potential

The departments have to rely heavily on external funds to support their research activities and laboratories. Increasing overhead and rents present a serious problem, jeopardizing many activities and essential laboratories. In order to maintain infrastructure (laboratories) they have to use a large part of their external funds to the extent that many groups are hardly able to support PhD students. Very often we find groups that only have one PhD student/professor. These groups are in danger of becoming sub-critical when essential knowledge cannot be transferred to the next generation of PhD students. This is not only noted by the review committee, but we also heard many PhD students voicing this concern. Furthermore, education of highly skilled PhD graduates is one of the major outputs of a university to industry and society. At the present level of one or two PhD students per faculty, which we found as the prevailing situation in the departments we reviewed, this is sub-optimal. Because of the severe dependency on external funds the long-term strategy of the departments is to a large extent compromised by the decisions of external funding agencies. The departments need more basic funding to reduce their dependency on external funding sources. Partially this can be achieved via:

- Substantial central support for essential infrastructures, which are used beyond the level of individual research groups (subject to a review process) (see above).

- Lowering the overhead rates for PhD student appointments – since well educated PhD students are one of the major outputs of KTH to society.

- Reducing the burden of rents for laboratories and office space for the departments.

6. Recommendations applicable to the whole of KTH

The panel noticed a considerable tension between the departments and the central administration, aggravated by the funding situation. The impression is that, while the general budget of the university has been increasing, a proportional increase in the budget of the departments has not occurred. This is accompanied by a lack of communication and discussions about strategic developments of the central administrative units.

A review of the KTH administration seems highly warranted, in order to re-establish trust, transparency, and a common vision for the strategy of KTH as a whole. This review should be conducted by an external panel, which has to include scientists/faculty from other universities or research organizations.

KTH should develop a career path for researchers, enabling distinguished permanent staff to gain some recognition for instance by directed promotion (researcher, senior researcher, staff researcher, senior staff researcher……) and salary increases. These long-term researchers are extremely important for the continuity and stability of the operation of the laboratories and internal facilities. The promotions should be exercised with care and should not turn into the development of a 'shadow faculty'. The clear career path for faculty should be via the academic positions. If a researcher advances to a high level of scientific competence (e.g., the level of 'docent'), he/she should be encouraged to apply for faculty positions at other universities. It should be made very clear that the chance of eventually obtaining a faculty position at KTH is very low.

The panel applauds the efforts to internationalize the faculty and **to increase the fraction of female faculty**. We observe, however, that success in these latter efforts requires role models within exciting research areas and this is not well served by early promotion of female faculty into administrative positions.

There seems to be no clear **strategy towards enabling and supporting spin-off activities/companies**. KTH should have a clearly defined code and set of rules for making laboratory/office space available for start-up activities. This also includes access to the use of equipment and services as well as guidelines for possible conflict of interest. Once the policy has been formulated and established, the proper documentation and the required decisions can be made at the department level, rather than obtaining permission from the president for each case individually.

Support the engagement of retired faculty with the departments. Presently KTH essentially cuts all ties with retired faculty. While retired faculty should not be involved in any management decisions, they are established scientists who can contribute greatly through their experience and networks to the success of KTH and their previous departments. Emeriti contracts can be a good tool as long as they align with the needs of the department, with decisions taken on a case-by-case basis.

Establish a scholar exchange program, supporting external visitors for extended visits to KTH and also for KTH faculty to spend time at another university, research institution or industry to foster scientific exchange.

Part B: Report for each department

Department of Physics

Major findings

1. Strengths and weaknesses of the department

Concerned and recommendations for improvement

Strengths:

- All activities are at the current forefront of their respective fields and carried out by researchers that are nationally and internationally recognized. The publication rate is high and stable, with many articles in prestigious journals with a high impact factor.

- The Medical Imaging division is very small, but with impressive achievements in terms of spin-off and patents. Considering the strong future potential, this important and presently highly successful activity should be nurtured, allowing it to grow into a less critical-size working unit.

- The Condensed Matter Theory division collaborates in a major way with individual researchers at universities around the world – and locally with SU and NORDITA. Collaboration with NORDITA enhances the scope of activities through participation in e.g., the NORDITA workshop programs.

- The Nuclear Energy and Nuclear Power Safety divisions are well connected within the SUNRISE collaboration and carrying out projects funded by the Swedish Radiation Safety Authority. They also have affiliated faculty from the nuclear industry.

- The Particle and Astroparticle Physics and Nuclear Physics divisions are engaged in experiments at major international facilities (like CERN and in the future FAIR - or at the ISS). In several cases, KTH researchers assume leading roles in these large collaborations. Notably, the PAP division is successfully pursuing development of novel instruments for international balloon-borne Xray missions.

- The department is very aware of the need to disseminate their research results beyond academia, through visibility in media, popular lectures, supervision of high-school student projects and more.

Weaknesses:

- Internal collaboration and synergy between divisions and research groups should be improved.

- The strong dependence on external funding prevents meaningful long-term strategic planning. This becomes a vicious circle, especially when the technicians and laboratories depend on opportunistic external resources – and at the same time are a prerequisite to obtain further external grants. This situation is similar for many research institutions in Sweden; directed long-term support to key laboratories should be an issue of national concern.

