Assessment Report
Leiden Institute of Physics (LION)
2010-2015

December 2016

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2. Preface

This report embodies the findings and recommendations of an international peer review of the Leiden Institute of Physics (LION) that took place in October, 2016.

The assessments were based on a self-evaluation report provided by LION and a site visit that took place on October 27, 28. The Committee was highly impressed by the quality of the research at LION, its facilities and by the enthusiasm and the dedication of the researchers and management involved.

This review report is both prospective and retrospective. The review also resulted in a number of specific recommendations.

As chair I wish to thank my colleagues and our secretary for their expert and sincere contributions to the discussions and final findings and the efficient way the whole process was executed. The work was not only intense but also socially very agreeable and academically rewarding.

On behalf of the Committee I would like to thank all members of LION, from the senior staff to the PhD students and in particular the management, for their open and constructive participation in the review process and the very professional and pleasant way the site visit was organized.

We hope this report will be the beginning of another successful period of excellent research and PhD education at LION.

December, 2016

Prof. Theo Rasing, Chair International Peer Review Committee LION

3. The Assessment Committee and the Assessment Procedure

Scope of the Assessment

In accordance with the Standard Evaluation Protocol 2015-2021 for research assessments in the Netherlands (SEP), the Committee was asked to assess the quality and relevance to society of the research conducted by the Leiden Institute of Physics (LION), its viability as well as its strategic targets and the extent to which it is equipped to achieve them. This included a reflection on the PhD programmes and on the research integrity policy. The Committee was furthermore asked to take into account current international trends and developments in science and society in the analysis and to provide recommendations for improvement.

In addition the Committee was asked to reflect on the following strategic question:

For its size (≈30 fte) LION has an unusual broad research profile while the research units are small. This allows for considerable flexibility to adapt to changes in the external environment. However, the current trend is to provide funding for largescale research programs, such as NWO zwaartekracht or EU flagships, and such programs tend to gravitate to big research units. How is LION to address this dilemma?

The assessment covers the research performed in the years 2010-2015. The unit of assessment is the Leiden Institute of Physics (LION).

Composition of the Committee

The Committee was composed as follows:

- Prof. Theo Rasing (chair), Radboud University Nijmegen
- Prof. Anne-Christine Davis, Cambridge University
- Prof. Daan Frenkel, Cambridge University
- Prof. Jochen Mannhart, Max Planck Institute Stuttgart
- Prof. Sir John Pendry, Imperial College London
- Prof. Monika Ritsch-Marte, Medical University of Innsbruck

A CV of each Committee member can be found in Appendix A.

The Committee was assisted by an independent secretary Dr.ir. Femke Merkx (Kenniscocreatie, onderzoek & advies).

Assessment Procedure

The Committee followed the Standard Evaluation Protocol 2015-2021 for Research Assessments in the Netherlands (SEP), assessing research quality, relevance to society and viability on a four point

scale.[1] The meaning of the categories and scale is described in Appendix D. The Committee based its evaluation on the information provided in the self-evaluation report, additional information requested and on interviews conducted during a two-day site visit. See Appendix B for details on the site visit programme.

Because LION, the chosen unit of assessment, is quite large, and because the Committee wanted to be able to look in some detail into the actual research being done, the Committee asked LION to provide an addendum to the self-evaluation report in which the various quality indicators were split up between the domain of Theoretical Physics and that of Experimental Physics. This enabled the Committee to divide tasks according to its members' expertise and thus to make an in-depth assessment possible. Three members focused their preliminary assessment on Theoretical Physics and three members focused on Experimental Physics. Shortly before the site visit and based on the preliminary assessments a request to send further details on a number of issues was sent to LION. These were swiftly answered and sent to the Committee a few days before the site visit.

The two-day site visit took place on October 27 and 28 and started with a private Committee meeting. During this meeting the Committee was briefed by the secretary about the SEP protocol. Also the issues of impartiality and confidentiality were discussed. Personal and professional relations were revealed and it was concluded that there was no specific risk in terms of bias or conflict of interest. Prior to the meeting all members had already signed the statement of impartiality and confidentiality. Based on the preliminary assessments the main issues and questions to be answered during the site visit were discussed and decided upon. After the interviews the Committee discussed the scores and recommendations and at the end of the site visit the Committee started writing the assessment report. An overall assessment was made for the institute as a whole, also taking into account the synergy and collaboration between Theoretical Physics and Experimental Physics.

After the site visit, the report text was further finalized through email exchanges. The final report was sent to the board to check for factual inaccuracies and where relevant the assessment Committee made corrections.

Data Provided to the Committee

Prior to the site visit the Committee received the following information:

- Self-evaluation report, including the appendices required by the Standard Evaluation Protocol (SEP).
- The research assessment report for the previous assessment period (2001-2009).
- Application for re-accreditation of the Casimir research school (2012).
- Self-evaluation report (2012-2016) Delta Institute for Theoretical Physics (DITP).
- Midterm report Leiden Institute of Physics (LION).
- Progress report NWO-Gravitation program Nanofront (2013-2015).
- A list of all peer-reviewed publications at LION (2010-2015).

[1] Note that in comparison to the previous assessment period, the SEP-scale has changed. Therefore a direct comparison with the results of previous assessments is not possible.

In addition, the Committee asked and received further information:

- An addendum to the self-evaluation report, with main quality indicators reported separately for the domain of Theoretical Physics and the domain of Experimental Physics.
- Answers to questions posed prior to the site visit.
- Additional data on the duration of the PhD-trajectory.