- A carefully planned entry level faculty recruitment strategy seems to be lacking but would be essential. The candidates with the highest potential will have found tenure track offers within 5 years of their PhD. A way forward might be to establish an active dynamic search (head-hunting) committee, continuously surveying the availability of potential applicants and, if possible, time the announcements appropriately. This could be especially interesting to help increase the number of female applicants. The recruitment strategy should be independent from externally attracted grants, which make the faculty dependent on decisions taken by the respective research councils.

- Due to dependence on external funding, the number of PhD students per faculty member is low when compared to similar groups in other countries. This, in turn, lowers the research group's competitiveness at the ERC or similar funding bodies.

- Recruiting and outreach strategies to attract Swedish students to the nuclear technology field seem insufficient. This is of importance to ensure a sustained knowledge base for future generations since the nuclear waste stored in the final repository needs to be safeguarded even if nuclear power is no longer supported in Sweden.

2. Relevant and forward-looking objectives

Are the goals relevant and forward-oriented?

The activities of **most** groups are well aligned with the most exciting research worldwide in their areas. The researchers know the state-of-art, where they stand themselves, where the field is going, and where their groups want to go in the future. Due to the leading position of the KTH groups in certain areas, key advances in these areas can be expected from KTH researchers and their collaborators.

3. International community engagement

The researchers are fully integrated into the international community in their areas. They have strong collaborative links to other leading groups worldwide and participate actively in the international community. A large fraction of the faculty and researchers has international origin.

The Particle and Astroparticle Physics division is engaged in experiments at major international facilities (like CERN- or at the ISS) or in other international projects. In several cases, KTH researchers assume leading roles in large international collaborations. The Nuclear Energy and Nuclear Power Safety divisions are well connected within the SUNRISE collaboration.

4. Future potential of the department

For a positive development towards fulfilling their goals, operating on the front line of international research, and exerting a beneficial impact on society

See 2 above.

5. Recommendations

- The Division of Condensed Matter Theory should further intensify the collaboration with SU and NORDITA, taking advantage of the planned co-location at the AlbaNova campus. Common seminars and PhD courses will be one vital element of this.

- The KTH Quantum Technology Hub (QTH), involving both the Physics and Applied Physics departments, will potentially have great impact – not only locally at KTH but also on the national as well as the international scene. It will significantly strengthen KTH's position towards national and international focus areas and funding opportunities and serve as a platform for collaboration with industry. It seems important for the QTH to not only focus on future technologies, but likewise on the fundamental aspects of quantum theory. Coordination on the national level, and also in connection with NORDITA, will be a significant benefit. NORDITA may here play an important role; the national, Nordic and international outreach through workshops and conferences is a great asset.

- Concerning nuclear technology, it is of utmost importance to at least maintain the technological know-how. Even if there were no more nuclear reactors in Sweden, the knowledge needs to be preserved for future generations since the nuclear waste stored in the final repository needs to be safeguarded. Active strategies to recruit Swedish students to the field should be developed.

- Continue and strengthen the studies for improvement of the safety and economy of the existing nuclear plants through collaboration with industry, European, and international organizations. Studies on decommissioning of facilities, radioactive waste management and disposal, and transmutation techniques for transformation of highly active trans-uranium elements to drastically reduce the amount and storage time of the nuclear waste are also recommended.

- The divisions are encouraged to continuously seek advice and collaboration with the industry, for instance through affiliated faculty.

- Periodical scientific retreats to discuss strategic issues and to foster future collaboration and the formation of more coherent research teams are encouraged.

- The use of centralized computing facilities vs. clusters in the individual research units has to be carefully balanced in order to achieve a cost- and time effective solution.

Specific issues

1. Research profile and quality

Main research activities

The department is divided into six divisions (see below), of which the latter five appear thematically connected relying on the science and methods of subatomic physics.

1. Condensed Matter Theory (CMT) – works to develop theoretical tools for discovering and understanding new materials and phenomena (e.g., superfluidity, superconductivity, disordered systems, spin ice …). Besides fundamental theoretical work, the aim is also to model complex materials and future quantum devices. Parts of the activities are very dependent on access to large scale computing facilities.

2. Nuclear Energy (NE) – explores sustainable nuclear power technologies (R&D and tests of new reactor designs and fuel; investigation of radiation damage to components, development of corrosion resistant steel with industry). The research includes risk-oriented analysis, especially regarding containment.

3. Nuclear Physics (NP) – includes on one hand experimental and theoretical research addressing fundamental nuclear phenomena – and on the other, activities relating to safeguards and security, e.g., radiation dosimetry and nuclear materials imaging.

4. Nuclear Power Safety (NPS) – addresses safety of nuclear power plants (evaluation and management of rare but catastrophic accidents; societal risk management in collaboration with chemistry and social sciences).

5. Particle and Astroparticle Physics (PAP) – encompasses design, construction, operation and data analysis of accelerator and non-accelerator-based experiments (e.g., ATLAS/CERN, Fermi

satellite, XL-Calibur), and includes particle phenomenology and studies of astrophysical phenomena.

6. Physics of Medical Imaging (PMI) – aims to devise new medical X-ray imaging techniques, from detector development to simulation and image reconstruction, and bring the devices to clinical use.

Contributions to the state-of-the-art and the body of scientific knowledge, and engagement in national and international research collaboration

All activities are at the current forefront of their respective fields and carried out by researchers that are nationally and internationally recognized. The publication rate is high and stable, with many articles in prestigious journals with a high impact factor.