4. Strategy and Targets of the Leiden Institute of Physics (LION)

The mission of the Leiden Institute of Physics is to perform physics research and to provide physics education at the highest international standard. Research and education go hand in hand at all levels.

The research is foundational and curiosity driven. All researchers share the desire to increase the knowledge of the world, in an open atmosphere of inquiry from which innovative ideas emerge that provide applications and value for society.

The institute values the unity of physics as a discipline, from the largest to the smallest scale, and it therefore studies a broad range of systems and phenomena, from cosmic strings to DNA strands, from granular materials to quantum dots, from protein assemblies to socio-economic networks. Because of this diversity the Institute is characterized by a variety of small groups, rather than a few large and more narrowly focused sub-departments. Close interactions between theory and experiment, and an emphasis on the development of novel, world-class instrumentation are two further characteristics of LION.

Because of the very different nature of the research methods and the very different infrastructural needs, the research at LION can be meaningfully divided into the two general domains of experimental and theoretical physics, the latter being represented by the 'Lorentz Institute for theoretical physics'. Crossing the boundary between the domains of experimental and theoretical physics, researchers within the institute work on the following research themes:

1. Quantum matter
2. Topological matter
3. Biological matter
4. Cosmological matter
5. Soft condensed matter
6. Econophysics and network theory
7. Intercellular processes
8. Ultramicroscopy and detection at the physical limits
9. Quantum information
10. Quantum optics

5. Assessment

The Committee assigned LION to the following scores for each of the three SEP categories:

Research quality	1	*The research unit has been shown to be one of the few most influential research groups in the world in its particular field.*
Relevance to society	1	*The research unit makes an outstanding contribution to society.*
Viability	2	*The research unit is very well equipped for the future.*

5.1. Research Quality

LION is proud of its long-standing history of excellence in physics and striving to uphold this level of quality and to extend it into the future. The evaluation Committee recognizes these efforts and considers them to be effective, reaching the conclusion that the overall research quality of LION is to be judged as "world leading / excellent" (score 1).

This assessment is substantiated by a number of indicators of excellence, such as the share of prestigious awards and grants (ERC synergy grant, ERC Advanced grants, Zwaartekracht grants, Spinoza awards, VIDI/VICI and others) LION has been able to obtain. Moreover, the Committee was impressed by the large positive resonance the Institute's publications caused in the scientific community. The Committee agrees with the benchmarking chosen by the institute to assess scientific quality and with the favourable conclusions drawn from the comparison with other similar-sized physics departments in the Netherlands and abroad. The Committee also acknowledges that LION has clearly responded to the recommendations by the previous research assessment Committee to strengthen the research in quantum optics and in biological physics, and secondly to strengthen the collaboration with Delft University of Technology.

While the quantitative indicators look excellent, "quantitative evaluation should support qualitative, expert assessment. Indicators must not substitute for informed judgement", as leading bibliometricians have said.[2] Therefore the Committee's assessment was primarily based on the judgement of the actual research being performed. The quality of the individual research groups was perceived as persistently high, with some prominent groups rising above this level in terms of international visibility. We were struck by the cohesion, enthusiasm and drive exhibited by all members of the research groups. Within the broad overall themes, the different principal investigators work on a range of different topics. Nevertheless, there is clear evidence of strong synergy between different research teams. Moreover, all theory group members had strong

[2] Hicks, Wouters et al., Bibliometrics, the Leiden Manifesto for research metrics, *Nature,* 520, p. 429–431 (23 April 2015). http://www.nature.com/news/bibliometrics-the-leiden-manifesto-for-research-metrics-1.17351

interactions with experimental groups, either in-house or elsewhere, one example is the strong interaction between Leiden and Delft on quantum computing.

The international reputation of the 'Lorentz Institute for theoretical physics' is excellent. Apart from the usual indicators listed above, this is reflected in the strong `pulling power' of the Lorentz visiting professorships – the names of the holders of this Chair read like a brief `Who is who' in the world top of theoretical physics. Theory in Leiden covers a broad range of topics, spanning three different energy scales: the low energy of nanoscale quantum physics and strongly correlated matter at low temperatures, the intermediate scale of soft and biological matter and the high energy scale of elementary particles and cosmology. Though working on these different energy scales, there is clear evidence of strong – and often highly original – synergy between the different research teams, which is greatly facilitated by their offices being on the same corridor and sharing morning coffee. As a particular striking example, the collaboration between string theory and condensed matter physics is impressive and could have future impact as a result of their authorship of the first monograph on the AdS/CFT (anti-de Sitter/conformal field theory) correspondence applied to condensed matter physics.

The Committee was particularly impressed by the innovative and up to date work on Majorana Fermions and their relationship to possible quantum computing. This is a very hot current topic. The highlighted and high quality paper on orbital angular momentum states of light addresses another topic of wide current interest. The theoretical effort in Soft and Biological matter has been strengthened substantially by recent hires, complementing the existing effort on elucidating the role of `structure control' on DNA organisation and expression. The new activities on active matter, mechanical topological insulators and unconventional and mechanical meta-materials (to name but a few of the topics) are of very high quality and hold great promise for the future. The outstanding cosmology section has grown from a sole member to three, spanning the areas of inflation, dark matter and dark energy/modified gravity plus a string theorist, with all being part of working groups for the International satellite experiment, EUCLID. Impressively one member has pioneered an experimental proposal, SHiP at CERN on the detection of dark matter. Beside publishing scientific papers, the 'Lorentz Institute for theoretical physics' has developed several software tools, such as KWANT for quantum transport simulations and EFT/CAMB for analysing current and future surveys to test gravity on cosmological scales. Both are freely available to the broader scientific community and form important contributions to the development of the respective fields. The broader physics community furthermore profits by the contributions made to ScienceWISE, a project to enable article annotation and scientific bookmarking.