The scientific contributions of the **Condensed Matter Theory (CMT) division** to the state of the art of the research field are of outstanding quality, impact and quantity. There is great and internationally leading competence in the fields of superconductivity and magnetism, superfluidity, topological quantum matter, and not the least, in front-line research in mathematical physics, from Luttinger liquids to the physics of many-body localization and thermalization, to mention some examples. The theoretical research performed is cutting-edge in the international comparison, documented for example by a long list of outstanding publications in leading physics journals, but also by prestigious research prizes and large grants. CMT collaborates in a major way with individual researchers at universities around the world (e.g., UK, Russia, USA, Japan, Scandinavia, Israel) – and locally within KTH, SU and NORDITA.

The CMT division presently runs its own computational cluster with about 500 local CPU cores. The maintenance and future update of such a local cluster is of vital importance for staying front-line with research activities as it enables quick access to computational power and flexibility. The combination with national and international grid structures is of course essential, but it cannot replace the direct and rapid access that the local cluster guarantees.

A significant fraction of the research in **subatomic physics (PAP and NP)** is discovery driven and concerns fundamental properties of matter and the universe. It is conducted at major international facilities (like CERN and in the future FAIR - or at the ISS), within large international research collaborations and on very long timescales. In several cases, KTH researchers assume leading roles in these large collaborations. Notably, the division is successfully pursuing development of novel instruments for international balloon-borne X-ray missions.

The publication record of the PAP division is dominated by the publications of the ATLAS collaboration (~ 100/a), an experiment where PAP members have initiated construction of a novel detector for HL-LHC boasting silicon sensors with high time resolution, to be deployed in 2025-2027. The experimental activities are complemented by theory. The theorists within NP and PAP engage in interpretation of experimental data and provide input for the design of new detector facilities. They collaborate with individual researchers at universities world-wide and are involved in several European networks. Applied nuclear physics is an area that has steadily been gaining ground since 2017, and this is reflected in the publication record of the NP division.

The existence of local facilities and labs is essential for the development of instrumentation for the large international projects but has also been crucial for inhouse development of, e.g., the successful balloon-borne X-ray polarisation instruments for PoGo+ and XL-Calibur. It is also key for development of instruments for applications within medical imaging, nuclear safeguards, radiation detection and dosimetry.

The Nuclear Energy (NE) and **Nuclear Power Safety (NPS)** divisions are performing broad research to improve existing nuclear plants and to develop new advanced nuclear power technologies. There are internal and external collaborations demonstrated through several projects and the development of large-scale programs, e.g., the sustainable nuclear energy research (SUNRISE) centre. The centre is coordinated by NE with participants from Uppsala University and Luleå University of Technology. The NE and NPS research activities are multidisciplinary and combine various scientific disciplines and approaches to reactor physics, nuclear materials, risk and safety analysis, thermal hydraulics, etc. The NPS has about 20 active research projects with funding from the Swedish Radiation Safety Authority (Strålskyddsmyndigheten, SSM), industry and EU. Both divisions have major facilities and equipment aiding in attracting external funding in the future. Currently, the societal interest in nuclear energy and nuclear safety is large. The nuclear security and safeguards are emerging areas of research and technology, and the divisions are looking for faculty renewal to support research and education. NE collaborates nationally (with, e.g., Chalmers and the universities in Uppsala, Luleå and Linköping) and internationally (e.g., France, Switzerland, Finland), and also participates in an impressive number of EU projects where, unfortunately, NEs role is unclear. One of the challenges is the retention of technical expertise.

The output from **Medical Imaging (PMI)** in terms of patents and devices is impressive, particularly considering the fact that the division is presently very small. Fruitful and longstanding research collaboration on clinical aspects exists with Karolinska Institute (KI), and with Linköping University on r/o electronics for the novel X-ray detectors. Collaboration also exists with the radiology departments at Stanford, Cambridge and Radboud.

c. Follow-up from previous evaluations

Since RAE2012, the Department of Physics was restructured, which resulted in a number of positive aspects and improved synergies.

- The merging with theoretical physics led to strengthening the work on quantum matter within the CMT division.
- The NE division, formed through the merge of Reactor Physics and Reactor Technology, has become a member of the KTH Energy Platform with the goal to improve interaction with external partners within the energy community.
- Exchange with the energy industry through affiliated faculty has been achieved, although on a minor scale.
- The NP division has expanded the nuclear safeguards and security team with two additional senior staff members, and a larger number of PhD students and postdocs.
- The MI division has been able to secure external funding to recruit an assistant professor.

2. Viability and research environment

Internal and external funding; current status and strategies for the future

The total turnover of the department is ~130 MSEK with 80% related to research. About 65% of the research-related turnover is resulting from external grants (60%) or contracts (5%). The ratio between external/internal funding varies considerably between divisions. Nuclear Energy has a ratio of 80/20 (external/internal funding), while Nuclear Physics is lowest on this scale with a ratio of 40/60. According to the department management this large spread presents a considerable challenge.

Substantial external grants allow hiring large numbers of research staff in non-faculty positions, staff that in principle cannot be kept when the external money disappears. This issue is not unique to KTH but was emphasized by the interviewed group of researchers as a major problem, making long-term career planning difficult. The problem might be alleviated somewhat by locally creating a career ladder and establishing criteria for promotion from “researcher” to “senior researcher” or “staff scientist”. The strong dependence on external funding prevents meaningful long-term strategic planning, which can be especially aggravating when the timeline of projects at international facilities like CERN or FAIR runs over decades. Difficulties with obtaining co-funding when applying for project grants for work at these facilities were emphasized by fundamental science groups.

Academic culture

The working environment is international, with internationally recruited faculty and students, high profile colloquia, journal clubs and facilities for spontaneous meetings at division level. It is, however, unclear to which extent the students attend colloquia or are involved in the journal clubs. The proximity to NORDITA with its regular sequence of month-long international workshops and schools is a great asset. It gives a strong regional advantage, with important and visible international impact. NORDITA has in recent years increased its local significance in comparison with interactions within the Nordic research landscape. Thus, the tightening of bonds between KTH, SU and NORDITA, and the alignment of the NORDITA workshop programs with the local research environment, seems logical. KTH can here play an important continued role to proactively foster and expand such collaboration.

Current faculty situation and composition of the research team(s)

In terms of personnel, the department is dominated by subatomic physics with focus on basic and applied nuclear physics. The fraction of females in faculty positions is low. In physics and, in particular, theoretical physics, such gender imbalance is rather the rule than the exception. The increasing number of females among the temporary staff is, however, promising and could indicate a positive trend for the future. The lack of assistant professors is noteworthy. The department should actively strive towards the appointment of female junior faculty, giving them a chance to serve as role models for a successful career in research, while abstaining from burdening them with administrative service too early.

It is also worthwhile noticing that a fair number of emeriti seem interested in contributing to the research, although their status at KTH is unclear. Specific agreements with emeriti regarding workspace and their access to the premises may here be in place, and help to foster an inclusive yet dynamical work environment.

Due to the scarcity of regular university jobs, the opportunistic researcher positions are perceived by many young scientists as an alternative first step in a university career, while in fact in most cases they do not and should not lead to faculty positions. This is a known problem across Swedish academia. On the other hand, a career development path for researchers should be defined (see general recommendations). A more restrictive local policy for the submission of grant proposals from local researchers without a clear and strategic career perspective may help to shape and strengthen strategy and profile of the department as a whole.

Recruitment strategies

During the past decade, in total, five assistant professors were hired. This is a rather low rate of renewal. Imminent retirements within the department allow new academic hires. The new positions that are envisaged will be within the already existing areas. This was presented as a strategic choice, but it seems unclear if a long-term strategy indeed exists. While there is an awareness of the low numbers of females among faculty and researchers, the strategy to improve the balance by leading through example is lacking. In general, a carefully planned recruitment strategy that identifies future potential and takes more explicit measures to attract new young talent, would be essential.

Open rank recruitment might be a way to improve the situation. A head-hunting committee, continuously surveying the availability of potential highly-promising applicants and, if possible, appropriate timing of the announcements could be very effective.

Slowness of the centrally KTH-managed recruitment process is a stumbling stone on the path to successful recruitment strategies. The efficiency of this procedure requires substantial improvement if KTH wants to remain competitive in hiring top scientific talents as professors.

e. Infrastructure and facilities

In general terms, the research environment has excellent potential, including science clusters with overlapping interest close by, at SU/AlbaNova and NORDITA. Subatomic physics, NE and MI need sufficient lab space and technical support to develop, construct and test specialized detectors, some of which are deployed at international facilities.

In the current situation where lab space, equipment and technicians have to be externally paid, retention of know-how and maintenance of equipment are concerns. Another concern is the increase of expenditure for design and construction work in the in-house mechanical workshop (at least partly due to major increases in rent), as well as the lack of an electronics workshop for development of advanced instrumentation.

3. Strategies and organisation

The main units are research groups headed by a professor. There is an established communication scheme with regular meetings at the department level.

Strategies for achieving high quality research output

Prerequisites for achieving high-quality research output are in place and working well, as the scientific output and international standing of the groups shows. However, because of the overwhelming dependency on external funding, the strategy of the research units is largely compromised by the need to pursue external funding opportunities.

Also, with regard to education, the strategies for success are well worked out, including councils for basic education, graduate education and outreach, periodic educational colloquia and workshops. Surprisingly, scientific retreats were not highlighted as a strategic instrument.

4. Interaction between research and teaching

In general, there is an efficient and up-to-date exchange between research and education. All faculty contribute actively to teaching, and so do most PhD students. It is unclear if the students are required to take pedagogical courses. Much effort goes into making science exciting to BSc students, e.g., popular lectures, student research projects, KTH makerspace.

The slate of courses offered to PhD students is increased through collaboration with similar fields at Stockholm University and NORDITA.

5. Impact and engagement in society

The department's activities contribute to society at large:

- Producing well trained graduates is the major contribution of any university to society. KTH graduates are very well received. They readily get jobs within academia (internationally), but also in industry, in governmental institutions and within policy making.
- Currently, nuclear technology is a focus of attention for policy makers and media and supported by the Swedish Foundation for Strategic Research (Stiftelsen för Strategisk Forskning, SSF).
- Nuclear Physics – dosimetry teams collaborate with Swedish Radiation Safety Authority (Strålskyddsmyndigheten, SSM) and the Skandion Clinic in Uppsala. Modelling for hadron therapy is an essential contribution for combatting cancer.
- The novel CT scanner technology based on highly sensitive x-ray detectors invented at KTH and now marketed by GE Healthcare is installed at the Karolinska Hospital. X-ray imaging systems previously invented in the group were installed at more than 1000 hospitals worldwide.