The Committee was also highly impressed by the quality of research by the Experimental Physics groups. The research projects are mostly curiosity driven and cover a wide range of topics from the limits of quantum physics, matter-photon entanglement to bottom-up molecular robotic structures. Exemplary are the world leading single molecule and nano-optics work, new ways to observe viruses and the use of half-metallic ferromagnets to improve superconducting logic. Also the work on macroscopic quantum coherence is exemplary and world leading. The collaboration with the quantum nanoscience and bio-nanoscience departments at Delft University of Technology with joint students and postdocs appears to be progressing very well. The Committee also highly appreciated the strong emphasis on instrument development, such as the high-resolution LEEM-PLD instrument, that allows one to make, characterize and measure nano-size materials with unprecedented

resolution. Strong collaboration with the Theoretical Physics group is evident on topics like quantum information, bio-matter and quantum optics. A very exciting new development is that of topological metamaterials that have very unusual mechanical properties. The excellent scientific quality of Experimental Physics is furthermore reflected in numerous prestigious awards such as the Spinoza Prize for Bouwmeester and the Edison-Volta, the Grand Prix Léon Brillouin and Physica Prizes for Orrit. To conclude, the Committee finds the experimental physics groups to be very well positioned and equipped to continue playing a leading role at the forefront in key fields of future research, in biological and soft matters as well as in quantum matters and optics.

5.2. Relevance to Society

Next to the advancement of knowledge and its direct impact in the academic world, the research and researchers of LION have a clear societal impact, which ranges from outreach activities, interactions with industry and exploring novel concepts in materials science, biology and econophysics. The Committee highly appreciated the variety and level of the efforts and results in the area of societal impact of LION and valued them to be excellent and exemplary (score 1).

All the various valorisation and outreach activities that LION has developed over the years fit within the mission of LION, but their societal impact is necessarily different. The bold research into exciting new directions in theoretical physics is unlikely to have *short-term* economic impact, but through the impressive, extensive and varied outreach activities of the institute (some of these specifically aimed at young women), it is likely to attract attention outside the confines of the university. The close collaboration with high-school teachers in the “Teachers at LION” program to gain inside advice from the teachers on the interaction with the high schools, the high-school student program of LION, and the interactions with primary school pupils were considered by the evaluation Committee as exemplary and commendable. The same can be said about the Physics Ladies Day, a special information day for female high-school students, which has attracted many more female students compared to the information days that were organized before. Though it is hard to tell whether the recent increase of women undergrads from 15% to 25% is directly related, the Committee is very pleased by this activity and the numbers do look impressive and promising for the future.

The research in materials science, biology and econophyics are likely to have medium to long term societal implications. The new developments for engineered metamaterials, for example, open a completely new window on how to design and manipulate functional materials with completely new and counterintuitive mechanical properties that open wide perspectives for applications and the Committee expects that this will be pursued with vigour. Also the recent appointment of Diego Garlaschelli, whose econophysics group has extensive collaborations in the financial sector, is to be highly commended.

The strong activities in instrument development, which has always been a characteristic of Leiden’s physics, has led to many spin-off activities, such as Leiden Probe Microscopy and Leiden Spin Imaging. The value of these activities has also been recognized by others as is evident from the Valorization Grant for Joost Frenken and the fact that he has been asked to become the founding director of ARCNL, a public-private institute to develop the next generation of nanolithography. The

development of the high resolution LEEM-PEEM that includes fabrication and measuring tools and serves as a facility for external users, is another example of the clear societal impact of the Leiden instrument developments.

Furthermore, the relocation of the bio-oriented groups to the CellObservatory has evolved in collaborations with SMEs and the dual appointment of Doris Heinrich with the Fraunhofer Institute for Silicate Research in Würzburg has created excellent opportunities for industrial links in the field of e.g. targeted drug delivery & drug screening assays. The Committee was further pleased to see that Marco Beijersbergen, founding director of Cosine, a small R&D company using applied physics and electronics expertise to solve a range of problems for their customers, is teaching as an extraordinary professor at LION, thus being a role model and specialist in entrepreneurship for both students and staff.

Though the university clearly appreciates and stimulates the Institute to interact with industry and to found start-up companies, the Committee received some feedback, however, that the support of the University for the commercialization of research results could still be strengthened.

The Committee's positive assessment of the Institute's relevance to society is further supported by demonstrable marks of recognition by society, including two instances of royal recognition, and funding of the econophysics chair and a PhD position by the Econophysics foundation.

5.3. Viability

The viability of the research at LION depends on five factors: first and foremost the quality of the staff and recent appointees, secondly the ability of the principal investigators to collaborate with the best possible partners, thirdly the ability to secure continued funding, fourthly the technical infrastructure and lab facilities available, and last but not least the leadership qualities of the Institute's management. The Committee highly values the various activities that LION has developed in all these areas and considers LION to be very well equipped for the future (score 2).