The department is very aware of the need to disseminate research results beyond academia, a statement supported not only by the large number of patents and spinoffs but also through visibility in media, popular lectures, supervision of high-school student projects etc.

Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

All activities can be mapped onto SDGs:

- Nuclear energy (sustainable power, incl. coupling nuclear power with CO2 negative technologies) -> SDG7 (Affordable and clean energy), SDG9 (Industry, innovation, infrastructure) and SDG13 (Climate)
- Medical technology -> SDG3 (Good health)
- Basic science (education and training in scientific thinking) -> SDG4 (Quality education)

6. Recommendations for strengthening the department and its future potential

During the interview week, we learned about the planned move-together of the premises of the CMT division with related divisions or research groups at Stockholm University, as well as with NORDITA. There is an existing strong collaboration between members of these different units already to date. Common premises and shared facilities, such as common coffee- and seminar rooms, will be a great asset for the future enhancement of synergy. Common seminars and PhD courses will be a natural element to further foster this growing collaboration.

Concerning nuclear technology, it is of utmost importance to at least maintain the technological know-how. Even if there may not be nuclear reactors in the future in Sweden, the knowledge needs to be preserved for future generations, not the least because the nuclear waste stored in the final repository needs to be safeguarded. One research area missing at the moment concerns the transmutation of highly active trans-uranium elements into less dangerous fission products. This offers the potential to drastically reduce the storage time of the highly active nuclear waste to periods of several hundred instead of thousands of years.

It is encouraged to establish an official scholar exchange program for faculty and to continue to seek advice and support from the industry affiliated faculty.

7. Final remarks

We obtained all the additionally requested information and want to thank our KTH colleagues for collecting and providing these data in a timely and professional manner.

In future evaluations, much labour and working time can be saved on both sides by providing the necessary information in an easy-to-read summary of the key facts, issues, and statistics, rather than a lengthy self-repeating document, where essential information is missing.

KTH has many outstanding achievements, these could be shared via the internet pages in a timelier fashion.

The panel report template contains many redundant sections---therefore we decided not to adhere too strictly to this extremely detailed template.

Department of Applied Physics

The Department of Applied Physics (AP) consist of seven divisions and about 40 research groups, with a total staff of about 230 people. The activities cover several important areas of contemporary physics, with particular emphasis on biological physics and imaging, optical physics and photonics, nanoscience and -technology, as well as quantum physics. This “bio-opto-nano” concept of the department highlights the fact that these areas have significant overlap and support each other.

Major findings

1. Strengths and weaknesses of the department

The main **strengths** of AP are as follows:

- Very high quality of research, on par with other leading activities worldwide.
- Very high societal impact through excellent spin-off activities.
- International composition of faculty and staff.
- Excellent links to other leading groups worldwide.
- Talented and highly motivated students and postdoctoral researchers.
- World-class experimental infrastructure and/or access to such infrastructure in most areas---- but largely based on funding provided by external grants.

The main **weakness** of AP is the fact the activities rely too heavily on external funding. This has the following consequences:

- Low number of PhD students and postdocs, making some groups subcritical in size.
- Challenges in maintaining essential experimental infrastructure, especially that of individual groups. The researchers which are essential to maintain and develop the laboratory infrastructure have no well-defined career path.
- Collaboration within department and KTH appears sporadic.
- Apparent lack of long-term strategic vision for the development of AP because of the large dependency on external funding.
- Lack of transparency and deficiencies in the flow of information between the central KTH administration and the department leads to issues with regard to decision-making.

2. Relevant and forward-looking objectives

The activities of AP groups are well aligned with the most exciting research worldwide in their areas. The researchers know the state-of-art, where they stand themselves, and where the field is going, and where their groups want to go in the future. Due to the leading position of the KTH groups in certain areas, key advances in these areas can be expected from KTH researchers and their collaborators.

3. International community engagement

The AP researchers are fully integrated into the international community in their areas. They have strong collaborative links to other leading groups worldwide and participate actively in the international networks through conference organization and editorial duties. A large fraction of the faculty and researchers has international origin.

Several groups are actively engaged in developing beamlines at the Max IV facility in Lund or are conducting or developing experiments at forefront synchrotron and FEL facilities, and one group plans to be active at the ESS. This group also performs experiments at the M-SR facility at PSI Switzerland. Since access to these forefront facilities is granted by a very competitive international review, this is another indicator of the high quality of the science performed by these groups.

4. Future potential of the department

See 2 above.

5. Recommendations

- Reconsider organization of AP into fewer divisions to take better advantage of the synergy between its research groups.
- Form a joint strategy on the AP level for the development of the whole department based on its strengths. Use this as basis for replacements of retiring faculty.
- Extend the strategy work to various topical research areas, e.g., following the “bio-opto-nano” concept of the department.
- Clarify the role of the KTH LaserLab as a central facility.
- KTH needs to develop a funding scheme to much better support its experimental infrastructure on various levels.
- Establish the KTH Quantum Technology Hub.
- Support a scholar exchange program to foster scientific exchange between KTH and other leading scientific institutions and/or industry.

Specific issues

1. Research profile and quality

Central research questions and themes, and main research activities

The “bio-opto-nano” concept of AP describes the research profile of the department quite well, except possibly for quantum physics and technology, which will become more and more important in the coming years. It is important to note that these areas are not separate but have strong overlap, thereby supporting each other. In fact, the activities of many groups are related to several of these topics.

The **Biophysics activities** which are spread across several divisions, are a showcase of successful integration of interdisciplinary research fostering quantitative biology. The groups working in this field are highly competitive at the international level concentrating on two pillars: (i) optical imaging of cellular biochemical networks, and (ii) modelling central cellular signalling processes. In this context, the units have developed methods for single-cell analysis using optical imaging techniques, which are of importance for biomedical applications and are already widely used in the Stockholm life-science community and beyond.

The super-resolution microscopy development is on the absolute international forefront as reflected by high-impact publications. These activities also attract significant funding. In addition, the theoretical biophysics activities have yielded important novel developments for the GROMACS software tool, which is one of the world’s widest used software packages for modelling protein structures and dynamics. Another highlight of the theoretical biophysics group is their contribution to the elucidation of 3D structures of biopolymers by improving the software RELION which is used world-wide to analyse single-particle images obtained by cryo-electron microscopy, which during the last decade resulted in a revolution of structural biology. In this area, KTH biophysicists very closely and successfully collaborate with colleagues at KI who are responsible for the cryo-EM infrastructure.

The competence in optics and image analysis is also exploited within the area of visual optics in collaboration with optometrists and ophthalmologists. A direct application of this work is the development of optical designs of spectacles, contact lenses, and intraocular lenses that can improve peripheral vision.

In summary, the biophysics activities at KTH have established supreme imaging techniques with applications in life sciences. This is reflected in a strong, very active research network between groups at KTH, KI an SU working in life sciences. Many Biophysics activities are located at the Solna campus. The interdisciplinary ‘Science for Life Laboratory’, supported by KTH, SU and KI, harbours state of the art bioanalytical and optical microscopy facilities and is responsible for running the national Advanced Light Microscopy (ALM) facility.

The **Photonics activities** consist of about fifteen research groups organized into three divisions. They represent several subfields of optics and photonics, with links to, e.g., biosciences, imaging, sensing, nanoscience, and quantum technology.

In addition, many groups that identify themselves as being part of biophysics, rely on photonic technologies and/or develop such technologies for applications in biosciences. A large fraction of the photonics activities is related to new materials for photonics. Ferroelectric and semiconductor materials for nonlinear frequency conversion are an important area, with applications in laser physics and generation of correlated photons for quantum optics. This work has also been extended to compression of femtosecond pulses and supercontinuum generation. The activities on semiconductors are extensive, including nanostructures, wide-bandgap materials, and quantum dots. Semiconductor light sources include LEDs, laser diodes, quantumcascade lasers, and single-photon emitters. This is complemented by the work on multifunctional optical fibers. The topics have wide-reaching applications in, e.g., integrated optics, optical communications, solar energy, and gas sensing. The sensitivity of many of these techniques can likely be enhanced by the work on superconducting single-photon detectors. Other important areas are various forms of super-resolution microscopy, fluorescence spectroscopy and imaging, with obvious links to biomolecular and cellular studies and the ALM Facility.

Overall, the photonics research at KTH is on a very high level. The activities are very close to the worldwide top in their areas, and in some cases the KTH groups are among the few leading groups globally. In addition, they have excellent connections to other leading groups worldwide.

The activities on **materials physics and nanophysics** are closely related, thereby forming the “nano” leg of the “bio-opto-nano” concept of AP. These activities are represented by about ten research groups organized into two divisions. Again, the work here has links to, e.g., bioscience and quantum physics.

The work in the nano-area includes leading-edge research on various forms of nanoscale imaging. KTH researchers have been actively involved with the development the MAX IV synchrotron in Lund, opening new opportunities for X-ray nano-imaging. In parallel they pioneered the development of laboratory soft X-ray sources for microscopy and imaging applications, which led to a very successful spinoff company. This work identified a viable path for laboratory-based X-ray fluorescence imaging to produce molecular and functional 3D imaging in bio, with 10x better resolution than other present methods.

Other work on imaging is related to new modes of atomic-force microscopy, including quantum-limited mode, and ultrafast electron microscopy. The development of new nanomaterials focuses on, e.g., photocatalysis and water cleaning, new types of fluorescent markers for bioimaging, as well as low-dimensional materials. The activities on magnetism include the development of spintronic devices and new computational methods to understand nano-magnetism. The activities on materials characterization address questions related to new types of superconductors and surface phenomena.

The KTH activities on materials physics and nanophysics are also on a very high level. The groups working in this area are highly competitive in the international context and well connected to other worldwide leaders in their areas.

Quality and quantity of contributions to the body of scientific knowledge, engagement in national and international research collaboration within academia and its outcomes

The overall quality of research in AP is on a very high international level. The activities are very close to the worldwide top in their areas, and in some cases the KTH groups are among a handful of worldwide leaders. In addition, the researchers have excellent connections to other leading groups worldwide. The quality of the work is reflected by the fact that its results are typically published in the leading journals of the topical area and regularly also in high-impact journals of more general interest.

Follow-up from previous evaluations

Previously the AP groups were located partially at the Kista campus. Expanding AlbaNova and relocating all the groups there is certainly very beneficial for the scientific interaction. This move should be completed including the relocation of the central Electrum infrastructure to AlbaNova.