In relation to strategy, the Committee was asked to reflect on the following dilemma: *For its size (≈30 fte) LION has an unusual broad research profile while the research units are small. This allows for considerable flexibility to adapt to changes in the external environment. However, the current trend is to provide funding for largescale research programs, such as NWO zwaartekracht or EU flagships, and such programs tend to gravitate to big research units. How is LION to address this dilemma?*

The Committee recognizes this dilemma, yet is confident that LION is able to collaborate with others for large scale highly focussed projects, as LION has already demonstrated in the recent past by its success in two Zwaartekracht programs and an ERC Synergy grant. The Committee is therefore of the opinion that this dilemma should not be used as an argument to change the otherwise very productive, flexible and recommendable character of LION, which is characterized by small, highly diverse groups.

The age distribution of the Institute members is very good, offering a fine combination of experienced and young scientists. LION has recently appointed eleven new faculty members, all of whom are outstanding and compare favourably with the best of their international peer group. The new faculty seem to be well integrated into LION. With the high quality recent appointments LION seems well set up for the future, though the Committee would also like to express the concern that opportunities for new hiring in the future seem limited as – at the time – all permanent positions that come available through upcoming retirements will be taken by the new faculty.

During the assessment period the principal investigators of LION have been successful in obtaining funding for their research, including a number of very large and highly competitive large collaborative grants such as two Zwaartekracht programs, in addition to equally prestigious personal grants like VICIs and ERC grants. There is every reason to believe that Institute members will be successful in the coming funding rounds of the Netherlands organisation for scientific research NWO, the ERC and other organisations. The faculty is well aware of the changing funding landscape and the challenges and opportunities that this gives and some of them have been very actively involved in shaping this landscape, in that way also creating new future opportunities for funding. Moreover, the informally organized procedures that LION has implemented, with the coordination team "nudging" principal investigators to apply for suitable grants and with more experienced principal investigators counselling younger colleagues on their grant proposals, seems to be highly effective.

The infrastructure, lab facilities, and equipment available to Experimental Physics was found to be up to par with the challenging and technically demanding research projects. Recently, the university has invested in a completely new building with new, high-quality infrastructure where facilities relevant to biomedical research are shared with other departments. With regard to infrastructure and lab facilities the institute is therefore well-prepared for the future. The Committee suggests that the relocation will foster the synergy between the groups that is so clearly present in the 'Lorentz Institute of Theoretical Physics' and facilitated by them being located close together.

The Committee was very impressed with the outstanding leadership shown by the Director of LION who has taken it upon himself to provide the overall leadership and administration of the Institute. LION seems to be an exceptionally happy and friendly place with an inclusive working environment. All members seem satisfied with the support they are getting and with the leadership shown. The management board and coordination team operate in an insightful and exemplary manner, which was noted in discussions with Institute members at all levels. Under the leadership of the current Director, LION has very well addressed the issue of equality and diversity, appointing four outstanding women within the assessment period.

An actual concern is that the current Director steps down in the near future and has provided a leadership model which might be hard to replicate by his successor. The Committee therefore welcomes the efforts currently undertaken to shift some of the tasks of the current director to others, so that under a new directorship the same high level of administrative and leadership quality can still be maintained.

5.4. PhD Programme and Research Integrity Policy

PhD Programme

The Committee was positively impressed by the open atmosphere in its interaction with the PhD students, and by the feedback it received from them. The PhD training is well embedded in the organisation of LION. It is organized both on the level of Research Schools (NOVA, Casimir, Dutch School of Theoretical Physics) for the in-depth training related to the thesis subject and on the level of the Faculty of Science (or FOM) for the soft-skills training. Both the in-depth training and the soft-skills training seem of high quality. The Committee was pleased to hear that the soft-skills training is tailor made for students in the natural sciences. The students value the large freedom they get and the opportunities to get advice in and outside their own group. Because the individual research groups are fairly small and because of the very open and collegial atmosphere, the students get ample guidance and supervision. In the end, the quality of PhD training is assured by those supervising. Hence, the excellent quality of the academic staff is the best quality assurance**.** The progress is well monitored by the yearly progress report and the “my thesis file”. The Committee appreciates the fact that all PhD-students have a co-supervisor, next to their daily supervisor.

The proximity of the Lorentz Center, a national center for international workshops in all scientific disciplines, is a great bonus. It allows students to broaden their perspectives. Furthermore, the Van der Waals and Ehrenfest Colloquia attract stellar speakers, although the Committee finds it hard to believe that it was not possible to find more than 1 stellar female Ehrenfest speaker (out of 59) since 2010. Similarly, it could find no evidence that there has ever been a female Lorentz Professor. The Committee is pleased that LION realizes this and has taken steps to improve this.

The figures for the time spent on completing a PhD look fine and have improved over the assessment period. Of those people that got a contract extension after the first year, 43% defended their thesis within 4.33 years, 39% of all PhDs handed in their manuscript between 4.33 years and 5 years, 4% handed in the manuscript within 6 years and another 3% graduated within 7 years. 3% is not yet finished (2 of them may still complete within 6 years) and 8% discontinued. Additional figures presented to the Committee furthermore show that the average time for completing a PhD (52 to 53 months) compares favourably with the average time for doing a PhD in the Netherlands (60 months for the sciences according to the VSNU) and is comparable to the average for FOM students (52 months in 2014). The Committee was furthermore pleased to hear that - if needed – PhD-contracts are extended for a few months until the thesis manuscript is handed in.

Research Integrity Policy

The Committee found the research-integrity policy of LION exemplary. Leiden University follows the Code of Conduct for Academic Practice and has a confidential Advisor on Academic Integrity. The Committee was pleased to note that the (mandatory) training on this subject -the course: “On being a scientist", which deals with real-life problems, often in the `grey zone' between acceptable and not acceptable - was appreciated by the PhD students. In addition to (tested) procedures to deal swiftly with plagiarism issues, LION makes use of commercial software to detect possible plagiarism in texts.