2. Viability and research environment

Internal and external funding; current status and strategies for the future

The total annual AP research funding is about 250 MSEK, out which 65% comes from external sources. This covers about 90% of AP activities, with the remaining 10% being undergraduate teaching. The external funding via successful grant applications is increasing by 5-10% per year. Despite this positive trend, a main concern is that even permanent faculty relies too heavily on external funding.

The funding situation and size of the AP research groups shows significant variation. In general, the situation seems to be better for the groups that have close links to biosciences, whereas some of the groups working in other areas feel that their size is subcritical due to funding constraints. We emphasize that this variation appears to be due to changing trends in the policies of funding agencies rather than related to the quality of performed research.

Current faculty situation and composition of the research team(s)

In terms of 'head count', this is a very large department. The fraction of females in faculty positions is low. In physics, such gender imbalance is rather the rule than the exception. The department should actively strive towards the appointment of female junior faculty, giving them a chance to serve as role models for a successful career in research, while abstaining from burdening them with administrative service too early.

The number of PhD students in several groups is too low, making these groups subcritical in size. This situation is considerably improved in the groups involved in the SciLifeLab activities.

Due to the scarcity of regular university jobs, the opportunistic researcher positions are perceived by many young scientists as an alternative first step in a university career, while in fact in most cases they do not and should not lead to faculty positions. This is a known problem across Swedish academia. On the other hand, a career development path for researchers should be defined (see general recommendations). A more restrictive local policy for the submission of grant proposals from local researchers without a clear and strategic career perspective may help to shape and strengthen strategy and profile of the department as a whole.

Academic culture

The academic interaction appears to mainly occur on the level of individual research groups or divisions. In addition, Biophysics organize monthly joint mini-symposia for all the groups, including those from the Stockholm University and Karolinska Institute. The AP also organizes AlbaNova seminars, which are well attended.

The researchers from AP participate in organizing international conferences, as expected. The PhD students are encouraged to attend and present their work in such meetings.

Recruitment strategies

The AP department had in recent years difficulties to hire new assistant professors. The panel revealed two major reasons for this situation and provides suggestions for improvement: (1) It seems, that the search committees apply too high expectations for the scientific standing of candidates for the assistant professor level. Instead of extending the 5-year window between PhD and application for an assistant professorship, a wish frequently forwarded by AP faculty, this panel suggests to accept the 5-years rule and choose assistant professors according to their future scientific and teaching potential rather than according to extremely high accomplishments which mostly will not be fulfilled at an early career stage. (2) The administration procedure for recruiting new (assistant) professors seems generally very complex and time-consuming. The efficiency of this procedure requires substantial improvement if KTH wants to remain competitive in hiring top scientific talents as professors.

Infrastructure and facilities

A large fraction of AP relies on experimental infrastructure. The researchers have access to very high-level facilities, but the panel sees significant risks in maintaining them.

The AP researchers utilize large-scale national and international infrastructures, most importantly the MAX IV synchrotron, where KTH has an important role in the development of beamlines and experimental infrastructure.

The Advanced Light Microscopy (ALM) Facility is integrated into the SciLifeLab. ALM is a node in the national microscopy infrastructure as well as a node in the European infrastructure EuroBioimaging-ERIC.

The AlbaNova NanoLab is well equipped for the time being. However, the impression is that its further development is not sufficiently support. The same conclusion appears to apply for the Electrum laboratory in Kista.

Finally, KTH LaserLab seems to qualify to become a centralized KTH facility. It has external users and is already part of the LaserLab Sweden network, whose Stockholm node apparently refers to the KTH LaserLab. However, the KTH LaserLab seems more scattered than the other nodes of the LaserLab Sweden. It lists many instruments that belong to small-scale ("spearhead") laboratories of individual groups. This also includes the BALTAZAR laboratory on angle-resolved photoelectron spectroscopy, which is at the forefront of international developments in this field. We are left wondering whether the LaserLab needs to be more visibly organized as a centralized facility. Of course, this lack of organization could be due to funding constraints in the present setting. Nevertheless, the **role of the LaserLab as a possible centralized KTH facility should be clarified and supported**.

The maintenance of the infrastructure is a significant financial burden. We heard that the centralized facilities are about 65% supported by external funding, whereas the "spearhead" laboratories are 95% (!) externally funded. These "spearhead" laboratories form the basis for scientific breakthroughs through discoveries of new phenomena and development of novel methods, whereas centralized infrastructure typically supports service to interdisciplinary activities. Hence, sufficient support to the "spearhead" laboratories is a prerequisite for maintaining the high scientific level of the research. It is alarming that the KTH administration has not reacted to recent changes in the external funding landscape. There should be an internal funding scheme established to maintain not only centralized laboratories, but also essential smaller-scale spearhead laboratories at the state-of-the-art level.

3. Strategies and organisation

The department has decided to present themselves and their research along the coordinates of the bio-opto-nano concept. This was convincing and appealing to the review panel. In the future this should also be reflected in the organizational structure to better exploit synergies and foster collaboration between the various research groups. A key ingredient in this strategy is the establishment of the Quantum Technology Hub at KTH jointly with research groups in the Physics department.

Congruence with university-level goals

Based on the assumption that KTH aims to be a leading technical university in the global context, AP is fully aligned with this goal. The graduates are very well educated and get jobs in international academia and research, industry, and administration. The various groups produce a substantial number of patents and have an excellent track record in founding successful spin-off companies. This is a technical university at its best.