The evident collegiality among principal investigators and the open contact between PhD students and Postdocs in different groups contribute to a climate where scientific integrity is a shared value. In addition, the mandatory appointment of co-supervisors for PhD students and the creation of an independent Doctorate Committee are complementary to the check by the supervisor on the integrity of the PhD thesis. In this context, it is also crucial that the supervisor is responsible for ascertaining that the PhD manuscript meets academic integrity requirements. In addition, neither supervisor nor co-supervisor are members of the Doctorate Committee that decides whether the thesis manuscript qualifies for defence.

Data handling and management are momentarily still the responsibility of the individual groups but policies and procedures at the level of LION are work in progress**.** The Committee recommends to swiftly take this further.

6. Summary and Recommendations

6.1. Summary

LION has the ambition to enhance our knowledge of the world around us at the highest possible level and strives to uphold this level of quality into the future. It does this by attracting a diverse, excellent faculty, creating an open and collegial atmosphere that fosters interactions and cross fertilization of ideas and having a management that cherishes and supports this in the best possible way. The evaluation Committee recognizes these efforts to be highly effective, concluding that the overall research quality of LION is “world leading / excellent” (score 1).

6.2. Recommendations

Research Strategy and Funding

- The Committee emphasizes the need for basic curiosity-driven research such as being performed very successfully at LION. Regardless of the current emphasis on valorization in Dutch science policy, the kind of research performed at LION provides fundamental new insights and breakthroughs, which will show their societal relevance in the long run.

- This being said, in the future there are prospects for application of the department’s research into highly novel mechanical structures and the Committee suggests that this will be pursued with vigour. Also in the connection to the financial world and in the areas of biophysics and instrument development there are ample opportunities for future valorisation that should be pursued.

- LION seems well prepared for the future by its engagement in the Dutch National Research Agenda and we recommend the researchers to optimally invest in this.

Governance and Human Resources

- The Committee noted that, as the complexity of key equipment and techniques is growing, it becomes increasingly difficult for the Institute to ensure the continuity of the necessary expertise, the more so as all PhD and postdoc funding is acquired in competition. Such grants do not allow for overlapping appointments. Crucial skills are lost when PhD or Post-doc funding runs out, if the research groups have no funding available for proleptic appointments to ensure knowledge transfer. The Committee is concerned about this negative side-effect of the strong reliance on external funding. The Committee realises that, at present, the necessary funds are

simply not available and strongly encourages the Institute to engage with other stakeholders to work out a strategy aimed at avoiding the loss of crucial expertise.

- With the recent appointments there seems to be little scope for appointments in the near future. The Committee recognizes this as a possible upcoming risk, in that it need to be ensured that the Institute remains in a position to hire young scientists of great potential in the next five to seven years. The institute is an ideal candidate for extra resources if this is possible. To recognize LION's pioneering effort in regards to gender balance, the Committee recommends fully subsidizing a new staff position for a woman scientist for a six-year period, enabling LION to further strengthen and rejuvenate itself.

- Some universities, like Cambridge, have a returning Carers fund to support those returning from a career break to 'kick start' their research. For example, to enable women to attend a conference with a carer to look after a baby, or hire an assistant to keep an experiment going whilst on maternity, or other caring, leave. We recommend Leiden University to consider such a scheme.

- The current Director steps down in the near future and has provided a leadership model which might be hard to replicate by his successor. We encourage the University to motivate more people to further take up managerial responsibility by giving it the proper credits.

Education and Training

- While the Institute's policy to improve the gender balance is to be highly commended, the Committee found that since 2010, out of 59 stellar speakers in the Ehrenfest Colloquium, only one of them was female. Similarly, the Committee could find no evidence that there has ever been a female Lorentz Professor. The Committee is convinced that it is well possible to invite more outstanding female physicists that can act as role models and therefore emphasizes the Institute's intention to improve these figures.

Other

- Given the excellent quality of the research it is surprising that there are no international awards in the theoretical physics department. The Committee recommends the institute to be more proactive in nominating people for international awards.

- It was mentioned that the universities policy on stimulating valorisation is struggling with the issue of allegedly potentially unfair competition in public-private partnerships. The Committee recommends the university to do a fact finding mission to find out how other universities solve this problem, so that both university and society can profit.

7. Appendices

A. Curricula Vitae of the Committee Members

Prof. Anne Christine Davis holds the 1967 chair of Mathematical Physics at the Centre for Mathematical Science, University of Cambridge, since 2013. Since 2014 she is Gender Equality Champion for STEMM, also at the University of Cambridge. Between 2002 and 2013 she was professor in the Department of Applied Mathematics and Theoretical Physics, University of Cambridge. Davis is Fellow of the Institute of Physics since 2001 and a member of Academia Europea since 2009.

Davis' research is in theoretical cosmology, both at very early and late times. She uses particle physics, quantum field theory and relativity. Her recent research is on modified gravity and dark energy. She is one of the prime inventors of the chameleon model of modified gravity and the environmental dilation theory. She also works on inflationary cosmology. She has investigated the theoretical constraints on modified gravity theories from laboratory experiments and she is involved in the CANNEX experiment in Amsterdam. She is a member of the international EUCLID satellite collaboration, due to fly in 2018, and member of the theory working group with particular responsibility for dark energy and modified gravity. She is also a member of the international eLISA collaboration with particular responsibility for novel sources of gravitational waves.

Prof. Daan Frenkel (1948) was appointed 1968 Chair of Chemistry at the University of Cambridge in 2007. He was Head of Department from 2011 to 2015. He is a Foreign Member of the Royal Society, of the American Academy of Arts & Sciences and of the US National Academy of Sciences (USA). He is furthermore member of the KNAW, TWAS (the World Academy of Sciences) and Academia Europaea and an Honorary Fellow of Trinity College Cambridge. He was awarded the Spinoza Prize in 2000 and the Boltzmann Medal in 2016.

Frenkel received his PhD in Physical Chemistry from the University of Amsterdam. Subsequently, he worked as a postdoc at UCLA. After that, he worked at Shell Research (Amsterdam), the Universities of Utrecht and Amsterdam and at the FOM Institute for Atomic and Molecular Physics.

Frenkel's research interests focus on numerical simulations of many-body systems, with a special emphasis on problems relating to ordering and self-assembly in soft matter. In the context of this research, he has developed novel Monte Carlo algorithms for free-energy calculations and for the simulation of chain molecules. In addition, he has developed techniques to compute the number of disordered packings of jammed particles. Applications of his research are in the area of liquid-crystalline ordering, crystal nucleation and complex self-assembly.

Prof. Jochen Mannhart (1960) is Director at the Max Planck Institute for Solid State Research in Stuttgart where he is head of the Solid State Quantum Electronics department, since 2011. He is a Scientific Member of the Max Planck Society and Honorary Professor at the University of Stuttgart,

Germany. From 1996 to 2011, he was a chaired professor at the Centre for Electronic Correlations and Magnetism at the University of Augsburg, Germany. From 1989 to 1996, he was a Research Staff Member at the IBM Zürich Research Laboratory. He has won several prizes and awards, including the 2014 European Physical Society Condensed Matter Division Europhysics Prize, the Gottfried Wilhelm Leibniz Prize (2008) of the German Research Society and the Friedrich Förster Prize of the University of Tübingen (1986).

Mannhart's research interests focus on:

- Exploring interfaces in complex electronic materials to create and understand new electronic systems, materials, and novel physical phenomena; investigating them for applications.
- Synthesizing complex oxide heterostructures on the atomic scale, studying the effects of lateral confinement on the nanometer scale to create lower dimensional, complex electronic systems.
- Understanding, designing, and using electronic properties of correlated electron systems.
- Exploring basic properties of matter on the atomic scale by using scanning probe techniques.

Prof. Sir. John Pendry (1943) is a professor of theoretical solid state physics at Imperial College London where he was head of the department of physics (1998–2001) and principal of the faculty of physical sciences (2001–2002). Before working at Imperial College, he spent time at Bell Labs (1972-1973) and was head of the theory group at the Science and Engineering Research Council at Daresbury Laboratory from 1975 to 1981. In 1984, he was elected a Fellow of the Royal Society. He is a Foreign Member of the US National Academy of Sciences, the American Academy of Arts & Sciences, the Norwegian Academy of Sciences and an Honorary Fellow of Downing College Cambridge. In 2014 Pendry received the Kavli Prize in Nanoscience together with Stefan Hell, and Thomas Ebbesen, and the Dan David Prize in Nanoscience in 2016 together with Chad Merkin and Paul Alivosatos. In 2004 he was knighted in the Birthday Honours.

His research focuses on electromagnetic 'metamaterials' whose properties owe more to their micro-structure than to the constituent materials and make accessible completely novel materials with properties not found in nature. Successively metamaterials with negative electrical permittivity, then with negative magnetic permeability were designed and constructed. In 2006, collaborating with Duke University, he deployed the technique of 'transformation optics' to design a cloak to hide an arbitrary object from electromagnetic fields. The simplicity of the new concepts together with their radical consequences have caught the imagination of the world's media generating much positive publicity for science in general.

Prof. Theo Rasing (1953) is full professor of physics at Radboud University, Nijmegen and Director of the Institute for Molecules and Materials. He obtained his degree in physics (cum laude) from Radboud University Nijmegen in 1976, where he also gained his doctorate in 1982. After postdoctoral stays at UC Berkeley (IBM fellowship) he became staff scientist and deputy program leader at the Lawrence Berkeley Laboratory, where he developed nonlinear optical techniques for surface and interface studies. His present research is mostly focused on the study and manipulation of magnetic

materials with light and the use of molecular self-organization to achieve novel functional materials for photonics.

Theo Rasing is an elected member of the Royal Dutch Academy of Arts and Sciences (KNAW), elected member of the Academia Europaea, honorary member of the Ioffe Institute in St. Petersburg, Knight of the Order of the Dutch Lion, Distinguished Lecturer 2009, IEEE Magnetics Society and recipient of, among others, an ERC Advanced Grant 2013, the Spinoza Award 2008, the Prize for Science and Society 2008 and the Physica Prize 2007.

Prof. Monika Ritsch-Marte (1961) has been full professor and director of Biomedical Physics at the Medical University of Innsbruck, Austria, since 1998. She is a theoretical physicist by training (PhD in New Zealand in 1988, supervised by D.F. Walls), who re-oriented her scientific interest towards Applied Optics. Her current research is focused on holographic optical tweezers and modern optical microscopy methods, with special emphasis on innovative applications of spatial light modulators in these areas.

Ritsch-Marte is committed to the promotion of women in physics. From 2007 to 2009, she was the first female President of the Austrian Physical Society. During her presidency she was one of the initiators of the Lise-Meitner-Lectures, an event series organized yearly in cooperation with the German Physical Society, consisting of public lectures by distinguished female physicists.