4. Interaction between research and teaching

The educational activities of AP reflect well its position within an applied area at a university of technology. 75-80% of their Ph.D. graduates are employed by industry, which show that they acquire relevant skills during their training. AP also has significant involvement in teaching courses on the B.Sc. and M.Sc. levels. Ph.D. students participate in teaching as supervisors for laboratory exercises and calculation exercises, which is a common and extremely positive practice in several leading universities worldwide. Having researchers as teachers is also favourable because the latest research findings can be included in the teaching material of advanced courses.

5. Impact and engagement in society

Relevance, scale, and impact of the department’s current engagement with society and industry

In addition to its high scientific impact, the research of AP has significant societal impact. This becomes evident from the large number of spin-off companies created from the work of the department during the past 20 years. The laboratory-based Xray source in combination with the X-ray optics developed at the department provides unique instrumentation for X-ray microscopy and analytics in science and industry worldwide.

In general, the bioanalytical experimental and theoretical methods/technologies developed and used by the bio-oriented groups (e.g., at the Science for Life Lab) to elucidate the complex function and dysfunction of biological cells are of utmost importance to understand the evolution of severe diseases. The steps are short to transfer fundamental scientific findings in this field to practical biomedical applications. This knowledge transfer pays off in the development of novel medicines for treating severe diseases by collaborating with hospitals (e.g., Karolinska) and pharma industries.

During our visit, we heard mixed messages regarding policies for setting up spin-off companies based on research results. Nevertheless, it seems that KTH is lacking proper guidelines for such activities that consider possible conflicts of interest while providing encouragement and support for exploiting research results. We recommend that clear guidelines for such activities be established on the KTH level and the decisions regarding, e.g., renting space or infrastructure then be delegated to the departmental level.

Research dissemination beyond academia

The department actively engages with media (traditionally printed and TV as well as social media). The images produced in the Sci-life Lab give ample opportunity for this. They have applied for a grant to give high schools access to some of their imaging labs and have established a summer program for high school students.

Relation to sustainability and the United Nations' Sustainable Development Goals (SDGs)

The activities are aligned with the SDGs as much as can be reasonably expected. Some examples include:

- Several projects on III-V solar cells and the development of a Si based multi junction solar cell.
- Project on LEDs from the Swedish energy agency.
- Project on development of hybrid thermoelectric materials and devices (FETOPEN, H2020).
- Project on project on building-integrated photovoltaics (Swedish Energy Agency). It is run together with a commercial company (Mercene Labs AB).
- Advanced nano-therapy and diagnostics (biomolecular sensing).
- Project on compact and low-cost LIDAR system applied to CO_2 monitoring (with Lund University) as well as OPO system for global CO_2 monitoring (in EU project).

6. Recommendations for strengthening the department and its future potential

The AP research was presented to the panel in five meetings, which were mostly disconnected from the present organizational structure (based on divisions and research groups). It was therefore difficult to follow who is doing what and in which part of the organization. We therefore recommend that AP reorganize into fewer divisions to better reflect their chosen structure along the bio-opto-nano concept. This would also serve the purpose of improving the synergy between AP research groups. The bio-opto-nano concept could possibly be extended to include "quantum", depending on how this emerging topic is integrated into the existing structure.

AP appears to have very little top-down management on the departmental level. The development is thus based on the activities and organic development of individual groups. While this approach has definite benefits, we recommend that AP start forming a joint strategy for the development of the whole department based on its strengths. This becomes particularly important as the replacements for retiring faculty are considered. The joint strategy development should also be extended to the various topical research areas, e.g., following the "bio-opto-nano" concept of AP.

In the context of an increasing interest and strategic investment in the field of quantum technologies at both European and international levels, **the panel strongly supports the plan to create a quantum technologies centre at KTH**. This is a priority for both the Physics and Applied Physics departments and will require only a relatively modest investment for KTH, but result in a number of positive outcomes. As has been witnessed by similar initiatives abroad, such a local centre has the potential to consolidate the high-quality research in this field (spanning activities in photonics, nanophysics and condensed matter physics) performed by several groups in both departments, contribute to community building and create new synergies that are a prerequisite for further development of ambitious research projects. From a strategic perspective, such a centre will strengthen the position of KTH with respect to the Wallenberg Centre for Quantum Technology (WACQT) led by Chalmers University, by highlighting the research activities that are unique to KTH but also complement activities supported by the WACQT. This will also contribute to creating a more balanced landscape regarding quantum technologies in Sweden, and attract interest for industrial collaborations. It will place KTH in a central position within Europe, which is particularly dynamic in this field. Joint initiatives with similar centres elsewhere in Europe or beyond can also be envisaged.

Because of the recent changes in the external funding policies, the essential laboratory infrastructure of various groups is seriously underfunded. KTH should put a process in place to evaluate these laboratories and provide adequate support where needed.

7. Final remarks

We obtained all the additionally requested information and want to thank our KTH colleagues for collecting and providing these data in a timely and professional manner.

In future evaluations, much labour and working time can be saved on both sides by providing the necessary information in an easy-to-read summary of the key facts, issues, and statistics, rather than a lengthy self-repeating document, where essential information is missing.

KTH has many outstanding achievements, these could be shared via the internet pages in a timelier fashion.

The panel report template contains many redundant sections – therefore we decided not to adhere too strictly to this extremely detailed template.