Ritsch-Marte received an ERC Advanced Grant in 2009, was elected Fellow of the Optical Society of America in 2013 and became a member of the Austrian Academy of Science in 2016.

B. Site Visit Programme

Thursday October 27th	
9.00 – 9.15	Arrival Committee
9.15 – 10.45	Committee meeting
10.45– 11.00	Welcome by Dean
Prof. dr. G.R. de Snoo	*Dean Faculty of Science*
Eric Eliel	*Scientific Director LION and Professor of Quantum Optics*
11.00 – 12.30	Meeting with management + Coordination Team
Eric Eliel	*Scientific Director*
Martin van Exter	*Director of Education, Quantum Optics*
Niels Laurens	*Institute Manager*
Carlo Beenakker	*Theoretical Condensed-Matter Physics, chair of theory section*
Ana Achúcarro	*Theoretical Cosmology*
Vincenzo Vitelli	*Theoretical Soft-Condensed Matter*
Edgar Groenen	*High-frequency EPR studies of proteins*
Thomas Schmidt	*Experimental Biophysics*
Jan Aarts	*Exp. Condensed-Matter Physics, chair of experimental section*
12.30 – 12.45	Committee meeting
12.45 – 13.30	Lunch with PhDs and postdocs
Maria Mytiliniou	*Experimental Biophysics*
Casper van der Wel	*Exp. Soft Matter, collorids*
Henk Snijders	*Casimir PhD, Exp. Quantum Optics, Quantum Dots*
Thomas Jollans	*Casimir PhD, Single Molecular Optics*
Jorgos Papadomanolakis	*Theor. Cosmology, Delta-ITP, jointly supervised E. Pajer, Utrecht*
Paul Baireuther	*NanoFront, Theor. Condensed Matter Physics, jointly supervised with Y. Nazarov, Delft*
Thomas O'Brien	*Physics of Condensed & Biological Matter*
Kyrylo Bondarenko	*Huygens Fellow, Theor. Cosmology*
Andrii Magalich	*Particle Physics & Cosmology*
Elena Beletkaia (postdoc)	*Inter cellular processes*
Johannes Jobst (postdoc)	*Ultra-Microscopy, LEEM-PEEM*
Alexander Krikun (postdoc)	*Particle Physics & Cosmology*
13.30 – 14.45	Meeting with permanent staff Theoretical Physics
Carlo Beenakker	*Theoretical Condensed-Matter Physics, chair*
Ana Achúcarro	*Theoretical Cosmology*
Vincenzo Vitelli	*Theoretical Soft-Condensed Matter*
Koenraad Schalm	*Particle Physics & Cosmology, Condensed Matter Theory*
Jan Zaanen	*Physics of Quantum Matter*
Diego Garlaschelli	*Econophysics & Network Theory*
Alexey Boyarsky	*Particle Physics & Cosmology*
Helmut Schiessel	*Physics of Soft & Biological Matter*

Thursday October 27th	
14.45 – 15.00	Committee meeting
15.00 – 15.15	Break
15.15 – 16.30	Meeting with representative part of permanent staff Experimental Physics
Jan Aarts	*Exp. Condensed-Matter Physics, chair*
Thomas Schmidt	*Experimental Biophysics*
Daniela Kraft	*Colloids & self-organization*
Tjerk Oosterkamp	*Exp. Condensed Matter Physics, Scanning Probe*
Michel Orrit	*Exp. Biological & Soft Matter Physics, Single Molecules*
Sense Jan van der Molen	*Exp. Condensed Matter, 2D Materials, LEEM-PEEM*
Stefan Semrau	*Biological & Soft Matter Physics, Stem cell differentiation*
Dirk Bouwmeester	*Quantum Optics, Knots of Light, Quantum Super Position of Material objects*
Marco Beijersbergen	*Director Cosine B.V., Applied Photonics*
16.30 – 16.45	Committee meeting
16.45 – 17.15	Lab visit Experimental Physics
LEEM-PEEM	*Sense Jan van der Molen*
Semrau Lab.	*Stefan Semrau*
17.15– 18.30	Committee meeting
18.30 - 19.30	Refresh
19.30	Working dinner

Friday October 28th

9.00 – 9.45	Meeting with tenure trackers
Alessandra Silvestri	*Theoretical Cosmology, Dark Energy*
Luca Giomi	*Theoretical Soft- & Active Matter*
Stefan Semrau	*Biological & Soft Matter Physics, Stem cell differentiation*
Milan Allan	*Exp. Condensed Matter, Quantum Matter*
Kraft	*Colloids & self-organization*
Boyarsky	*Particle Physics & Cosmology*
Garlaschelli	*Econophysics & Network Theory*
Vitelli	*Theoretical Soft-Condensed Matter*
9.45 – 10.00	Committee meeting
10.00 – 10.45	Research integrity + PhD programme
	Eric Eliel, Edgar Groenen, Jan Aarts
10.45 – 11.00	Committee meeting
11.00 – 11.45	Meeting with PhDs
Hedwig Heerkens (EP)	*Experimental Quantum Optics*
Kaveh Lahabi (EP)	*NanoFront, Exp. Condensed Matter Physics*
Kim Akius (EP)	*Exp. Condensed Matter Physics*
Yvette Welling (TP)	*De Sitterprogramme, Cosmology*
Brian Tarasinski (TP)	*Theor. Condensed Matter Physics*
Jeroen Franse (TP)	*Leiden Huygens Fellow, Theoretical Cosmology*
11.45 – 12.00	Committee meeting
12.00 – 12.45	Open slot for remaining questions / writing draft report
12.45 – 13.30	Lunch (in canteen, Physics Ladies Day)
	Kraft, Achúcarro
13.30 – 15.30	Committee meeting + writing draft report
15.30 – 15.45	Break
15.45 – 16.00	Preliminary feedback to LION
16.00 – 17.00	Drinks

C. LION's Composition and Financing

Personnel funded by each type of funding	Year 2010		Year 2011		Year 2012		Year 2013		Year 2014		Year 2015	
	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE	#	FTE
Scientific staff	29	24.9	30	25.8	31	26.9	33	29.0	34	27.5	32	29.8
Postdocs	56	41.1	59	39.6	50	36.6	53	36.8	52	34.3	53	35.0
PhD students	87	67.8	86	67.8	96	79.1	115	86.4	108	92.6	107	92.4
Subtotal research staff	172	133.8	175	133.2	177	142.6	201	152.2	194	154.4	192	157.2
Technicians FLD, ELD and Cryo	33	31.2	33	30.1	30	28.3	30	28.5	37	29.2	33	30.4
Support staff	28	18.4	24	17.4	22	16.4	25	18.3	26	17.4	29	19.1
Subtotal technical & support staff	61	49.6	57	47.5	52	44.7	55	46.8	63	46.6	62	49.5
Total staff	233	183.4	232	180.7	229	187.3	256	199.0	257	201.0	254	206.7

Table 1 Research staff LION

The scientific staff includes tenured and non-tenured faculty at the level of assistant professor (Universitair Docent), associate professor (Universitair Hoofddocent), and full professor (gewoon hoogleraar). The postdocs and PhD students include those employed by Leiden University as well as those employed by the FOM Foundation. The technicians work in the departments of precision engineering, electronics, and cryogenics of the Faculty of Science. They are officially employed at LION. The work they do outside LION is reimbursed to LION by the other institutes. The research support staff is staff support for administration, finances, computer systems, and outreach.

	Year 2010		Year 2011		Year 2012		Year 2013		Year 2014		Year 2015	
Personnel funded by each type of funding	**FTE**	**%**	**FTE**	**%**	**FTE**	**%**	**FTE**	**%**	**FTE**	**%**	**FTE**	**%**
Support staff funded by local funding	44.6	24.3	44.3	24.5	35.1	18.8	34.9	17.5	35.4	17.6	42.5	20.6
Scientific staff funded by local funding	31.3	17.1	29.4	16.3	24.0	12.8	28.7	14.4	36.2	18.0	35.8	17.3
Personnel funded by national grants	80.1	43.7	80.1	44.3	94.6	50.5	107.4	54.0	114.1	56.8	116.4	56.3
Personnel funded by EU grants and other grants as well as contract research	27.5	15.0	26.9	14.9	32.7	17.5	27.9	14.0	15.2	7.6	12.0	5.8
Total	183.4	100	180.7	100	187.3	100	199.0	100	201.0	100	206.7	100
	Year 2010		**Year 2011**		**Year 2012**		**Year 2013**		**Year 2014**		**Year 2015**	
Expenditure:	**M€**	**%**	**M€**	**%**	**M€**	**%**	**M€**	**%**	**M€**	**%**	**M€**	**%**
Personnel costs	10.8	72.8	10.4	71.7	12.4	78.7	12.6	74.2	12.6	72.5	13.1	75.7
Other costs	4.0	27.2	4.1	28.3	3.4	21.3	4.4	25.8	4.8	27.5	4.2	24.3
Total	14.8	100	14.5	100	15.8	100	17.0	100	17.4	100	17.3	100

Table 2 Funding LION

The local funding is the “eerste geldstroom” or “basis financiering” in The Netherlands and is a lump-sum budget granted by the government to universities and includes the “Sektorplan”. The local funding for support staff includes the reimbursement of hours of technicians. Expenditure for personnel cost includes teaching staff. Numbers are rounded up to the nearest decimal

D. Explanation of the SEP Categories and Criteria

Categories	Meaning	Research Quality	Relevance to Society	Viability
1	World leading/ excellent	The research unit has been shown to be one of the few most influential research groups in the world in its particular field.	The research unit makes an outstanding contribution to society.	The research unit is excellently equipped for the future.
2	Very good	The research unit conducts very good, internationally recognised research.	The research unit makes a very good contribution to society.	The research unit is very well equipped for the future.
3	Good	The research unit conducts good research.	The research unit makes a good contribution to society.	The research unit makes responsible strategic decisions and is therefore well equipped for the future.
4	Unsatisfactory	The research unit does not achieve satisfactory results in its field.	The research unit does not make a satisfactory contribution to society.	The research unit is not adequately equipped for the future.

Research quality

The committee assesses the quality of the unit's research and the contribution that research makes to the body of scientific knowledge. The committee also assesses the scale of the unit's research results (scientific publications, instruments and infrastructure developed by the unit, and other contributions to science).

Relevance to society

The committee assesses the quality, scale and relevance of contributions targeting specific economic, social or cultural target groups, of advisory reports for policy, of contributions to public debates, and so on. The point is to assess contributions in areas that the research unit has itself designated as target areas.

Viability

The committee assesses the strategy that the research unit intends to pursue in the years ahead and the extent to which it is capable of meeting its targets in research and society during this period. It also considers the governance and leadership skills of the research unit's management.